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THE RUFIJI BASIN
TANGANYIKA

REPORT TO THE GOVERNMENT OF TANGANYIKA ON THE PRELIMINARY RECONNAISSANCE SURVEY OF THE RUFIJI BASIN

VOLUME VII Soils of the Main Irrigable Areas + MAPS

RUFIJI BASIN SURVEY

VOLUME VII

A Soil Reconnaissance Survey of the Main Irrigable Areas of the Rufiji Basin

by

B. Anderson
Tanganyika Department of Agriculture

With note on
THE PHYSICAL PROPERTIES OF SOILS AT FOUR LOCALITIES IN THE RUFIJI BASIN

by

H. C. Pereira

FOOD AND AGRICULTURE ORGANIZATION (FAO)

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INTRODUCTION

This report presents the results of a reconnaissance soil survey of certain lands in the Rufiji Basin in Tanganyika. The object of the survey was to find land on which the waters of the Rufiji River and its tributaries could be used for irrigated cropping.

The work was done in the period 1954 to 1959 while the writer was on secondment to the Rufiji Basin Survey team of the F.A.O. Owing to the inaccessibility during the wet season, of most of the land surveyed, field work was limited to the months July to December each year. From 1955 onwards the soil samples taken during the course of the survey were analysed by the writer's laboratory staff at the Southern Regional Research Centre, of the Agricultural Department, at Nachingwea in Southern Tanganyika. (Until 1957 this Centre was under the auspices of the Tanganyika Agricultural Corporation).

There are four areas of land within the Rufiji Basin which seemed likely to be suitable for irrigation. These are (1) The Usangu Plain, (2) The Kilombero Valley, (3) The Lower Rufiji Valley and (4) Pawaga (see figure 1). Soil reconnaissance maps on a scale of 1:125,000 were produced for all four areas. Land Suitability Maps, showing an assessment of the value of the land for irrigation, have been produced for the first three of these areas. Less work was possible on Pawaga and there was insufficient information, particularly as to the incidence of alkalinity and salinity in the soils, to justify attempting a suitability map. In the Kilombero Valley a soil survey carried out in 1952-53 by R. F. Loxton has been incorporated in the present work, by permission of the Tanganyika Government for whom the survey was done.

Valuable help was given by Dr. H. C. Pereira and his staff, from the East African Agriculture and Forestry Research Organisation, who made several trips to parts of the Rufiji Basin and took undisturbed core samples from several soils. On these samples they determined percolation rates, pore space, field capacity, etc. Dr. Pereira has prepared a summary of these determinations and this appears as Appendix 3 of this report.

Grateful acknowledgement is made of help given by W. E. Calton Esq., Government Chemist, for analysis of samples in the first year of the survey; by Drs. P. J. Greenway and B. Verdcourt and their staff at the East African Herbarium, for identification of botanical specimens; by C. A. Waldron Esq. of the Tanganyika Department of Agriculture, for the field work in Pawaga; by the staff of the Tanganyika Agriculture Corporation in Dar es Salaam and of the Agricultural Department at stations in the Rufiji Basin, for supply of equipment and help in the field; by District Officers at Mbeya, Mahenge and Utete, for securing the co-operation of the local people; and by many others too numerous to mention.

THE USANGU PLAIN

INTRODUCTION

Usangu is an extensive alluvial plain in the Southern Highlands Province, lying to the north of the Kipengere and Poroto Mountain ranges. Its position in relation to the rest of the Rufiji Basin is shown in figure 1. Its altitude is about 3,500 feet above sea level.

This present reconnaissance soil survey covered about 1,500 square miles of the plain. A further 200 square miles, approximately, in the west and north could not be visited, owing to lack of time. The unsurveyed area in the west, between Utengule and the Chunya escarpment, suffers from lack of permanent rivers. The Rail Link Survey Report (1952) shows the soils to be generally similar to those just east of Utengule. The unsurveyed area in the north, to the north-east of Ulanga, is largely, if not entirely, clay. These two unsurveyed areas are each of about 100 square miles.

Where possible the soils were studied in profile pits dug to a depth of 6 feet. Sometimes auger borings were made in the bottom of a pit to extend the depth of soil studied. These profile pits are indicated on the soil map by the prefix P., e.g. P241.

Often there was not the labour or the time to dig a pit and it became necessary to take samples with the auger. Most of these auger borings were on the clay soils of the northern part of the plain, where there is rarely any sudden change down the profile. Information was chiefly required about possible alkalinity or salinity and for this purpose auger sampling was adequate. Auger samples were usually of successive feet down to three feet depth but a few deeper bores were made. The sites of these auger bores are indicated by the prefix letters, B, K, M, R, and U.

The map only shows those profile pits and auger bores which are referred to in the text. Many other pits and auger holes were sampled and the samples have been analysed. Typical examples have been selected for inclusion in the report.

In 1957 a detailed survey of the proposed Mbarali Irrigation Scheme site was made. The detailed soil map produced has been reduced in scale (and inevitably simplified) and incorporated in the 1:125,000 map. An unsimplified portion of the detailed map is shown in fig. 2 to demonstrate the complexity of the soil in this area.

PHYSICAL FEATURES OF THE USANGU PLAIN

It is believed (D. R. Grantham, 1952) that the drainage of the Usangu area was originally southwest-wards towards the Nyasa-Rukwa trough. This southerly drainage was blocked, in Neogene times, by the eruption of the Rungwe volcanics. A lake then formed on the site of the present Usangu plain. Eventually this lake found an outlet to the north near the village of Utengule. (This is a different Utengule from the larger village of the same name in the western portion of the plain.) The Ruaha at the present day passes over a rock bar here; the consequent restriction of flow is the cause of the vast swampy area in the north-east part of the plain. The overflow has developed into the present Great Ruaha River.

The Usangu plain is therefore an old lake-bed. In the northern part of the plain the great expanses of clay soils have probably developed on the original lake-bed deposits.

In the southern part of the plain the original lake deposits have been covered by more recent alluvial fans laid down by the rivers draining the high land to the south of the plain. Since this high land is an area of considerable rainfall and the slopes are steep there has been much natural erosion and the alluvial fans are extensive. To the north of the Usangu plain the rainfall is smaller and the relief is low. There has therefore been only slight alluvial-fan formation.

To the east there is the high ground of the Southern Highlands from Iringa to Njombe but the rainfall is low on the western side of this high ground. There is a considerable area of alluvial fan deposits but more of the soils are saline or alkaline due to the intermittent flow of most of the streams. The Ndembera (Mwima) river is the only one to reach the Ruaha throughout the year. The others cease to flow at the edge of the plain, or do not even reach so far, during the dry season.

Rivers

The Mbarali is the largest river entering the plain, followed by the Ruaha, Kimani, Ndembera and Chimala, in that order. Details of their flow at different times of the year are given in the Hydrological section of this report. Up to the point at which they enter the plain they are descending steeply and are contained in narrow valleys. On reaching the plain their gradient decreases abruptly and there is therefore considerable deposition of alluvial sediments. The rivers silt up their beds and periodically break their banks and develop new courses.

In the case of the Mbarali particularly, many of these old channels are still visible and some of them are shown on the soil map. From local tradition it seems that for most of the last century the Mbarali flowed in the channel which cuts across the north-east corner of the Mbarali Irrigation Scheme. Towards the end of the century it moved to the channel which forms the southern boundary of this scheme, joining the Kimani and the Ruaha at the point where the "Old Ruaha" runs into the present combined Mbarali-Kimani. Then about 25 years ago the Mbarali moved even further west, into its present course, and took over the lower reaches of the Kimani.

The Kimani river continued for a time along the channel marked on the map as "Kimani river (old course)". An ill-conceived irrigation cut near Mgalo then provided it with an easier course. At present practically the whole dry season flow of the Kimani is lost by evaporation in a swamp between Nakambalala and Senyera.

The Ruaha escaped from its old course at about the same time as the Kimani, probably again through an irrigation cut. Most of the Ruaha's dry season flow is lost by evaporation from swamps. Some water finds its way into the Itambo and Wanenyika rivers and so into the Mkoji and thence to join the Mbarali. In late August 1958 this flow through the Wanenyika had ceased but a few cusecs were passing via the Itambo. All this water was from the Ruaha since the upper portion of the Itambo was dry.

GEOLOGY

The floor of the Usangu plain is composed, as already described, of lacustrine deposits overlaid by alluvial fans. Around Utengule (in the west) several low hills project through the alluvium to a height of 15 to 20 feet above the alluvial plain;

Luhanga, Uhando and Soliwaya are examples of such hills. No exposures of unweathered rock were seen in these hills but from the soil produced it is probably the same as that of the hills to the north of the plain, i.e. granitic.

Information about the geology of the higher ground surrounding the plain can be obtained from the Geological Map in Volume VI of this report. The Tanganyika Geological Department's "Chimala Quarter-degree sheet (71 SW)" gives a detailed picture for the southern boundary of the plain between Chimala and Rujewa.

The Mbarali river catchment area lies mainly on porphyroblastic microcline granite, with lesser areas of migmatites and biotite muscovite gneiss. The granite stretches eastwards and northwards round the edge of the plain up to the Ndembera river in the north-east. The northern boundary, from the Ruaha westwards, is similar.

The Kimani and Ruaha catchments are on rocks of the Bukoban System; these are mostly shales, with bands of dolomite and quartzite and some leucogabbro. There is also a small area of recent volcanic rock in the Ruaha catchment.

The Chimala catchment includes a considerable area of recent volcanics, together with leucogabbro and granite. The granite forms the Chimala escarpment and is considered to be of post-orogenic type of Proterozoic age and younger than the microline granite to the east of Rujewa.

North of the Ndembera river there are some metasediments belonging to the Ndembera Series (Ndembera Volcanics).

CLIMATE

Although there is a high rainfall in the Kipengere and Poroto Mountains the Usangu Plain has a semi-arid climate.

Mean annual rainfall

Rujewa	22.75	(13 years)
Chimala	31.60	(19 years)
Madibira	22.72	(22 years)

The rainfall probably diminishes towards the north-west (see isohyetal maps in the Hydrological section (Volume II part I). The wet season is from December to April, with little or no rain from June to October.

Three years of temperature records are available from the Rujewa Trial Farm. A screen temperature of 96°F has been reached on several occasions in October and November. The mean of the daily maximum and minimum temperature averaged over a month varied from 66° to 70°F.

In the dry season skies are generally clear and the night temperature is low, though frosts are unknown. The daily range is usually 20° to 25°F but may reach 40°F. At one of the camp-sites in the centre of the plain a thermometer in the open in July registered 39°F (4°C) at sunrise.

During the dry season strong easterly winds blow for most of the day, and often well into the night, and have a strong desiccating effect on growing plants. The winds are particularly marked on the boundaries of the plain, at least in the Chimala, Rujewa and Madibira districts. Near the centre of the plain the winds did not seem so strong though there are no measurements to confirm this. It is likely that the Usangu plain forms a convectional cell, with heated air rising in the centre and cold air flowing in from the mountains.

Further information will be found in the Meteorological Appraisal in Section 3 of this Rufiji Basin report.

SOILS

GENERAL DESCRIPTION

In drawing up a classification of soils for this survey it was necessary both that the soil groups distinguished should be recognisable on the aerial photos which were the basis of the survey and also that the groups should as far as possible be a guide to the irrigation engineer and agriculturalist.

In the classification adopted the primary division is into Alluvial and Non-alluvial soils. The alluvial soils are then sub-divided on their texture. This produced reasonable-sized units for the sandier soils but left a large block of alluvial clay which it was considered desirable to sub-divide further. Here a conflict arose between the needs of the agriculturalist and those of the surveyor since the properties of the clay which will probably prove of most importance to the agriculturalist could not always be recognised on the aerial photos. For reasons explained below, when the clays are described in detail, the clays were divided into five groups. Three of these indicate the intensity of flooding, under present conditions, and a fourth is for alkaline clays, so far as these can be recognised in the vegetation. A fifth group includes some small areas of clay with a very hard surface.

In places the pattern of the soils was too complex for the different textural groups to be shown on the map scale of 1:125,000 (often it was too complex to be distinguished on the photos at a scale of 1:30,000) and it was necessary to map such areas as complexes. Three complexes were used, one for predominantly sandy soils, one for predominantly heavy soils and a third where both sandy and heavy soils occurred together. This last group will be difficult for the irrigation engineer to evaluate; it includes substantial proportions of both sandy soils and of clays but it is impossible to indicate what is the proportion of each, valuable though this information would be.

The non-alluvial soils have been shown in much less detail since most of them are of no value for irrigation. The term non-alluvial has been used in rather a wide sense and includes clays in minor valleys bordering the plain which are probably partly alluvial. But since they include a proportion of coarse sand which has probably washed down from the nearby hill-sides and are of little irrigation potential anyway, it was found convenient to include these with the non-alluvial soils. The term "pediment catena", which is used in some parts of the map, is briefly explained in the detailed description of the "clays of the pediment catena" (page 33).

The sub-division of the non-alluvial soils is on the basis of colour, texture, presence of cemented horizons, etc., after examination of the whole profile, or as much of it as was practicable.

Finally there are five groups of soils which have a composite structure in the top two feet (the usual depth to which auger borings were made) and which could not be fitted into any of the other soil groups. These soils all consist of alluvium which has been deposited over alluvium of a markedly different texture or over non-alluvial material. Layers less than 6 inches in thickness were ignored, so these soils have an upper layer between 6 and about 20 inches in thickness over-lying the lower layer, which extends to at least 24 inches below the surface.

The complete soil classification is given below.

SOIL	MAP SYMBOL
Alluvial:	
Sands, in ridges or banks	S
Sands, in seasonal water courses	M
Sandy loams, usually including patches of sand	A
Loams	B
Recently deposited clays	K
Older clays, not subject to prolonged flooding	C
Older clays subject to prolonged flooding and treeless	Co
Older clays, subject to flooding but carrying some trees	Ct
Alkaline alluvial clays	Cs
Clays hardening on drying	Ch
Sandy loams affected by alkali	As
Soils formed from lake-bed silts	W
Alluvial complexes, predominantly light-textured	Xt
Alluvial complexes, predominantly heavy-textured	Xh
Complex of light and heavy alluvial soils	Xm
Soils with sodium carbonate	Q
Non-Alluvial:	
Red and brown soils of well drained sites	R
Red and brown soils affected by alkali	Rb
Grey sandy soil, ill-drained, of foothills	G
Cemented sandy soils of low-lying ground	H
Clays of the pediment catena	Cp
Alkaline non-alluvial clays	D
Pale sands of gentle slopes	T
Bare rock and shallow stony soils	Z

SOIL	MAP SYMBOL
Soil profiles which are composite in the top two feet of the profile:	
Sandy loam overlying cemented sandy soil (H)	AH
Clay overlying cemented sandy soils (H)	CH
Clay overlying cemented sandy loam (As)	CAs
Recent clay overlying sandy loam	KA

DETAILED DESCRIPTIONS OF THE SOILS

ALLUVIAL SAND IN RIDGES OR BANKS

This coarse sand occurs both in long, narrow strips and in wider sheets. The narrow strips are old river-beds which have sanded-up to the level of the surrounding land, and often higher. The sand sheets have been deposited where a river has broken its banks, or at least overflowed them violently during a high flood. There is an example of such a sheet in the north-east corner of the Mbarali Irrigation Scheme; the sand has come from an old course of the Mbarali River which cuts across this north-east corner. Similar sand sheets can be deposited by small rivers, such as the Chimala, which in the dry season lose themselves in swamps and minor channels on reaching the plain. When in flood these rivers discharge their bed-load of sand in a delta where the main channel of the river ends.

The greater part of the coarse sand shown on the soil maps is probably of the sanded-up river-bed type. At the scale of 1:125,000 it was not possible to show all the recognizable sand strips, nor was there time to map them all. As an example of the complexity in part of the area (not all) a portion of the detailed soil map of the Mbarali Scheme is reproduced (fig. 2).

It is surprising that these sand strips often form ridges with their crests several feet above the adjoining plain. One of these sand ridges is shown in figure 3. The line of flags runs across the ridge and indicates its cross-section. There is, however, little doubt that these strips do follow the lines of former rivers. The evidence is:-

a) Their long winding courses resemble those of rivers.
b) Pits dug in these ridges disclose water-worn gravel.
c) Two such strips were seen which were declared by the local people to have been active rivers ten years previously. Their statements are supported by aerial photographs taken in 1948. In one case an existing sand strip coincided with the main course of the Halali (or Kioga) River as appearing on the photograph taken 11 years earlier.

This particular sand strip was only level with the land on either side, not standing above it, but it seems unlikely that the raised sand ridges which occur elsewhere have a different origin. Possibly these other channels were lined by reeds and tall grasses which acted as bunds to retain the sand in the channel.

Profile 220, described over the page, is a typical example of these sand ridges.

PROFILE NO.

Location — Mbarali Irrigation Scheme.

Parent material — Sandy alluvium.

Topography — An in-filled river-bed, forming a ridge about one foot above the surrounding plain.

Drainage — Rapid.

Vegetation — Thin scrub of Commiphora sp. etc.

0 - 15 cm.	Dark brown loamy coarse sand (10 YR 4/3, dry). Porous and soft. Grading into:-
15 - 35 cm.	Brown loamy coarse sand (10 YR 4/3, dry). Less porous than above and harder. Grading into:-
35 - 90 cm.	Brown coarse sand (10 YR 4/3, dry) with some gravel. Slightly porous; soft. Diffuse wavy boundary.
90 - 260 cm. (+)	Pale brown gravelly coarse sand (10 YR 6/3, dry approx. but speckled with darker grains). Loose, single-grain structure but slightly cemented with clay along old root channels.

N.B. Examined with auger below 120 cm. since sides of pit caved in.

It will be seen from table 12 that the lower horizons of the profile are almost entirely coarse sand, with an appreciable amount (9.5 per cent) of gravel. The uppermost layers, deposited when the channel was nearly filled, have an increased proportion of the finer particles. This is typical of these sand ridges, the surface often having the texture of a sandy loam. The level of calcium and available phosphorus in the upper part of the profile is quite good but potassium, organic matter and nitrogen are low.

Huts and cattle compounds are usually situated on these sand ridges because the soil is well-drained and they are above flood level. Where the surface soil has an appreciable amount of clay mixed with the sand, maize and groundnuts are often grown. If there is a reasonably good rainfall in any particular year reasonable yields are said to be obtained.

These sands have, of course, a very low capacity for retaining water and they are not suitable for irrigation.

The other type of alluvial sand, the sandy sheet, is built up by deposits from successive floods. Since water over-flowing a river-bank usually carries a lesser proportion of coarse particles than that remaining in the channel, these sheet deposits are usually somewhat finer-textured than the sand ridges.

Profile 243 (table 12) illustrates this. The soil is predominantly a fine sand with an appreciable amount of silt, at any rate in the horizons analysed. The horizon 127 to 160 cm. was, however, a coarse sand, and contained 38 per cent of gravel. This particular stretch of sand is at Kibau, near Brandt Mission, and was probably deposited by the Chimala River. The gravelly coarse sand horizon may once have been in the bed of the river.

These sheet sands are usually shallower than the sands of infilled channels and rest on heavy alluvial material; or the sandy horizons may alternate with somewhat heavier horizons, such as the 102 to 187 cm. horizon of profile 243. The effect of these heavier horizons is to retain water in the profile. These sands are often used for rain-grown crops, particularly maize. The soil around profile 243 was so used. The general fertility of this soil, at any rate down to a depth of one metre, is quite good, though organic matter is low and with it the nitrogen.

Below one metre depth profile 243 is affected by alkalinity and some salinity. The clay loam horizon below 160 cm. depth has a very high exchangeable sodium level (over half the total cations) and all plant roots stopped at a depth of about 150 cm. A similar, rather shallower, sand within the boundary of the Mbarali Scheme did not show this alkalinity, which is probably the exception rather than the rule.

These sheet sands have a somewhat undulating surface and although they are often not quite so permeable as the ridge sands they are not suited to furrow irrigation. Sprinkler irrigation might be more successful.

SANDS IN SEASONAL WATER COURSES

These sands occur as banks in the beds of seasonal water-courses. Similar banks of course appear in permanent rivers. The banks tend to move when water is flowing and if the thickness of sand is small the water may expose the underlying material (often clay) between the banks of sand. Or, if the flow of water in the channel has diminished, clay may be deposited in low spots where deep pools form and may here overlie sand.

These sands are of no value for irrigation.

ALLUVIAL SANDY LOAMS

The alluvial sandy loams have been deposited on the banks of rivers during floods. The material is deposited from fairly fast-flowing water so that the surface is often somewhat uneven; patches of coarse sand frequently occur within areas of sandy loam. Since successive floods vary in velocity the soil texture usually varies down the profile. It is, in fact, rare for there to be even 2 feet depth of sandy loam without some intervening bands of alluvium with a heavier or a lighter texture.

The soils were normally judged by their feel but subsequent analysis has shown that soils described as sandy loams usually possess 12 to 25 per cent of clay.

Profile 225 is described over the page as an example of these sandy loams. Analytical figures for this and two other profiles are given in table 12.

PROFILE 225

Location Mbarali Irrigation Scheme, western boundary.

Parent Material Alluvium.

Topography Very gentle undulations.

Drainage Probably somewhat impeded by the clay horizons below 190 cm., or by seasonal high water-table.

Vegetation Open Acacia thornbush. Grass heavily grazed.

0 - 15 cm. Grey-brown sandy loam (10 YR 5/2, dry). Weak blocky to massive structure; many pores.

15 - 30 cm. Dark brown sandy loam (10 YR 4/3, dry). Massive but porous.

30 - 60 cm. Brown very sandy loam (10 YR 5/3, dry). With a few faint mottles. Massive but porous.

60 - 88 cm. Pale brown gravelly coarse sand (10 YR 6/3, dry). With much brown mottling. Massive, with a few pores. Abrupt boundary.

88 - 190 cm. Very dark grey loam (10 YR 3/1, dry) with common dark reddish-brown, dark grey and yellowish-red mottles. Medium blocky structures. Very hard when dry. Grading into:-

190 - 300 cm. Very dark grey silty clay (10 YR 3/1, dry). Little mottling at top but common dark brown and dark reddish-brown mottles below 240 cm. Very hard when dry.

N.B. The lowest horizon was examined and sampled with the auger.

Profile 225 has a sand horizon between 60 and 88 cm. depth and rests on clay at 190 cm.

The sandy loams are usually somewhat low in organic matter but generally have adequate amounts of calcium, phosphorus and potassium. They are much used by the local people for maize and excellent crops are obtained without the use of fertiliser.

The soils are in general more permeable than is desired for irrigation but many will be satisfactory, particularly if there are heavier layers in the subsoil. Some tests were carried out on the Rujewa Trial Farm, using a central cylinder in which water was maintained at a depth of 3 inches and which was surrounded by a guard ring. The soil was moist at the start of the test (see table 1).

TABLE 1. Rates of infiltration for a sandy loam

Infiltration under 3 inch head of water (inches per hour)

	Site 1	Site 2
1st inch	3.0	1.0
2nd "	2.0	1.0
3rd "	0.9	0.7
4th "	1.3	0.6
5th "	1.6	

Some channelling seems to have developed at Site 1 after the 3rd inch had entered but in general the rates are not excessive. Care will be needed in the laying out of fields and canals to avoid the very permeable sandy patches which occur in the sandy loams.

In the Chimala area there is often some salinity in the subsoils of sandy loams. Profile 247 (Table 12) is an example. Below 100 cm. depth the exchangeable sodium percentage rises to 65 per cent and there is some accumulation of soluble salts. Satisfactory maize crops are obtained on this site under the natural rainfall but care will be needed under irrigation to prevent a rise of the salt into the upper part of the soil.

These saline-alkaline sandy loams occur chiefly in the area lying between the Chimala and Ruaha rivers. In isolated patches in the same area quite high concentrations of sodium carbonate occur in the soil. This is usually in alluvial loams, but sometimes in sandy loams. These patches are indicated on the map by the letter Q and a fuller description is given on page 28. No evidence was seen of salts in the Mbarali alluvium, but one pit showed a slight rise in exchangeable sodium below 120 cm. depth.

ALLUVIAL LOAMS

These soils develop in medium-textured alluvium deposited from quieter flood waters than those which produce the sandy loams and sands. As in the sandy loams there is considerable variation in texture down the profile due to differences between successive floods and also, probably, to changes in the courses of the rivers from which the flood-water came.

This variation is shown in profile 242, described over, in which only the top 35 cm. can properly be described as a loam. Analytical figures for profile 242 and for another loam profile, J7, will be found in table 12.

PROFILE 242

Location	Brandt Mission.
Parent material	Alluvium.
Topography	Very gentle undulations.
Drainage	Affected by high water-table (at 4 feet depth in late July)
Vegetation	Cultivated for maize. Ridges about one foot high, four feet apart. The pit was situated between two ridges.
0 - 35 cm.	Dark brown loam (7.5 YR 4/2, moist) with common, fine, red-brown mottles. Subangular blocky structure, slightly hard when dry. Fairly porous at surface, diminishing with depth. Clear, smooth boundary.
35 - 45 cm.	Dark yellowish-brown sand (10 YR 4/4, moist). Single grain structure, loose. Clear, wavy boundary.
45 - 55 cm.	Dark brown loam (7.5 YR 4/2, moist) with common, fine, red-brown mottles. Weak, medium blocky; slightly porous. Clear, wavy boundary.
55 - 75 cm.	Dark yellowish-brown coarse sand (10 YR 4/4, moist) with common yellow-brown and very dark grey-brown fine mottles. Massive; very friable (moist).
75 - 110 cm.	Dark grey-brown clayey coarse sand with many very dark grey-brown and common yellow-brown fine mottles. Massive; very friable (moist).

Water standing at 110 cms.

These loams are excellent soils, with moderate amounts of organic matter (about 2 per cent) and a neutral to slightly acid reaction. There is a high level of calcium, potassium and available phosphorus. The two profiles analysed were free from salts or harmful amounts of exchangeable sodium.

These alluvial loams are probably the best all-round soils on the Usangu plain but unfortunately never occur in extensive stretches and are usually mixed with patches of sandy loam or sands.

In the zone lying between the Chimala and Ruaha rivers there are isolated patches of sodium carbonate occurring in these loams, as in the sandy loams. These are described on page .

RECENTLY DEPOSITED ALLUVIAL CLAYS

In certain parts of the Usangu plain the soil is a dark clay, with good structure, relatively easy to work and without accumulation of alkali or salts. This contrasts with the hard, usually paler, clays found elsewhere, and described below a "older alluvial clays".

The main occurrence of the younger clays is in the Mwima valley; smaller patches, not always distinguished on the map, are found elsewhere. It is not clear why there should be more young clay in the Mwima valley than in the Mbarali valley, for example. It is possible that the clay brought down by the Mbarali is spread over a much wider area than that brought down by the Mwima, and so is very thin over most of the deposition area. It is also possible that the weathering processes tha convert the young clays into older clays are less active in the Mwima valley so tha the clay retains its youthful properties longer. Only the uppermost foot or two of a young clay profile have these desirable properties. Below this the clay becomes harder and paler and may accumulate alkali or salts.

Both types of clay are deposited in quiet flood water away from water courses. The surface is therefore level and well-adapted to irrigation.

One profile is described below; analyses of this and another profile, M14, are given in table 12:

PROFILE M20

Location	About 6 miles WNW of Madibira.
Parent material	Alluvium.
Topography	Flat.
Drainage	Slow; flooded in the wet season.
Vegetation	Grassland, burnt.
0 - 30 cm.	Black clay loam (10 YR 2/1, moist) at surface. Below: black clay with many grey-brown and yellowish-brown mottles.
30 - 60 cm.	Dark grey clay (10 YR 4/1, moist) with common very dark grey and dark brown mottles. Hard when dry.
60 - 140 cm.	Grey clay (10 YR 5/1, moist). A few mottles in upper part; without mottles but with concretionary carbonate below. Hard. Some coarse sand grains.
140 - 230 cm.	Grey clay (10 YR 6/1, moist). A few yellow-brown mottles in upper part, becoming more frequent with increasing depth. Carbonate diminishing.
230 - 260 cm.	Grey clay (10 YR 5/1, moist). Common, fine, brown mottles. Very hard when dry.

NB. Samples taken with auger. This description is based on examination of the auger samples.

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These clays are neutral to slightly acid in reaction (pH $5\frac{1}{2}$ to 6) in the top-soil with about 2 per cent organic matter in the top foot. This organic matter seems somewhat deficient in nitrogen in profile M20. Calcium and potassium levels are good but phosphate is low.

In profile M20 the younger clay ends at about 60 cm. depth. Below this the soil is greyer, with some concretionary carbonate. At 140 cm. there is an accumulation of salts just sufficient to affect susceptible crops. One other deep profile did not show any salts so they are not, perhaps, widely spread. Detailed surveys would, of course, have to be carried out before any irrigation development starts and they would show whether there is any salt problem. It does not seem likely that there is any serious problem.

The chemical analyses of these younger clays do not reveal any difference between them and the older clays. The younger clays do, however, seem to be more easily workable and are therefore to be preferred for agricultural development.

OLDER ALLUVIAL CLAYS

The older alluvial clays occupy the greater part of the Usangu Plain. The clays have a considerable range in properties and need to be sub-divided into smaller and more uniform units. It was necessary, for a reconnaissance survey, that the units be distinguishable on aerial photos.

A useful division would have been into:-

(1) Clays shrinking greatly on drying and disintegrating into a slurry within a few seconds of wetting.

(2) Clays shrinking less on drying and absorbing water less rapidly on wetting, i.e. at a "normal" rate.

Unfortunately these two divisions of the older clays could not be distinguished on the aerial photos and there was no time to visit all parts of the plain on the ground, to plot the boundary between the two divisions. Descriptions of each type are given below but for mapping purposes a classification based on visible vegetation differences had to be followed.

Five sub-groups of the older alluvial clays are shown on the soil maps and three of these are based on differences in flooding during the wet season. Flooding has a very great effect on tree growth and differences in the duration of flooding produce differences in density of the bush which show up clearly in the photos. These differences in duration of flooding are in general due to slight differences in ground level and do not appear to have had much effect on the soil, either its appearance or its composition. If, therefore, complete flood control is obtained before development starts these distinctions will have little significance. If, on the other hand, only partial flood control is obtained at first, the soil maps should help in the selection of the more easily protected land.

The five sub-groups are listed below. Fuller descriptions are given later.

(a) Clays usually above flood level (C)

Identified by the presence of huts, cattle compounds, bare ground due to over-stocking and by questioning the local inhabitants. Bush is present on the clays of type (2) (the "normal" clays) but usually absent from those of type (1) (rapidly dispersible).

(b) Clays subject to prolonged flooding and therefore treeless (Co)

These carry grassland without trees or with Acacia seyal or Acacia pseudofistula only. Some of the easily dispersible clays which are included here were said by the local people only to be flooded by rain-water and only for a few days at a time. The absence of trees from this type of clay may be due to a very slow recovery from anaerobic conditions after flooding or to a recent change in the extent of flooding. This point is discussed later.

(c) Clays flooded for short periods (Ct)

Trees are present in considerable numbers but not huts or cattle compounds. Grass growth is vigorous and there is no bare ground. The clay is usually of the "normal" type.

(d) Alkaline clays (Cs)

The definition adopted in this report of an alkaline soil is that proposed by the U.S. Soil Salinity Laboratory, viz. a soil in which the exchangeable sodium exceeds 15 per cent of the total exchangeable cations. It was not possible to determine this for large numbers of samples and for the soil maps the dominance of Acacia kirkii or A. stuhlmannii was taken as indicating alkalinity. This, in effect, limits this group to the clays of the "normal" type since the "dispersible" clays do not support A. kirkii or A. stuhlmannii whether alkaline or not.

(e) Clays hardening on drying (Ch)

These clays dry to large hard clods, without much shrinkage. The clods do not absorb water easily. Bush is present but usually sparse and the ground flora is poor; often there is much bare ground.

In the following descriptions of the five sub-groups only the "normal" clays are described. The rapidly dispersible clays are dealt with immediately afterwards; although they are divided between the (a) and the (c) sub-groups on the map there is a considerable uniformity amongst all the profiles examined, so they have been described in one group.

DESCRIPTIONS OF THE OLDER ALLUVIAL CLAYS, EXCLUDING THE RAPIDLY DISPERSIBLE CLAYS

(a) Clays usually above flood level

These are soils containing 40 to 70 per cent of clay and often a considerable

..ount of silt. Clay loams, with 30 to 40 per cent of clay, are included in this roup.

These clays were fairly thoroughly studied on the Mbarali Irrigation Scheme and 2 pits were dug, mostly to a depth of 2 metres but some to 3 or $3\frac{1}{2}$ metres. In no ..se was the bottom of the alluvium reached. Outside this Irrigation Scheme most of ..e examination and sampling was done with the auger. Most of the auger borings ere 3 feet (1 metre) in depth, but a few were continued to $9\frac{1}{2}$ feet (3 metres).

Profile 226, described below, is typical of the clays of the Mbarali Irrigation ..cheme. Sandier strata occur in the clay of this profile and this is not uncommon n the alluvial fans in the southern part of the plain. Further out on the plain ..ose sandier horizons are not found.

ROFILE 226

ocation	Western boundary of Mbarali Irrigation Scheme.
..rent material	Alluvium.
opography	Flat, with minor undulations.
ainage	Slow. Site liable to short duration floods (?)
egetation	Thin Acacia spirocarpa woodland; tall herbs and grass.
- 20 cm.	Light brownish-grey clay (10 YR 6/2, dry) with common reddish-yellow fine mottles. Strong, coarse granular structure, with visible pores. Very hard consistence (dry). Clear boundary.
) - 40 cm.	Light brownish-grey clay with many yellow-red fine mottles. Strong thick platy to medium blocky structure. Pores and consistence as above. Clear, wavy boundary.
) - 75 cm.	Pale brown clay (10 YR 6/3, dry) with many reddish-yellow fine mottles. Moderate, thick platy to medium blocky structure. Moderately porous. Very hard (dry). Clear, smooth boundary.
5 - 130 cm.	Dark grey clay (10 YR 4/1, dry) with common strong brown staining along roots. Strong, coarse subangular blocky structure. Fairly compact; hard. Gradual boundary.
30 - 150 cm.	Grey-brown clay loam (10 YR 5/2, dry) with staining along roots. Massive and compact; hard. Gradual boundary.
50 - 200 cm.	Yellow-brown micaceous sand (10 YR 5/8, dry) with common pale brown fine mottling. Massive and compact; soft consistence (dry)
)0 - 230 cm.	Pale brown sandy loam (10 YR 6/3, dry) with many strong brown fine mottles.
30 - 305 cm.	Grey clay (10 YR 6/1, dry) with many brownish-yellow fine mottles. Darker below 275 cm.

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305 - 350 cm. Pale brown micaceous clay loam (10 YR 6/3, dry) with many brownish-grey and brownish-yellow fine mottles.

350 - 365 cm.(+) Very dark grey clay (10 YR 3/1, dry) with some coarse sand grains and a few brown fine mottles.

Note: The horizons below 200 cm. were examined with the auger.

The pH value of these clays is 6 to 7½ in the topsoil and 7 to 8 at greater depths (table 12). The organic matter is rather low, usually 1 to 2 per cent. In profile 226 it is a little higher (2.2 per cent). This was an area which had only been lightly grazed; in addition to there being more organic matter and perhaps because of this fact, the structure of the surface soil was better (figs. 7 and 9). In heavily grazed areas near villages and along the routes to the river the organic matter is lower and the surface is more compact. Profile 223, with 1.7 per cent organic matter, is an example (fig. 8 and 10 and table 12).

Available phosphorus is usually low in the topsoil, perhaps because of its removal in the grass eaten by the cattle and its accumulation in the manure in the cattle compounds.

Exchangeable calcium and potassium are in good supply. Exchangeable sodium is often about 10 per cent of the total cations. This is below the limit of 15 per cent adopted by the U.S. Soil Salinity Laboratory but even 10 per cent, when associated with a high clay content, will produce slow drainage. Out of 47 profiles analysed (half of these being on the Mbarali Irrigation Scheme) 12 had exchangeable sodium percentages of over 15 at some level in the soil (usually in the third foot). In no case was the percentage over 24 in the upper 3 feet of the profile. Table 2 gives exchangeable sodium figures for two typical profiles from the Irrigation Scheme.

Table 2. Exchangeable sodium and clay percentage for two clay profiles:

P 221			P 223		
Depth cm.	Sodium %	Clay %	Depth cm.	Sodium %	Clay %
0 - 12	8	25	0 - 15	5	47
12 - 30	-	-	15 - 50	12	-
30 - 60	11	29	50 - 100	7	60
60 - 90	-	-	100 - 150	-	-
90 - 165	24	39	150 - 190	12	60
165 - 195	10	30			

In profile 221 the sodium is probably above 15 per cent for the 60 to 90 cm. horizon since the pH is similar to that for the 90 to 165 cm. horizon (8.8 and 8.9 resp.). This soil may be too alkaline for alkali-susceptible crops. In profile 223 the sodium is below 15 per cent at all levels but the heavy texture will mean slow internal drainage. Some other profiles, e.g. P226 and K7, have much lower sodium percentages.

Dr. H. C. Pereira has carried out percolation tests on undisturbed cores from six clay profiles within the Mbarali Irrigation Scheme. His conclusions were that percolation rates, though low in places, were adequate for irrigation. Details of these tests are given in Appendix 3. The six clay profiles are Pit V on the Rujewa Trial Farm and the five pits on the Mbarali Irrigation Scheme. Although some of the latter soils were described at the time of sampling as loam or alkaline clay, analysis has shown that they all fall within the group of Older Alluvial Clays.

Only one profile showed serious amounts of salt, viz. a conductivity of the saturation extract of 8 millimhos per cm. at a depth of 3 feet. However this profile was in an mbuga north of Madibira and not on the plain proper.

Taken as a whole, therefore, these clays are suitable for irrigation and of good fertility. The heavy texture of some of them will make them difficult to work and will necessitate careful control of water to prevent water-logging. Where the subsoil is alkaline some crops are unlikely to do well.

(b) Clays subject to prolonged flooding and therefore treeless.

These soils are flooded for so much of the wet season that growth of most species of tree is prevented. Thin stands of Acacia seyal, which is apparently tolerant of flooded conditions, sometimes occur, also scattered individual A. spirocarpa and A. kirkii here and there.

These soils are all heavy in texture, with 50 to 70 per cent of clay. Sandy strata do not occur. Profile U22, described below, is a typical example; it is from the west end of the plain, near Utengule

PROFILE U22

Location	Ugomutwa, north of Utengule.
Parent material	Alluvium.
Topography	Flat.
Drainage	Poor; liable to flooding in wet season.
Vegetation	Grassland, heavily grazed.
0 - 30 cm.	Very dark grey silty clay (10 YR 3/1, moist) with faint brown staining along roots. Very hard when dry.
30 - 85 cm.	Very dark grey-brown silty clay (10 YR 3/2, moist) with a few, fine, brown mottles. Very hard when dry; slightly sticky when wet.
85 - 120 cm.	Dark grey-brown loam (10 YR 4/2, moist). Common dark yellow-brown mottles. Some black iron staining.
120 - 215 cm.	Dark grey-brown clay loam (10 YR 4/2, moist). Otherwise as previous horizon. A little concretionary carbonate.

215 - 260 cm. Very dark grey-brown clay (10 YR 3/2, moist). Common, fine, brown and dark grey mottles. A little concretionary carbonate.

NB. Samples taken with auger. This description is based on examination of the auger samples.

Analyses of this profile, together with eight others (R7, B15, U10, U24, U8, M15, J16 and U17) are given in table 12. A view of the grass plains in which they occur is shown in figure 11.

These clays are in general similar to those in sub-group (a) just described. The pH values are 6 to 7 at the surface and 6 to 8½ in the subsoil. There is not usually any calcium carbonate in the top 3 feet of the profile though there may be some at greater depths.

Organic matter contents ranged from 1⅓ to 3½ per cent. This is rather better than in the higher-lying clays and may be due to the rest from grazing enjoyed by these clays when they are flooded. Available phosphorus is usually low.

Exchangeable calcium, magnesium and potassium are in good supply. Exchangeable sodium is again often about 10 per cent of the total exchangeable cations. In 2 out of the 10 profiles analysed on exchangeable sodium percentage of over 15 occurred in the top 3 feet. In neither case did the value exceed 15 by very much.

Provided flooding can be prevented, these soils should behave very similarly to the higher-lying clays of sub-group (a).

Percolation and water-storage measurements have been made by Dr. Pereira on one of these soils from near Utengule in the western part of the plain (Appendix 3, site B). This soil had an exchangeable sodium percentage of 8 in the topsoil, rising to 15 in the third foot (pH values 6.7 and 8.4 resp.). The corresponding "silt and clay" figures are 73.5 and 83.6 per cent. Small amounts of calcium carbonate, less than one per cent, were present in the second and third foot."

(c) Clays flooded for short periods.

These soils are liable to be flooded, but for shorter periods than the clays of sub-group (b) so that growth of many species of tree is possible. Acacia spirocarpa is probably the commonest species.

These clays are again very similar to the clays of the higher ground sub-group (a). Analyses of four profiles - R6, B18, U13 and M9 - are given in the tables.

Clay figures vary from 40 to 70 per cent. The pH is 5½ to 6½ at the surface and 6 to 8 in the subsoil. There is not usually any carbonate in the soil.

Exchangeable calcium, magnesium and potassium are adequate. In only one out of nine profiles did the exchangeable sodium exceed 15 per cent of the total cations and this was by only a slight amount in the third foot. No profiles had any soluble salts.

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The analyses suggest that these clays are slightly more acid than those of the two previous sub-groups but this is probably an accidental effect due to there being only nine profiles of this sub-group.

Dr. Pereira has examined one soil from near Utengule (Appendix 1, site A). This soil was very similar to that at site B. The pH was 6.1 in the top foot and 8.6 in the third. The latter figure corresponded to an exchangeable sodium percentage of 14.

The behaviour of these clays under irrigation should be very similar to that of the first sub-group, assuming control of flooding.

(d) Alkaline alluvial clays.

As already stated, alkaline soils are defined as those in which the exchangeable sodium exceeds 15 per cent of the total exchangeable cations. As it was not possible to do large numbers of these determinations the presence of thick stands of Acacia kirkii (see figure 12) was taken as indicating alkalinity for the purposes of reconnaissance survey. The A. kirkii is not an infallible indicator of alkalinity but it is believed that it does enable the main areas of alkaline soil to be recognised. It must be understood that there will be patches of alkaline soil not supporting A. kirkii and also patches of non-alkaline soil in areas mapped as alkaline because of A. kirkii.

Profile 249 is an example of an alkaline soil under Acacia kirkii. Analytical figures for this and three other profiles are given in table 12.

PROFILE 249

Location	Half a mile SE of Luhanga, in western part of Usangu.
Parent material	Alluvium.
Topography	Flat.
Drainage	Very poor. Said to be flooded about 6 inches deep for short periods in the rains.
Vegetation	Thick thornbush. Acacia kirkii, Commiphora sp., Delonix alata, Acacia spirocarpa, grass.
0 - 15 cm.	Dark grey-brown clay (10 YR 4/2, moist) (10 YR 7/2 when dry). Common reddish-brown fine mottles. Strong, coarse subangular blocky. Extremely hard consistence (dry). Some small black iron concretions. Gradual boundary.
15 - 40 cm.	Dark grey-brown clay (10 YR 4/2, moist) with a few yellowish-brown fine mottles. Medium subangular blocky. Compact and extremely hard. Concretions as above. Gradual boundary.
40 - 90 cm.	Brown clay (10 YR 5/3, moist) no mottles. Medium, subangular blocky. Hard and very compact. Black iron concretions and white calcium carbonate concretions. Diffuse boundary.

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90 - 190 cm. Similar, except fine blocky structure, increased carbonate and diminished iron concretions.

In the six alkali soil analyses the clay varied from 40 to 60 per cent. The
6 pH was $6\frac{1}{2}$ to $8\frac{1}{2}$ at the surface, rising to about 9 in the subsoil. Organic matter is low, about one per cent. Available phosphate is higher than in the less alkaline clays, perhaps because of a lower production of grass and so a lower rate of removal of phosphorus by grazing cattle.

Exchangeable calcium and magnesium is adequate, in total amount if not in proportion to the sodium. Potassium is high.

Exchangeable sodium is always over 15 per cent in the second foot and below, though there is often less in the top foot. B14, north of Msaka, is particularly high in sodium, which is the predominant cation throughout the profile. In profile 249 the top 15 cms. (6 inches) is unsaturated, with a pH of 6.4 and a sodium percentage of less than 10. At 40 cms. depth, however, it rises to 27. The unsaturated surface horizon suggests that natural leaching is occurring.

Small amounts of concretionary calcium carbonate are found in many of these soils and it might be possible to reclaim these by leaching alone. The process will be slow in these heavy soils. Other soils are without calcium carbonate and would need gypsum before leaching. Small, but not serious, amounts of soluble salts occur in some of the profiles analysed.

These soils are not suitable for cropping in their present state and in view of the large areas of better soil available there seems to be no point in attempting to reclaim them.

(e) <u>Alluvial clays hardening on drying.</u>

This class covers a small area of clay soil at the eastern edge of the Usangu plain. On drying, the clay forms very hard coarse clods; there is not much shrinking of the soil on drying.

Only two profiles have been examined. One is described below and analytical figures are given in the tables.

<u>PROFILE M17</u>

<u>Location</u> West of Madibira; about 2 miles NE of Mpongolo.

<u>Parent material</u> Alluvium.

<u>Topography</u> Level.

<u>Drainage</u> Poor. Liable to flooding in the wet season.

<u>Vegetation</u> Sparse grass and woody herbs (Blepharis sp., etc.) Scattered trees; Acacia spirocarpa, Baobab, etc.

0 - 30 cm. Very dark grey clay (10 YR 3/1, moist) with some coarse sand grains.

A few, faint, mottles. Very hard when dry, slightly sticky when wet.

30 - 60 cm. Similar, but without mottles.

60 - 90 cm. Dark grey clay (10 YR 4/1, moist) with a few faint fine mottles. Hard when dry, sticky when wet.

NB. Sampled with auger.

The exchangeable sodium is quite low and it is not clear why the soil should be so hard. Probably the very low content of organic matter (1 per cent) is responsible. Otherwise the soil is similar to the non-alkaline clays already described.

The other profile was situated in the narrow belt of hard clay bordering the plain to the north of Ikoga. Here the hardness is probably due to exchangeable sodium. Sodium constituted 17 per cent of the exchange complex in the top foot, though it was less at greater depths. In this soil there was an accumulation of soluble salts at a depth of 3 feet. The conductivity of a saturation extract was 9 millimhos per cm. The sodium and the salts in this soil probably originate from the evaporation of water seeping down from the higher ground to the east.

This second soil is unsuitable for cropping. The soil M17 should be satisfactory though with so little organic matter it would be difficult to work.

RAPIDLY DISPERSIBLE CLAYS

These soils have a high clay content - about 70 per cent of clay. They crack widely on drying and break up into hard, small, angular clods. If these are placed in water they crumble in a few seconds to a slurry.

The colour of these clays, at least in the subsoil, is usually a neutral dark grey, e.g. N. 3/0 in the Munsell system. They are usually calcareous in the subsoil (i.e. at a depth of 2 to 3 feet) and often in the topsoil also. One profile (M15, see table 12) was strongly saline but other profiles showed no serious salt accumulation, at any rate in the top three feet. Gilgai relief is frequently present (fig. 3).

The natural vegetation is short to medium grass. Trees are rare but Acacia seyal or A. pseudofistula sometimes occur, either sparsely scattered or in clumps. These trees seem to be very tolerant of badly aerated soils.

These clays are found in the northern half of the Usangu plain and may represent the original lake-bed sediments without much addition of river alluvium since the disappearance of the lake. The boundary between these rapidly dispersible clays and the more normal clays start near Mzawa on the west side of the map (sheet 1). From here it runs slightly south of east to pass just south of Mwasembe; it then runs east to Malegee. It next follows the Mbarali (or Ruaha) river north and north-east until a point is reached approximately north-west of Udinde. From there it runs south-east through Udinde to Mwagwalisi and then east along the northern edge of soil As, past Ipunga and up to the eastern boundary of the plain. To the north of this line clays marked as C or Co are usually of this rapidly dispersible type; to the south they are of the normal type. This boundary appears on the Land Suitability maps as the line separating the class 2 clays from those of class 4.

It was not possible in the time available to penetrate far into the great Utengula swamp (northern part of sheet 2). Round the edge the clay was of the rapidly dispersible type but in the centre it may be different.

One sample of this rapidly dispersible clay has been examined in the Rothamsted Pedology Department. It was found (R. Greene-Kelly and A. Muir, private communicatio that the clay mineral is a hydrated mica. The rapid dispersion is attributed to the high percentage of clay particles and to their unusually small size.

Much of this clay in the eastern half of the Usangu plain is flooded every wet season. This is shown by the appropriate symbol (Co) on the map. In the west there are large areas around Ukwaheri, Ipangu and Mwasembe which are not flooded, according to the local inhabitants. There are a few trees on this, chiefly Acacia seyal, and it has been marked C on the map.

There is a large area stretching northwards from Yala in which trees only occur sparsely, chiefly in small clumps. In this area there are several villages in the southern part and signs on the aerial photos of abandoned settlements in the north, though the latter may only have been temporary dry season camps of the graziers. The people say this area is not flooded from the rivers but that water lies on the surface for several days after rain. It is shown on the map as subject to prolonged flooding (Co) since it seems probable that the absence of trees is due to the prolonged waterlogged state of the soil during the rains resulting from the very poor internal drainage. The villages are situated on slight rises or on the banks of the Mkohi and other rivers which have cut deeply into the plain and provide local surface drainage. The tree clumps are probably also on small rises, some of them apparently cattle compounds.

It is possible, however, that this area was formerly flooded from the Mkohi river and that the present absence of trees is only temporary. Until a few decades ago the Mkohi River turned north at Uyaule and, passing to the north of Ukwaher, made a wide sweep to the north of the plain before joining the Ruaha south of Utuya. Many current maps still show it following this course. This old course is full of meanders and the river may well have caused extensive flooding in this part of the plain. There has certainly been a considerable thickening of the bush in places, e.g. about half-way along the track from Udunguzi to Utuya, since the RAF aerial photography of 1948/49.

Since there is this doubt as to the cause of the absence of trees from so much of these rapidly dispersible clays, and since there appears to be little difference in the analyses of the soil from different sites, the several profiles will be dealt with as one group. A typical profile, U24 from near Mwasembe, is described below. Analyses of this and four other profiles (U8, M15, J6, U17) are given in table 12. The site of profile J6 is shown in figure 13.

<u>PROFILE U24</u>

<u>Location</u> Half a mile east of Mwasembe village.

<u>Parent material</u> Alluvium.

<u>Topography</u> Flat; slight gilgai relief locally.

Drainage Poor.

Vegetation Grassland, with occasional small trees of Acacia seyal and A. kirkii. Thick A. seyal thicket occurs 200 yards to the north.

0 - 30 cms. Very dark grey clay (10 YR 3/1, moist). Strong, fine to medium blocky structure. Cracks about 5 cm. wide. Very hard when dry, but peds break down rapidly on wetting. Concretionary carbonate present.

30-150 cms. Very dark grey clay (N 3/0, moist). Peds very hard when dry but break down rapidly on wetting. Much concretionary calcium carbonate.

150-215 cm. Similar, but colour 10 YR 3/1 (moist).

215-260 cm. Dark grey-brown clay (2.5 Y 4/1, moist). Very hard when dry. A little concretionary carbonate.

NB. Samples taken with auger. This description is based on examination of the auger samples.

These soils contain 70 to 80 per cent of clay and negligible amounts of sand. The pH is about 7 at the surface, rising to $7\frac{1}{2}$ or $8\frac{1}{2}$ at 3 feet depth. Calcareous concretions are usually present, either throughout the profile or only in the lower horizons. Some profiles had no concretions, at any rate in the top three feet.

Organic matter is low, usually between 1 and 2 per cent. Available phosphorus is low. Exchangeable calcium is often very high and potassium is high.

Exchangeable sodium tends to be higher than in the "normal" clays already described. In 6 out of the 11 sites sampled the sodium exceeded 15 per cent of the total exchangeable cations at some level in the top 3 feet. The highest value was 29 per cent. Harmful amounts of salt occurred in M15 and at one other site. In M15 the conductivity of the saturation extract was 32 millimhos per cm., at the surface; values above 4 are considered harmful.

Reclamation of the alkaline and saline soils of this group will be exceedingly difficult, owing to the very heavy texture and the consequent slow percolation rate. The humps and hollows (gilgai relief) which commonly occur in this soil (figure 13) would have to be levelled off before irrigation could be installed, and they might well re-form. The rapid absorption of water by the clods, and their subsequent collapse, might lead to constructional difficulties. These dispersible clays are therefore much less attractive for irrigation than the more normal clays in the southern part of the plain.

Nevertheless some crop plants will grow on these soils, at any rate on the less alkaline ones. Many of the villages have plots of maize and sorghum and the plants grow to a reasonable size. Only the dry stubble was seen and yields are not known. Growth of grass was dense and vigorous, even on the more alkaline soils like J6, where the land had not been overgrazed by cattle.

There therefore appears to be a reasonable chance that these soils could be utilised for irrigated crops but much experimental work will be needed to prove their utility before any large-scale development can be contemplated.

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SANDY ALLUVIAL SOILS AFFECTED BY ALKALI

In the eastern part of the Usangu plain there are large areas of fairly sandy alluvium with a high content of sodium and often soluble salts as well. The soil is hard and cementlike in the dry season and absorbs little of the available water during the rains. The growth of grass and other herbaceous plants on these soils is very poor and much bare ground occurs.

In the Madibira area these soils are mostly fairly sandy but clay loams do occur. The surface is slightly undulating, as is usual in coarse alluvium. On the ridges the soil has a sandy loam texture (12 to 20 per cent clay) while the heavier soils are found in the hollows. The hollows, which are 10 to 50 yards across, probably hold pools of water during the rains. In the hollows a spiny herb (Blepharis sp.) is often dominant; trees are absent. The ridges carry a thin scrub; Acacia kirkii, A. senegal, Commiphora sp., Candelabra Euphorbias, Boscia sp. (? holtzii) were noted. Profile 262, described below, was on the edge of a depression and represents the heavier soils.

To the north of Isunura there is another stretch of these soils but here the surface is usually level and the soils seem more uniformly sandy. This levelling may be the result of wind erosion since this area is greatly overgrazed and trampled. In the wet season the cattle are driven off the clay plains by the floods and are excluded from the better sandy soils since these are mostly under crop. They are therefore concentrated on soils such as these alkaline sandy soils at a time when trampling will do most damage. The trees in this area are usually Commiphora sp., with Boscia and some A. kirkii. The profile J4 (fig. 15 and table 12) is typical of the soil in the Isunura area.

PROFILE 262

Location	Three miles west of Madibira on footpath to Mpongolo.
Parent material	Alluvium.
Topography	Flat, with undulations of a few inches in height.
Drainage	Poor. Rain-water collects in the slight depressions.
Vegetation	Scrub on the slight rise (including Acacia kirkii, A. senegal, Commiphora sp., Euphorbia bilocularis and Boscia holtzii); Blepharis sp. and grass in the depressions (the pit was on the edge of a depression).
0 - 15 cm.	Dark grey sandy clay loam (10 YR 4/1, moist) with a few dark brown mottles. Weak subangular blocky structure. Very hard when dry; a few pores.
15 - 30 cm.	Dark grey-brown sandy clay loam (10 YR 4/2, moist) with a few dark brown mottles along roots. Compact and extremely hard when dry; sticky when wet.
30 - 160 cm.	Grey-brown clay loam (2.5 Y 5/2, moist). Moderately developed fine subangular blocky structure. Compact and very hard when

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dry; slightly stick when wet. Some carbonate concretions.

160 - 190 cm. Light brownish-grey clay (2.5 Y 6/2, moist) with many yellowish-brown and very dark grey fine mottles. Compact and very hard when dry. Much carbonate.

190 - 225 cm. Light brownish-grey sandy clay (2.5 Y 6/2, moist) with many strong brown mottles. Otherwise as above.

225 - 240 cm. Light brownish-grey coarse sand (2.5 Y 6/2, moist). Slightly hard when dry.

N.B. Samples below 190 cm. taken with the auger.

There is very little organic matter in these soils, due to the poor ground flora. The two profiles P262 and J4 have one per cent in the topsoil; other profiles had similar or lesser amounts. The available phosphorus is high, except in the surface soil. In the exchange complex sodium is the chief cation, forming 30 to 50 per cent of the total and giving pH values up to 9.6. There are small amounts of carbonate in the subsoil of most profiles and often some soluble salt. These are the result of the low rainfall on the land to the east and south-east. The rain is sufficient to carry dissolved salts, including calcium, to the foot of the slope but the streams dry up during the dry season and much of the salt is left in the soils at the foot of the slope. This is also the reason for the high sodium content of the soils. The soils are unsuitable for cropping in their present state. Reclamation, even if possible, seems unjustifiable when there is so much better land.

SOILS DERIVED FROM LAKEBED SILTS

At some stage in the history of the Usangu plain small lakes formed and in these a whitish silt was deposited. The chief occurrence discovered was in the vicinity of the Songwe cattle market. This area lies astride the Mbarali river (still known locally as the Ruaha river although most of the water of the Ruaha now joins the Mbarali much further downstream). The appearance of these silts is shown in fig. 6 which shows the lower part of profile 241, between 130 and 215 cm. below the surface. This profile was naturally exposed in the bank of the river.

Along the river bank these silts have been covered by more recently deposited river alluvium. In profile 241, right on the bank, the top 50 cms. consist of this river alluvium. Half a mile or so from the river the silts appear at the surface, giving a light grey powdery soil.

In profile 241 the silt is about 150 cm. in thickness and lies on a dark grey clay, typical of the alluvial clay in other parts of the plain. The other profiles were only examined to a depth of 3 feet and the thickness of the silt was not determined.

Apart from the silts in the vicinity of the Songwe cattle market there is a patch of silt represented by profile R4, a few miles north of Mahongole. Here the silts are exposed on the surface. The limits of this patch were not surveyed and were not distinguishable on the aerial photos. It is likely that the patch is small and not connected with the larger area at Songwe.

A description of profile 241 is given below. The upper 28 cm. of the profile is river alluvium and the layer from 28 to 50 cm. is probably a mixture of silt and river alluvium.

PROFILE 241

Location	In bank of Mbarali (Ruaha) River by Songwe Cattle market.
Parent material	River alluvium and lake-bed silts.
Topography	Level.
Drainage	Subject to flooding but probably for short periods only.
Vegetation	Open woodland, Acacia spirocarpa dominant. Good growth of grass (including Rhodes grass) and herbs.
0 - 3 cm.	Pale brown sand (10 YR 6/3, dry). Loose. Abrupt boundary.
3 - 28 cm.	Grey clay (10 YR 5/1, dry) with common brown fine mottles. Strong fine blocky structure. Hard when dry. Abrupt boundary.
28 - 50 cm.	Grey-brown clay (10 YR 5/2, dry) with common, yellowish brown fine mottles. Strong, medium blocky. Very hard when dry.
50 - 85 cm.	Pale brown sandy loam (10 YR 6/3, dry) with common, yellowish-brown fine mottles. Transition to:-
85 - 112 cm.	Pale brown sand. Massive and fairly compact. Friable when moist. Clear boundary.
112 - 208 cm.	White fine sandy silt (10 YR 8/2, dry) (pale brown when moist) with common strong brown fine mottles below 150 cm. Massive at top; thin platy below. Porous. Friable at top (moist) becoming firm below.
208 - 240 cm.(+)	Dark grey clay (10 YR 4/1, dry and moist) with common light yellowish-brown fine mottles. Strong medium blocky structure. Compact and very hard.

NB. The dry season level of the river is at 350 cms. approx. The profile was moist below 75 cm.

In profile 241 the soil is approximately neutral in reaction but in R4 (see table 12) and another to the north of profile 241 (analyses not included in the tables), in both of which the silt is exposed at the surface, the pH was 8 or higher and there was considerable sodium in the exchange complex. In a fourth profile, to the south of profile 241, the silt was fairly high but was less than the clay and the sodium was not excessive (about 12% of total exchangeable cations).

In the three profiles near the Mbarali river there is a reasonable amount of organic matter ($1\frac{1}{2}$ to 2%); the top 3 cms. of profile 241 is a recent overwash of sand and can be ignored. In the fourth profile, R4, the organic matter is extremely low (0.65%); there may have been some loss of topsoil by erosion at this site. The available phosphorus is high, as it usually is when there is much fine sand.

The two profiles with a pH of 8 or above (R4 and that to the north of profile 241) both showed exchangeable sodium percentages of over 15 at all levels in the profile. At the other two sites it was less than 15. There was no serious accumulation of soluble salts at any site.

The more alkaline members of this group are not suitable for cropping and should be excluded from any irrigation scheme. The other two are satisfactory. A detailed survey would be required to determine the extent of the unsuitable soil.

ALLUVIAL COMPLEXES

Much of the alluvial fan of the Mbarali river consists of a mosaic of alluvial sands, sandy loams, loams and clays on too fine a scale to be shown on the maps, or to be distinguished with any reasonable reliability on the aerial photos. The same is true of the fans of the Halali (Kioga) river and to a lesser extent of the other rivers. The map of a portion of the Mbarali Irrigation Scheme illustrates the complexity.

On these reconnaissance maps three alluvial complexes have been distinguished:

Xt = mainly light-textured alluvium: sands, sandy loams and loams.
Xh = mainly heavy-textured alluvium; loams, clay loams and clays.
Xm = including both light and heavy alluvium.

The soils of the light-textured group are, many of them, too sandy for irrigation. Capital cost per acre of irrigable land would therefore be high. If, however, canals were to pass by or through one of these areas on their way elsewhere it would be possible to develop a proportion of the soils of the complex.

The soils of the heavy-textured complex are suitable for irrigation. The complex including light and heavy soils should also be irrigable but a variable proportion of the area will be unusable.

SOILS WITH SODIUM CARBONATE

These soils were only seen in the southern projection of the Usangu plain which lies between the Chimala and Kimani rivers. The soils are characterised by a white encrustation forming on the surface when the soil dries. This encrusting material is impure sodium carbonate; it is called "magadi" by the local people.

The soils are loams or sandy loams and lie at or a little above normal flood level. This position favours a strong capillary rise of water from a water-table not much below the surface. The continued evaporation of the ascending water leaves a concentration of sodium carbonate in the upper part of the soil.

These soils, if undisturbed, carry a thin grass cover. In many places the grazing and trampling of cattle have destroyed the grass and pulverised the soil to a fine dust. Great clouds of this blow away when the wind is strong.

Five sites were examined and analyses of soils from two are given in table 12. In profile 248 (a few yards to the east of profile 247 at Utulo) the top 20 cm. is not particularly alkaline; the pH is 7.9 and the exchangeable sodium is 14 per cent of total cations. Below 20 cm., however, the pH rises rapidly to over 10 and the sodium to 82 per cent. There was some accumulation of salts below 80 cm. The water-table stood at 125 cm. at the time of sampling (mid-August). The upper 20 cm. of this profile is not unsatisfactory but below this the soil becomes too alkaline for crops and the soil as a whole is unsuitable.

At the other four sites, of which B17 is an example, the pH was 10 or higher at the surface; the exchangeable sodium was usually about 75 per cent of the total cations. These soils are quite unsuitable for crops.

The tables show the presence of $CaCO_3$ in these soils. This is calculated from the evolution of CO_2 on acidification. The material is probably sodium carbonate and not calcium carbonate.

These magadi soils occur in small patches in loams and sandy loams not affected by sodium carbonate. The symbol Q, by which they are indicated on the map, is used to show the presence of scattered patches of the soil in the vicinity and is not meant to show the location of particular patches. It would probably be possible to reclaim the soils by the application of gypsum. Leaching alone would not be sufficient because the soils have no reserve of calcium to replace the sodium removed. However since they are mostly rather sandy in texture and lie on ridges they are not important to an irrigation scheme. A particularly extensive area of these soils is shown in figure 16.

NON-ALLUVIAL SOILS

The soil maps show 8 different non-alluvial soils. Only one of these, the clay of the pediment catena, is at all suitable for irrigation and very little of this clay lies in a suitable position for inclusion in an irrigation scheme covering the Usangu plain. However, brief descriptions of the soils will show why the limit of irrigable land has been drawn where it has.

1. Red and brown soils of well-drained sites.

These reddish sandy loams, develop wherever there is free drainage within the soil and provided that the parent material is not a pure sand. They are derived from granite in the Madibira area and from Basement Complex schists and gneisses near Rujewa. The "pediment catena" in the Chimala area and to the east of the Kimani river has a red or brown soil as its upper member (neglecting bare rock) and the "stony soils (lithosols)" shown in the south between the Ruaha and Kimani rivers are shallow reddish soils derived from shales of the Bukoban system.

When of reasonable depth and not damaged by erosion these are soils of moderate fertility. Being on slopes, and usually on slopes dissected by seasonal water-channels, they are not conveniently situated for irrigation and are in any case rather sandier than is desirable.

No samples have been analysed.

2. Alkaline red and brown soils.

These are found on the left bank of the Mbarali below Rujewa. They appear to have formed as normal well-drained reddish soils, and only later to have acquired the considerable amount of sodium necessary to make them alkaline. Only one profile was examined.

PROFILE 240

Location	Mayota, about 100 yds. south of village.
Parent material	Probably colluvium; derived from Basement Complex gneisses.
Topography	Lower slope of pediment; slope about 1½% to north.
Drainage	Surface drainage good: internal drainage poor.
Vegetation	Thornbush, with Commiphora sp. and A. kirkii, etc. Much bare ground near the village.
0 - 20 cm.	Brown sandy loam (7.5 YR 4/2, dry), strong, medium subangular blocky structure. Fairly compact; hard.
20 - 50 cm.	Brown sandy clay (10 YR 5/3, dry). Weak medium subangular blocky. Compact; hard. Diffuse boundary.
50 - 100 cm.	Brown sandy clay (7.5 YR 4/4, dry) with a few faint paler mottles. Massive and compact. Diffuse boundary.
100 - 185 cm.(+)	Reddish-brown sandy clay (5 YR 4/4, dry) with common faint, darker mottles. Massive and compact. Carbonate concretions present.

The soil is uniform in texture throughout its depth, with 24 per cent of clay and a little calcium carbonate. Organic matter is very low. The pH is 9 or higher at all levels and the exchangeable sodium percentage is above 20 except at the surface. There are also serious amounts of soluble salts in all horizons except the surface.

The soil would be unsatisfactory without reclamation. It is also topographically unsuited to irrigation, being well above the level of the river and being badly affected by erosion gullies.

3. Grey sandy soils of foothills

The hills around Madibira, in the north-east corner of the plain, have steep rocky upper slopes and long, gently-sloping lower slopes (pediments). The upper part of the pediment slopes, at the foot of the rocky slope, is usually a red sandy loam and the lower part, fringing the plain, a grey sand.

Only one pit was dug on the grey sands (P 263). There were: 20 cm. of grey-brown coarse sand (10 YR 5/2, moist) overlying a very hard clayey coarse sand containing quartz and feldspar gravel. Below 80 cm. depth there were brown mottles and iron concretions.

The analyses (table 12) showed that the surface horizon was neutral in reaction but below 20 cm. the soil was strongly alkaline. The alkaline horizons appear practically impervious to water. In the vicinity of this profile there were several seepage spots where water draining from the hills is forced to the surface.

It is not known how well profile 263 represents these grey sandy soils. The soils are cultivated in a few places so at least sometimes in these soils there will be more than 20 cm. of fairly neutral sand above the alkaline subsoil.

The soils are not suitable for irrigation owing to their sandy upper horizons and to the poor drainage and alkaline reaction below.

Sandy soils also occur in the southern part of the plain near Mporo and around Mabadaga. They were not examined but those around Mabadaga seemed more fertile than the general run of these soils. Here the sand may be old sandy alluvium.

4. Cemented sandy soils of low-lying ground

These soils occupy much the same position fringing the plain as the grey sandy soils just described. The cemented soils, however, are hard right up to the surface, at any rate when dry. On the whole, also, they are on a lesser slope than the non-cemented sands.

A description of one profile (profile 246) is given below. Analyses of this and two other soils (M3 and M8) are given in the tables.

PROFILE 246

Location	Brandt Mission, about 500 yds. from the Chimala river.
Parent material	Probably colluvium, derived from granite.
Topography	Lower edge of piedmont slope; slope about 1%.
Drainage	Very poor internal drainage.
Vegetation	Open thorn scrub: Acacia spirocarpa, Combretum obovatum, etc.

0 - 10 cm. Dark grey-brown loam (10 YR 4/2, moist) with common dark brown mottles. Weak, fine blocky structure. Compact and hard. Clear boundary.

10 - 30 cm. Dark grey-brown coarse sandy loam (10 YR 4/2, moist), no mottles. Massive, compact and extremely hard. A few iron concretions with MnO_2. Merging into:-

30 - 100 cm. Grey-brown loam (10 YR 5/2, moist) with common yellow brown fine mottles. Many non-stained quartz grains and some iron concretions, with MnO_2. Massive, very hard and compact. Becoming sandier, slightly less hard and with calcium carbonate concretions below 60 cm.

100 - 130 cm.(+) Brown clayey coarse sand (100 YR 5/3, moist), not mottled. Many iron and manganese concretions and calcium carbonate concretions. Massive and very compact; slightly hard when dry, sticky when wet.

The soils so far analysed have about 20 per cent of clay in the surface horizon. This increases with increasing depth to 60 cm. or 100 cm. and then (in P246 at any rate) it decreases again. This probably indicates movement of clay and the formation of a horizon of clay enrichment.

In profile 246 the exchangeable sodium is quite low in the top 60 cm. and the reason for the hardness of the upper horizons is not clear. Probably the clay, being mobile, fills the pores in the soil and cements together the sand particles. Below 100 cm. (and probably below 60 cm.) the sodium is high and this would account for the imperviousness of the soil. Concretionary carbonate occurs below 60 cm. depth.

In M3 and M8 the exchangeable sodium is high throughout the profile and the organic matter is very low. Both these profiles were on somewhat steeper ground than P263 and ground which was dissected by shallow erosion channels. The ground on which they have developed is probably an erosion surface rather than a colluvial fan, which the site of P263 more resembles. The vegetation at sites M3 and M8 was open Commiphora bush, with sparse ground cover. The commiphorae will stand drier conditions than Acacia spirocarpa; the absence of the Acacia from M3 and M8 points to drier conditions than those prevailing near profile 246, where Acacia spirocarpa was present. This aridity would explain the greater alkalinity of M3 and M8.

Two other soils, one near Mayota on the Kimani and the other near Mabadaga, were similar to M3 and M8. The bush at these two sites includes Commiphorae and Acacia kirkii but no A. spirocarpa.

Another soil, on a level site near Ikoga at the eastern side of the plain, was extremely sandy, the top 9 inches of the profile having an exchange capacity of only 1 me./100 g. The exchangeable sodium was 40 per cent of the total cations in this surface horizon and 68 per cent in the heavier-textured subsoil.

The soils in this group are obviously of varied origin but have in common a compact, hard consistence usually, if not always, due to a high exchangeable sodium figure. It will be noted that many of them are acid in the upper part of the profile

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in spite of their high sodium. This suggests that they are degraded alkali soils.

Those soils are not suitable for irrigation.

5. Clays of the pediment catena

The pediment catena in the Chimala-Kimani area consists of red and brown well-drained soils on the upper slopes, sometimes grey sandier soils on the lower slopes and clays in the valleys. There is a strip of such clay at Mgalo on the Kimani river which might be irrigated within a scheme covering the soils of the plain but most of these clays are in small patches away from the plain and could not easily be commanded.

Only one of these soils have been examined. It is described below and analytical figures are given in the tables. It tends to be somewhat alkaline in the subsoil but should be quite satisfactory for irrigation.

PROFILE K8

Location	Mgalo on east bank of Kimani river; 3 miles north of main road.
Parent material	Alluvium.
Topography	Near foot of hillside. Slope about 1½ per cent.
Drainage	Probably poor.
Vegetation	Acacia spirocarpa woodland. Scattered small cultivated plots used for finger millet.
0 - 30 cm.	Dark grey clay (10 YR 4/1). Some iron-stained quartz sand grains.
30 - 60 cm.	Grey clay (10 YR 5/1) with a few yellow-brown mottles. Slightly sticky when wet. A little concretionary carbonate.

N.B. Sampled with auger.

6. Alkaline non-alluvial clays

This soil occurs on the south bank of the Mbarali below Mayota and extends southwards for an undetermined distance. It is a clay and is classed as non-alluvial because it occupies the slope bordering the plain but it is probably alluvium deposited by some seasonal river draining the higher ground to the south. This river may have been the Msimansi in a former course.

The soil is too alkaline for cropping in its present state and is above the general level of the plain so would be difficult to command. A description is given below and analyses will be found in table 12.

PROFILE 239

Location — On left bank of the Mbarali river, 5 miles below Mayota and 500 yds. south of the river. Near the village of Kwangangala.

Parent material — Probably alluvium derived from Basement Complex gneiss.

Topography — Sloping about 1 per cent to south.

Drainage — Flooded during rains. Internal drainage very slow.

Vegetation — Grass and gall acacias (A. pseudofistula?)

0 - 15 cm. — Dark grey clay (10 YR 4/1, moist). Strong, medium subangular blocky structure. Wide cracks, but clods compact and extremely hard when dry.

15 - 90 cm. — Very dark grey clay (10 YR 3/1, moist) with a few faint grey-brown mottles between 15 cm. and 30 cm. only. Angular blocky below 30 cm. Otherwise as above.

90 - 185 cm. — Black clay (10 YR 2/1, moist) with a few coarse sand grains. Compact and very firm (moist).

7. Pale sands of gentle slopes

These sands occupy the gently rising ground which forms the northern boundary of the Usangu plain. They also cover a few low hills which project through the alluvium in the western part of the plain. The soils are derived from the underlying rock, which is probably granite.

This group of sands includes profiles with a fairly wide range of properties. Some are loose sands, similar to the "grey sandy soils of foothills" though they differ in not being in association with red soils higher up the slope. Others are alkaline and cemented and would be better put with the "cemented sandy soils of low-lying ground". There was, however, no time for detailed mapping and they all had to go into the one group.

The profile 250, described below, was from the low hill on which Luhanga village stands. It was near the hill-foot and the lower part of the profile is affected by a seasonal high water-table. The other profile was from the rising ground near Ulanga on the northern boundary.

PROFILE 250

Location — Luhanga, near Utengule, in western part of the Usangu plain.

Parent material — Probably granite or granitic gneiss.

Topography — A low hill rising through the alluvium of the plain.

Drainage — Impeded in lower part of profile, perhaps because of seasonal high water-table.

Vegetation Thornbush, including Acacia spirocarpa, Commiphora sp., etc., with grass and herbs.

0 - 65 cm. Dark brown coarse sand (7.5 YR 4/4, moist) (Pinkish grey, 7.5 YR 6/2, dry). Massive structure, but soft (dry). Few visible pores. Abrupt, wavy boundary.

65 - 170 cm. Brown coarse sand (7.5 YR 5/4, moist). Abundant white, black and yellowish-brown mottles; many black iron concretions. Partly cemented and very hard. Massive and compact. Becoming less hard below 150 cm., probably because moist.

The profile 250 is an acid leached sand, poor in all nutrients down to a depth of 65 cm. Below this there is a concretionary zone, probably representing a seasonal water-table, in which leaching is much less severe. Below 150 cm. there is a rise in exchangeable sodium to 20 per cent of the total cations.

The soil U20, on the other hand, is neutral in reaction and has retained a fair amount of calcium and quite large amounts of phosphorus. Unfortunately it has also accumulated harmful amounts of sodium and soluble salts. This soil was strongly cemented. A third soil, U21, was strongly alkaline throughout (pH 9.2 to 9.8) but was not affected by salts.

The soil pattern in the vicinity of Utuya and Ulanga is complicated by severe wind erosion around the sites of existing and former villages. In the worst areas the sites of cattle compounds, where the soil has been protected by the cattle dung, stand up as mounds several feet above the surrounding stretches of exposed subsoil. What little cultivation there is in these sands is confined to old cattle compound sites where the soil has been enriched by the dung.

These pale sands are of no value for irrigation.

SOIL PROFILES WHICH ARE COMPOSITE IN THE TOP TWO FEET

In a number of places the soil profile consisted of a shallow layer of alluvium laid down over non-alluvial material or over another alluvial soil of quite different texture. This is actually quite common, as the detailed soil map of the Mbarali Irrigation Scheme shows. Most of the occurrences, however, were small in area and could be omitted from the reconnaissance map at a scale of 1:125,000. A few larger areas remained which were too large to be ignored and it was necessary to create 4 groups of composite soils to cover these cases. The groups are:-

Sandy loam overlying cemented sandy soil
Clay overlying cemented sandy soil
Clay overlying cemented sandy loams, i.e. the sandy alluvial soils affected by alkali.
Recent alluvial clay overlying sandy loam.

These composite groupings were only used if there was a change in the soil in the top 2 feet (60 cm.) of the profile. Also, if the top layer was less than 6 inches thick it was ignored and the soil classed according to the underlying material. In these composite profiles, therefore, there is from 6 to about 20 inches of the upper member overlying the lower member. Any changes below 2 feet depth in the profile were ignored.

These soils are not very suitable for irrigated cropping. Where the upper layer is fairly thick (say 18 to 20 inches) they could probably be used with care. Those consisting of alluvium overlying cemented material, which is slow draining, would have to have the water applications carefull controlled to avoid water-logging in the alluvial horizons. Those consisting of alluvial clay overlying alluvial sandy loam or sand will have a low water-holding capacity and will need applications of water more often than would a more uniform profile.

LAND CLASSIFICATION

The system adopted for the land classification maps presents the information obtained by the survey relating to the value of the land under irrigation. Thus hilly land, too steep to be economically irrigated, is placed in the lowest category (class 6) although some of it is capable of giving satisfactory yields under the existing rainfall.

In classifying the land it has been assumed that flood control has been achieved, i.e. that the rivers will be kept within their banks. The possibility of flooding due to the ponding of rain-water on impermeable soils has, however, been taken into account since this will not be affected by control of the rivers.

All land regarded as irrigable or possibly irrigable (classes 1 to 5) is level or nearly so and it is assumed that water can be supplied by gravity from intakes on the river-banks. The distance of a particular piece of land from the head-works of the irrigation system is not considered in evaluating the land since the positions of the head-works are not known. Some land has minor undulations of two or three feet in height; in such cases land has been down-graded owing to the extra expense which would be involved in supplying irrigation water.

The present occupation of the land has not been considered in evaluating the soils. Nearly all the present cultivation is by African peasants. Some land is held by Asians and Europeans at Madibira, Rujewa and Chimala. The total holdings of irrigable land by Asians and Europeans is believed to be less than 1,000 acres on the whole Usangu plain. The distance of land from the main road or from centres of population is not considered in classifying its irrigability.

Six suitability classes are used. The first four are considered suitable for irrigation, the remaining two are unsuitable or at least very doubtful.

Class 1. Excellent irrigable land.

Land highly suitable for irrigation farming, being capable of producing sustained high yields of a wide variety of climatically adapted crops. The soils are deep, with a medium to heavy texture and good water-holding capacity. Good soil management can produce or maintain a soil structure and a fertility favourable to plant growth. The land is topographically suited to irrigation.

Class 2. Good irrigable land.

Land suitable for irrigation but measurably lower than Class 1 land in productive capacity. The soil may be rather more sandy than desirable, or have a lower permeability. The class includes clays which will be rather difficult to work and soils with slight alkalinity or salinity. There may be a complex of soils of different textures, which will complicate management, or slight undulations in the surface, which will increase the cost of installation of an irrigation system.

Class 3. Fairly good irrigable land.

Land still suitable for irrigation but of lower suitability than Class 2 because of greater deficiencies in soil, topography or drainage. The soil may be sandy, so that water losses will be high, or of rather low natural fertility, or with more marked surface unevenness than soils of Class 2. There may be drainage problems or, in complexes, considerable differences in permeability between the different soils of the complex. Alkalinity or salinity may be more marked than in soils of Class 2.

Class 4. Land irrigable under special conditions or for a limited range of crops.

This land could still be irrigated but, owing to deficiencies in soil, topography or drainage still greater than those in Class 3, would only produce a limited range of crops or would be expensive to bring under irrigation or would be difficult to manage as arable land. Soils may be very sandy or very heavy in texture; they may be shallow or occur in small parcels amongst unsuitable soils; the surface may be markedly undulating.

Class 5. Undetermined suitability for irrigation.

Land at present unsuitable for arable cropping but which may prove to be reclaimable. Also land which cannot be recommended on present information but which a detailed survey might show to be usable in part. Further studies are needed before an economic assessment of this land is possible.

Class 6. Non-irrigable.

Land permanently unsuitable for irrigated cropping. This includes sands, hill lands, very shallow soils and land which, though perhaps reclainable from salt or alkali, would not justify the expense of such an operation.

It is re-emphasised that in classifying the soils the present flooding has not been taken into account, it being assumed that the rivers will be controlled by dams. Also, the land has been classified according to its suitability for irrigation. It may not be economically practicable to convey water from suitable storage sites to all soils recorded as suitable for irrigation.

The soils of the Usangu Plain will now be considered individually, to indicate which land classification group they have been put into, and why.

..SESSMENT OF THE SOILS OF THE USANGU PLAIN

..nds, in ridges, banks and water-courses (S and M)

Class 6. Too permeable and often standing above the surrounding land.

..ndy loams (A)

Class 3 if in fairly wide stretches. Their disadvantages are a rather high ..rmeability and an uneven surface; patches of sand often occur. Sandy loams in ..rrow strips usually include a considerable proportion of sand and these have usually been put in class 6; in addition to the sand there are usually topographic difficult- ..es.

Loams (B)

Normally Class 1. A small area standing above the surrounding land was down- graded to Class 3 and loams with a high degree of alkalinity and also affected by erosion were put in Class 6.

..ecently deposited clays (K)

Class 1. These soils have a good texture and fertility and favourable topo- ..raphy.

..lder clays (C, Co, Ct) (excluding rapidly dispersible clays)

Class 2. These soils have a poorer texture than the recently deposited clay and a tendency towards an alkaline subsoil.

..apidly dispersible clays

Class 4. The low class is due to the high clay content, the frequent existence ..f alkali in the subsoil, the wide cracking on drying and the common presence of gilgai relief.

The boundary between these clays and the previous ones is very provisional. It would require a more detailed survey to plot it accurately.

..lkaline alluvial clays (Cs)

Class 5. These clays require reclamation, the feasability of which is unknown.

..lays hardening on drying (Ch)

Those believed not to be affected by alkali are in Class 2; those affected by ..lkali are Class 5.

Sandy loams affected by alkali (As)

These soils, even if reclaimed from the alkali, are too sandy to be good irri- gable soils and are therefore placed in Class 6.

Soils formed from lake-bed silts (W)

Two out of the four profiles in this soil were alkaline. The soil is therefore placed comparatively low in Class 3. Further survey is needed to give a better estimate of the extent of the alkali and might result in a regrading of this soil.

Alluvial complexes, predominantly light-textured (Xt)

Where these complexes were mostly loams and sandy loams they were put in Class 3. The presence of undulations and patches of porous sand are the reason for the low grading. Where the complex was mostly sandy loam and sand it was put in Class 4, since only part of the area will be suitable for irrigation. Where wind erosion had removed the topsoil it was put in Class 5 since the possibilities of restoring such a soil are not known.

Alluvial complexes, predominantly heavy-textured (Xh)

Class 2. The loam itself is Class 1 but when in a complex with clay, in which moreover, there are often slight differences in level between loam and clay, a lower grading is called for.

Complexes of light and heavy alluvial soils (Xm)

Class 3. Some of the components of the complex will be of a higher class but the fact that they are in a complex creates difficulties. The sandy component is often at an appreciable height (2 or 3 feet) above the heavier component.

Red and brown soils of well-drained sites (R)

Red and brown soils affected by alkali (Rb)

Grey sandy soils, ill-drained, of foothills (G)

Cemented sandy soils of low-lying ground (H)

Alkaline non-alluvial clays (D)

Pale sands of gentle slopes (T)

Bare rock and shallow stony soils (Z)

All these soils are Class 6. They are unsuitable for irrigation on account of topography, texture, alkali or shallowness.

Clays of the pediment catena (Cp)

Class 2. These are usually quite good soils. Only a small area is shown on the soil map but it is not apparent whether this could be incorporated in an irrigation scheme for the plain.

Sandy loam overlying cemented sandy soil (AH)

Clay overlying cemented sandy soil (CH)

Both these soils are Class 4. This low grading is because of the shallowness of the alluvial (upper) layer.

Clay overlying cemented sandy loam (CAs)

The usefulness of this soil will depend on the thickness of the upper (clay) horizon. This could not be determined for the whole area on a reconnaissance survey so the soil is Class 5.

Recent clay overlying sandy loam (KA)

This is not quite so satisfactory as a deep clay so is Class 2.

In addition, small areas of irrigable land lying enclosed in large areas of land of Class 5 or 6 have been shown as the same class as the surrounding land, i.e. class 5 or 6. Such small areas could not be economically irrigated unless the surrounding area was also irrigated.

ACREAGES OF IRRIGABLE LAND IN THE USANGU PLAIN

The following acreage figures were obtained by measuring the areas of the six soil suitability classes as shown on the Land Suitability Map. The unsurveyed area in the north has been assumed to be Class 4. Areas shown in table 3 as "suitable for irrigation" include land of Class 1 to 4. Areas shown as "unsuitable for irrigation" include land of Classes 5 and 6.

Table 3. Acreages of land of the different suitability classes in the Usangu Plain.

	Sheet 1.	Sheet 2.	Whole Plain	
	acres	acres	acres	%
Class 1	6,600	16,500	23,100	2.2
Class 2	256,200	33,700	289,900	27.6
Class 3	64,900	18,800	83,700	8.0
Class 4	172,500	116,600	289,100	27.5
Class 5	43,700	21,500	65,200	6.2
Class 6	124,700	174,700	299,400	28.5
Suitable for irrigation	500,200	185,600	685,800	65.3
Unsuitable for irrigation	168,400	196,200	364,600	34.7
Total	668,600	381,800	1,050,400	100.0

DEVELOPMENT OF IRRIGATION IN USANGU

A start has already been made in the 5,000 acre Mbarali Irrigation Scheme. If the water available from the Mbarali permits it, this could be extended to the north-west and also, to some extent, within the re-entrant angle in the present western boundary of the scheme. There are several thousand acres north of Itamba, in the angle of the Mbarali where its course changes from west to north, but this area is at present subject to deep flooding.

There is another area favourable for irrigation on the left bank of the Mbarali in the vicinity of the villages of Ulongwa and Mwanyimba. This area is bounded on the west by the old course of the Ruaha and on the east by the Mbarali River. Its southern boundary lies about a mile to the south-east of the Kimani River. This land is mostly fairly high but is subject to a certain amount of flooding. Protection could perhaps be obtained by bunding.

Once the main rivers entering the plain are controlled the main source of flooding on the plain will have been removed and a vast area of land will become available for irrigation. This land is mostly clay, of class 2 suitability. The western boundary of the main block of this land follows approximately the course of the Chimala River from Chimala village to Giriki. It then runs north along the eastern edge of the alkaline clay (class 5) to the Itambo River and then north-east to Wanenyika. From Wanenyika the boundary follows the Great Ruaha River for some miles before turning east-south-east to pass near Udinde and Mwagwalisi. The position of this boundary is marked on the Land Suitability Map as the junction between the Class 2 and the Class 4 clays. The eastern boundary of this area suitable for irrigation is approximately the course of the Kioga (Halali) River from Isunura to Mwagwalisi.

Within this area there is a certain amount of unsuitable or low-grade land, in particular from the Mbarali River near Ujewa to Mahongole. Other unattractive areas are at Nyeregete, near the Kioga River and in the Kapunga, Utulo, Kilambo and Matowo area between the Ruaha and Kimani Rivers.

Some of the land in sandy areas and on the lake-bed silts is subject to small subsidences (fig. 18). These subsidences occur in lines and seem to follow the courses of buried sand strips. They caused trouble on the line of the canal supplying the Rujewa Trial Farm at the southern end of the Mbarali Irrigation Scheme. They are especially prevalent just north of Ujewa Mission and near the Mbarali River just north of Songwe cattle market.

The cause of these subsidences is not clear. It may be due to an alteration in the packing of the buried sand or, perhaps more likely, to the decay of wood and other vegetable matter buried in the sand.

The line of such buried sand strips is often marked by a line of trees and shows on aerial photos looking rather like a string of beads. The "beads" are the trees and the thin line joining them represents the line of subsidences and, probably, rather better growth of grass and herbs whose roots can tap water stored in the buried sand.

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On sheet 2 of the Usangu map the only area which can be recommended at present is the Mwima (Ndembera) flood plain. Until trials show the contrary, the vast stretch of clays in the Ruaha Swamp and surrounding flood plain should be regarded as of lower value for irrigation, and not suitable for any wide range of crops.

It must be emphasised that the areas just mentioned as being favourable for irrigation schemes are chosen on the basis of a reconnaissance survey only. Before there is any detailed planning of irrigation projects it will be necessary to make a detailed soil survey. This will delimit accurately the boundaries of sand patches, alkaline soils and other features which would influence the lay-out of an irrigation scheme.

THE KILOMBERO VALLEY

INTRODUCTION

The name Kilombero Valley is used in this report to describe a long trough of land some of which is not strictly within the Kilombero catchment. The rivers which make up the Kilombero (the Mpanga, Mnyera and Ruhuji are the most important) enter at the south-west end of the trough and continue as the Kilombero for about 95 miles. The Kilombero then turns south-east and leaves the trough. For another 30 miles the trough continues in a northerly direction up the valley of the Msolwa River, a tributary of the Kilombero. All this could be properly described as the Kilombero valley. North of the Msolwa Valley there is a low divide separating the Kilombero Valley proper from the Great Ruaha catchment. The last (most northerly) 10 miles of the trough lies in the catchment of the Great Ruaha.

The total area of soils shown on the accompanying maps is 2,600 square miles. This includes 330 square miles incorporated from a soil survey made by R. F. Loxton in 1952 - 53. The remainder was surveyed by the writer in 1955, 1958 and 1959. The aerial photography used by the writer had been flown at various times between 1948 and 1957 and the courses of rivers shown on the maps are in general those existing at the time of the photography. Some changes have occurred since then of which the chief is a change in the course of the Furua just below Malinyi; it now flows through Kipingo and this has necessitated a re-alignment of the roads in the vicinity. This change occurred after the soil survey of this area had been done and there was not time to revise the area; so the map shows the situation before the change.

The valley is large and difficult of access, particularly in the central area between the Kilombero and Kihanzi rivers. In spite of considerable extrapolation there remains a large blank of about 375 square miles in the middle of the map which it would have been guesswork to fill. It is probable that this is similar to the area immediately to the west of the blank, i.e. mainly clay, much cut up by channels some of which will contain sand, and with a few sand-ridges formed by the filling-in of channels.

In the south-west smaller areas of alluvial land bordering the Mnyera and Ruhuji rivers were also omitted, again through lack of time. Apart from these gaps all the irrigable land in the Kilombero Valley is believed to have been included. The gap in the soil map to the west of Msita is hilly and not suitable for irrigation.

As for Usangu the soil map is based on photo-interpretation. From the roads traverses were made along footpaths, game tracks and sometimes in the Land-rover across country. The alluvial soils produce a tall and dense growth of grass which it is impossible to penetrate on foot at any reasonable speed. Even when the grass is burnt in September and October the grass stems are moist enough to remain as a tangle of canes which are almost as difficult to pass through. A Landrover will go through the grass and with a local guide who knows where channels can be crossed it is often possible to drive for considerable distances. Two such journeys made in the course of the survey were from Sofi Majiji to the Kilombero river and from Mpanga to the Teeto mbuga. Nevertheless the fact remains that to get to parts of the valley would require teams to cut paths through the grass and canoes for river crossings.

Where possible 6 foot profile pits were dug to examine the soil. Such pits are shown on the map by a number prefixed by a P. When labour was unobtainable or time was short samples were taken with a 2 inch auger. Such sites are indicated on the map by the prefixes M or L.

PHYSICAL FEATURES OF THE KILOMBERO VALLEY

The Kilombero Valley, in the wide sense in which this name is used in this report, consists of a trough of land running roughly south-west to north-east. On the north-west this trough is bounded by an escarpment which rises abruptly from the 800 or 900 foot altitude of the valley floor to 4,000 or 5,000 feet at the edge of the escarpment.

On the south-east side the rise is less steep. Behind Lupiro, Iragua and Itete the land rises fairly steeply to the Mahenge mountain block, about 3,500 feet above sea-level. North-eastwards from Lupiro there is flattish country up to the Great Ruaha river; north of this river the country becomes somewhat more hilly. South of Itete and continuing round the western end of the valley trough, there is hilly country rising steadily but not precipitously to the headwaters of the Ruhuji, Mnyera and Mpanga rivers.

These three rivers on combining form the Kilombero River (though some of the lo- local people use the name "Mnyera" down to the confluence with the Kihanzi and "Kilombero" after this). The more important tributaries between Ifwema and Boma ya Ulanga, where the river leaves our area, are the Furua on the right bank and the Kihanzi, Ruipa, Lumemo and Msolwa on the left. These flow throughout the year though in dry years the Msolwa may dry up before reaching the Kilombero. Other tributaries, like the Luasesa, Mchilipa and Luri, flow throughout the year in their upper courses but lose themselves in swamps on the plain in the dry season.

The altitude of the valley floor is about 950 feet at Ifwema (fig. 19) and 820 feet at Ifakara. A cross-section between Mgeta and Iragua, surveyed by the Rufiji Basin Survey Team, showed a 5 mile fall on the Mgeta side at a gradient of 1 in 1,200 followed by a 17 mile level section and a 3 mile rise at 1 in 175 at the Iragua end.

A. M. Telford (1928) published some Kilombero Valley sections including one running south-east from Mgeta and generally similar to that just described. Another of Telford's sections ran S.S.E. from the Narabunga river. This showed, starting from the Narabunga end, 2 miles descent at 1 in 235, followed by 7 miles at 1 in 1,200. There was then an eight mile level section and finally a 5 mile rise at 1 in 800. In a third section, south from Ifakara, the central level section was only one mile wide; there was a rise of about 1 in 500 to north and to south.

The central level portion of these sections is the flood plain of the Kilombero River. The gentle rise on each side of the flood plain appears to be the basal plane of erosion though nearly everywhere it is covered by alluvial deposits of the tributary streams. The southern part of the Ifakara section is the least affected by deposition and here the gradient is 1 in 490 over a distance of 6 miles.

The central level portion of the valley is filled with a network of watercourses. Towards Ifakara this level portion narrows and becomes the meander zone of the Kilombero River. The flatness of the valley and the meandering course of the river are due to a rock bar just below Boma ya Ulanga. Below this bar the river flows in a narrow valley with no appreciable deposition of alluvium.

In the northern continuation of the valley from Ifakara the section up to the Ruaha River is mainly the valley of the Msolwa River. From the foot of the escarpment the Msolwa flows east to within about 2½ miles of the Ruaha. It then turns south.

In this southerly course the Msolwa flows as a small meandering river in a channel cut in a flat valley between a quarter and half a mile wide. At each side of this valley there is a rise of 5 or 6 feet to a belt of sand which stands slightly above the surrounding land like a raised levée. Everything seems to point to this quarter-to half-mile wide valley being a former course of the Ruaha. The small Msolwa River could not produce so wide a channel or deposit so much sand on the banks. When the Ruaha River was flowing here the bed will have been coarse sand but in its lower courses it is now a clay, presumably deposited since the Ruaha formed a new course. Longitudinal depressions still remain where the deeper channels in the bed have not yet been filled. In the upper reaches of the channel the sandy bed is not yet completely covered and in places banks of sand still show above the clay.

Other, more recent, courses of the Ruaha run a little to the south of the present course and strips of sand obviously originating in the Ruaha run southwards right up to the Msolwa River. It is remembered locally that in the early years of this century the Ruaha overflowed its banks and water flowed along some of these old channels. The water is said to have returned to the Ruaha further downstream but the height of the divide between the Ruaha and Msolwa must be only a few feet above the flood level of the Ruaha.

The present course of the Ruaha cuts right across the trough of the "Kilombero Valley", It emerges from a deep gorge cutting through the escarpment on the west and enters a lesser one on the east side of the map.

The remaining part of the trough north of the Ruaha is the valley of the Msowero River. This is a permanent river but the Msindazi, to the east, dries up during the dry season. The Luhembe River joins the Msowero near the north end of the trough and appears to be the bigger river but the local people use the name Msowero for the combined river below the confluence. The Luhembe is very subject to flash floods and deposits large amounts of sand in and near its course after leaving the hills to the north. Near Kidodi changes in the course of the river occur almost yearly.

All the rivers entering the Kilombero Valley suffer a lessening of gradient as they reach the plain and so tend to build up alluvial fans. These fans are particularly extensive on the south-east side of the valley, perhaps because there has been more destruction of the original forest cover on this side. The Ruhuji and Furua rivers are continually silting up their channels and breaking out into new ones. In 1928, when Telford was studying the area, the Ruhuji turned east at Magini and joined the combined Mpanga and Mnyera to the north of Igawa, along the course now used by the Furua. Numerous other old courses of the Ruhuji can be picked out on the soil map. Between them the Ruhuji and the Furua Rivers have strewn about 150 square miles of the plain with sand. The sand cover is not complete but the patches of better soil are so scattered and surrounded by sand that the whole area has probably been rendered useless for development.

The fate of this land emphasises the necessity of preserving what forest still remains and of endeavouring to stop burning of the hill-side. Some of the forest s now protected in forest reserves but in other parts destruction still continues (see fig. 21) and is likely to lead to further blanketting by sand of good alluvial land.

GEOLOGY

The Kilombero Valley lies largely within the Usagaran System of the Basement Complex. In this region the Usagaran System consists chiefly of migmatitic biotite gneiss and acid granulites. There are occasional dyke rocks such as dolerites and mica pegmatites. A geological map is given in volume VI.

On the north-west side of the valley Usagaran rocks constitute the entire escarpment, from Udagaji in the Kihanzi valley in the south-west to beyond Kidodi in the north. Usagaran rocks also form the hills at the south-western end of the valley and those on the south-eastern side at least as far as the Kivukoni-Lupiro-Mahenge road. It is fairly certain that they also underlie the alluvium of the valley floor as far down as Ifakara.

To the east of the Msolwa river there is a belt of Karroo sandstone. J. Spence (1957) showed that to the north of Kidodi the Karroo extends up to the foot of the escarpment. E. G. Haldemann (private communication) found Karroo sediments at Boma ya Ulanga and considers that from the structural setting and known exposures the Karroo must be expected to extend up to the escarpment for some distance to the south of Kidodi. It will be seen later (under the description of the "Pale Sands") that much of these Pale sands lying between the Msolwa river and the escarpment on sheet 1 of the soil map appears to be derived from Karroo sediments. The distribution of these sands suggests that the Karroo abuts on the escarpment at least as far south as Signale, just north of Segemaganga. From here the boundary will run southwards across the Kilombero, with Usagaran to the west and Karroo to the east.

CLIMATE

The rainfall in the Kilombero Valley is dominated by the escarpment along its north-western side, and by the Mahenge mountain block to the south east. There is a high rainfall on this high ground and on the lower ground in the immediate vicinity; but in the centre of the valley, particularly where it is widest, the rain is much less.

Thus at Kipingo, near Malinyi, the annual rainfall is about 40 inches. At Ifakara and Igota, where the valley is constricted between the north-western escarpment and the Mahenge highlands, the rainfall is 48 and 50 inches respectively. At Kisawasawa, at the foot of the escarpment, there is an average of 71 inches of rain a year.

From Igota southwards there is a rapid rise to 74 inches at Mahenge. To the south of Mtimbira and Malinyi and to the west of Mpanga the rise is more gradual. The rain falls mostly in the months December to April. Other months often have occasional showers but this rain is erratic and varies greatly from year to year.

The valley lies at a low altitude (800 to 900 feet) and is far removed from the moderating influence of the sea. In October to December high temperatures prevail and screen temperatures of over 100°F have several times been recorded. At Ifakara the mean of the daily maximum and minimum temperature, averaged over a month, has varied from 71° 82°F.

Further information on the climate will be found in the Meteorological Appraisal of the basin - Paper 2 of section 3 of this Rufiji Basin Report.

SOILS

GENERAL DESCRIPTION

In considering the soils of the Kilombero Valley the area is best divided into three sections:-

(i) The Kilombero Valley in the strict sense, i.e. Mpanga to the mouth of the Msolwa River.

(ii) The Msolwa Valley.

(iii) The Msowero and Luhembe Valleys.

The first is much the largest area of the three and occupies sheets 2, 3 and 4 of the soil map and the southern-most portion of sheet 1. Clays cover the flood plain and parts of the bordering planes of erosion described earlier. These clays are somewhat weathered since their rate of deposition is very low and weathering processes have had time to produce changes in the deposited material whilst it was still near the surface. The low rate of deposition is a result of the small amount of suspended matter in Kilombero flood water.

From a few miles above Ifakara to Boma ya Ulanga the Kilombero flows in a "meander zone". Here the river is constantly eroding at some points and depositing complexes of sand or clay at others. The soils of this zone have not been mapped since the land is uneven, subject to changes in the river and therefore unsuitable for irrigation. An idea of the land can be obtained from the Ifakara-Kivukoni road. There is a good proportion of clay but many sand strips and sand banks which could not be separated at the small scale of the reconnaissance soil maps.

The rivers and stream entering the valley have laid down alluvial fans on the gentle slopes bordering the flood plain. The young alluvial soils in these fans contain many little-weathered minerals and are the most fertile soils in the valley. The loams and clays are very suitable for irrigation, provided flood control can be obtained. The sandy loams will be rather wasteful of water and the sands are altogether too porous.

There are also large areas of poorer sands in some of the alluvial fans, particularly those on the south side of the valley. It seems likely that these sands are the result of excessive soil erosion in the catchment areas of the rivers which have brought them down. The catchment areas to the south and south-west of the Kilombero Valley have been largely denuded of their original forest cover and it is the tributaties on this side, from the Luri to the Mnyera, which have brought down the most sand. The catchments of the Mpanga and the rivers along the northern side still retain considerable areas of forest and do not have the same extent of sand in their alluvial fans. Even amongst the rivers along this northern side those which come from forest reserves are noticeably clearer than those from forest in which some clearing takes place.

Figures for the sediment carried by the rivers, given in the Hydrological section of this report (Vol. II) show that the Furua carries the most sediment per unit volume of water, of all the Kilombero tributaries which have been regularly sampled; the Ruhuji carries the next largest amount. When the greater discharge of the Ruhuji is taken into consideration the Ruhuji is shown to bring down the greater weight of sediment. The following figures are for the year Nov. 1958 to Oct. 1959:-

Ruhuji: 706,000 tons.
Furua : 456,000 tons.

In agreement with these figures these two rivers, together with the Mnyera which cannot be separated from the Ruhuji, have the most extensive areas of sand in their alluvial fans.

These sandy alluvial fans on the south-east side of the valley are a complex of sand ridges with loam or clay in pockets between the ridges. They were often not separable at the scale of the maps and are then shown as a complex (Cs).

On the north-west side of the valley the alluvial fans are smaller but contain a higher proportion of good soil. The fans do not cover the whole of the slope and non-alluvial soil derived from the underlying rock occur between successive fans. This is particularly marked between the Ruipa and Lumemo Rivers.

On the hills bordering the valleys there are red, brown and grey soils formed in situ. These are poor soils and anyway unsuited to irrigation. In valleys between the hills and along the edge of the main valley at the foot of the hills there are sands and sandy clays formed on colluvial material, i.e., which has been washed down from the higher ground. These are in general of low fertility but could often be used for irrigated cropping.

In the Msolwa Valley there are a number of small alluvial fans along the foot of the escarpment. There are also some fairly extensive areas of alluvial clay, particularly just south of the Ruaha and near the mouth of the Msolwa.

The most widespread soil in the Msolwa Valley is a clay with a rather sandy and somewhat undulating surface. This is of lower fertility than the normal alluvial clays (without the sandy surface) and will be more difficult to irrigate on account of the undulations.

On the left bank of the Msolwa there are poor sandy soils derived from Karroo sediments. There are also extensive areas of sand between the Msolwa and the escarpment which are probably of the same origin. Other patches of sand bordering the Msolwa on its west side are probably old levées of a large river, probably the Ruaha, which once followed the present course of the Msolwa. These sands have been weathered in situ and are of lower fertility than fresh alluvial sand.

In the Msowero and Luhembe valleys, north of the Great Ruaha River, the sand formed from Karroo sediments approaches the escarpment and the alluvial area is reduced in width. The alluvial soils are mostly sandy loams, with a lesser but still considerable area of loam and clay.

The Kilombero soil map incorporates an area surveyed by R. F. Loxton. Some of Loxton's soil groupings did not correspond with those adopted by the writer and it was necessary to include these as additional groups in the list of soils.

The complete list of soils shown on the maps is given below. As in the Usangu soil classification, there are certain complexes of alluvial and of non-alluvial soils where the soil pattern was too complicated to show on the final maps or to be mapped in the available time. There are also 5 soils with a composite profile where a shallow layer of alluvium overlies alluvium of a different texture or else non-alluvial material.

SOILS	MAP SYMBOL
Alluvial	
Sands, in ridges or banks	S
Sands, in seasonal water courses	M
Sandy loams, usually including patches of sand	A
Loams	B
Recently deposited clays, subject to seasonal flooding	K
Recently deposited clays, above present flood level	Kc
Clays affected by weathering since deposition	C
Clays with partial overlay of sand	Cn
Complex of clay and sand ridges	Cs
Alluvial complexes, predominantly light-textured	Xt
Alluvial complexes, predominantly heavy-textured	Xh
Complex of light and heavy alluvial soils	Xm
Non-Alluvial	
Red and brown soils of well-drained sites	R
Grey sandy soils, ill-drained, of foothills	G
Low-lying sandy soils, seasonally flooded	L
Pale sands, developed from underlying sediments	Ps
Pale sands, with permanent water-table	Pm
Other pale sands	P
Sandy clays of enclosed basins (mbugas)	D
Grey sandy clays on sloping ground	H
Grey sand with clay subsoil, on sloping ground	Gd
Bare rock and shallow stony soils	Z
Complex of pale sand (P) and low-lying sand (L)	P + L
Soil groupings used by Loxton which do not fit exactly into above scheme	
Flood flow	F
Ferruginous sands	U
Ground-water forest soils	W
Shallow alluvial soils	T

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Foothill catena E

Soil Profiles which are composite in the top two feet of the profile

Sandy loam overlying clay	AC
Sandy loam overlying sand	AS
Recent clay overlying alluvial sand	KS
Recent clay overlying low-lying sand	KL
Clay overlying sandy loam	CA and KA

DETAILED DESCRIPTIONS OF THE SOILS

ALLUVIAL SANDS IN RIDGES OR BANKS

These sands are found in long narrow strips and in wider sheets and their formation appears to be exactly analagous to that of the similar sands of Usangu. The narrow strips are old rivers which have filled with sand, often above the level of the surrounding land. The sheets or banks were deposited by flood waters breaking out from the river channel.

The sands occur chiefly where a river leaves a narrow valley and reaches the level plain. There are, for example, large stretches of sand bordering the Ruaha River after it has left the gorge to the west of the main road (sheet 1) where it starts to meander on the plain. Other stretches of sand are to be seen at the upper end of the Kilombero Valley where the Kihanzi, Mpanga, Mnyera, Ruhuji and Furua rivers leave the hills (sheets 2 and 4).

Profile 177, described below, is an example of sand on a ridge. Analytical figures are given in table 13. Figures are also given for profile L13 which was taken in a stretch of sand near the Ruaha.

PROFILE 177

Location	Itete, on track to Ipera.
Parent material	Alluvium.
Topography	Alluvial fan of Mchilipa river: level.
Drainage	Rapid. Site not subject to flooding.
Vegetation	Tall grass (Hyparrhenia, etc.) and shrubs, secondary to cultivation. Probably originally Acacia campylacantha forest.
0 - 30 cm.	Very dark grey-brown sandy loam (10 YR 3/2, dry). Fine sub-angular blocky structure.
30 - 55 cm.	Reddish-brown loamy coarse sand (5 YR 4/3, dry) with common fine orange mottling. Weak, medium subangular blocky structure. Fairly compact.

55 - 230 cm. Brown river sand and gravel. Quartz, feldspar, mica and iron concretions (to 10 mm. across) with MnO_2. Becoming somewhat finer below 130 cm.

This profile shows the typical decrease in gravel and coarse sand from the bottom of the profile upwards, and an accompanying increase in clay. The 55 to 130 cm. horizon contained 44 per cent of gravel, the topsoil only 0.8 per cent. The clay rose from 1.4 per cent of the whole material in the lower horizon (allowing for the 44 per cent of gravel) to 18 per cent in the topsoil.

Profile L13 is essentially a fine sand. This profile shows a similar increase in clay in the topsoil but this is not a typical feature of the sheet sands.

Organic matter is higher in general in the sands of the Kilombero than in those from Usangu and usually lies between 2 and 3 per cent. Profile 177 is strongly acid in its upper horizons but three other soils analysed, including L13, were only slightly acid. Available phosphorus is high. In these soils of the Kilombero Valley, and in other parts of the Rufiji Basin, a high available phosphorus figure is usually associated with a large fine sand fraction in the soil. Presumably the phosphate-containing mineral is of fine sand dimensions. The exchangeable calcium, magnesium and potassium levels are reasonably good, except for the lower horizons of profile 177.

In spite of a reasonable fertility these soils are not suitable for furrow irrigation owing to their coarse texture and consequent rapid drainage. Overhead irrigation would probably give better results.

SANDS IN SEASONAL WATER-COURSES

In the Kilombero Valley these sands are found chiefly in abandoned river-beds, which probably fill with water in the wet season but may not carry flowing water. They occur, for example, in several former courses of the Ruhuji River, north of Magini.

These soils are not suitable for irrigation.

ALLUVIAL SANDY LOAMS

The sandy loams occur extensively along the foot of the escarpment which bounds the Kilombero Valley on the north-west, and particularly in the numerous small alluvial fans formed by rivers draining the escarpment. The soil is widespread, also at the upper end of the valley where the Kihanzi, Mpanga Mnyera and Ruhuji rivers enter the plain.

Like the sandy loams of Usangu this soil is very variable in texture and areas shown on the map as sandy loams include much sand and loam. In any sandy loam profile, i.e. where the topsoil is a sandy loam, horizons of sand or loam are liable to occur in the subsoil, though probably less often than in Usangu.

One profile is described over the page. Analyses of this and two others are given in the tables. L15 is situated at the north end of sheet 1 and M9 in the upper Kihanzi Valley on sheet 2.

PROFILE 255

Location	One mile east of Kiberege.
Parent material	Alluvium.
Topography	Alluvial fan of Kiberege river; ground slightly undulating; slope 1 per cent.
Drainage	Free within profile but affected by a seasonal high water-table.
Vegetation	Deciduous woodland. Trees include: Sclerocarya caffra, Vitex doniana, Ficus sp., Acacia campylacantha, mango. Grass burnt in dry season.
0 - 10 cm.	Very dark grey fine sandy loam (10 YR 3/1, moist) with common, brown fine mottles. Weak, fine subangular blocky structure. Porous.
10 - 25 cm.	Very dark grey sandy loam (10 YR 3/1, moist) with some gravel. Common, dark brown fine mottles. Massive; slightly hard (dry) Porous. Merging into:-
25 - 70 cm.	Dark brown micaceous sandy loam (7.5 YR 4/2, moist) with common dark grey fine mottles. Massive and slightly hard. Porous. Clear boundary.
70 - 95 cm.	Dark brown micaceous loam (7.5 YR 4/2, moist) with many dark grey fine mottles. Otherwise as above.
95 - 200 cm.	Dark grey micaceous loamy sand (10 YR 4/1, moist) with many dark grey brown fine mottles and, below 120 cm., common reddish-brown mottles. Massive but friable (moist). A few pores. Some black iron and manganese staining below 120 cm.

Water table at 215 cm.

The sandy loams are soils with 12 to 25 per cent of clay, though horizons with a clay percentage outside this range are likely to occur in the profile. The soil is usually just on the acid side of neutral (pH 6 to 7) but occasional soils much more acid than this occur. Soil M9, with a pH of 4.8, is an example. The level of organic matter is usually quite good - 2 to 5 per cent. The carbon/nitrogen ratio is generally higher than in the Usangu soils, indicating that the organic matter is relatively poor in nitrogen. Nitrogen fertilisers may be needed for the best results, particularly after a few years of cropping. On most sites the available phosphorus is good, but occasional low values have been found.

Exchangeable calcium and magnesium are in good supply, except in the soil M9. Potassium is usually adequate though it was low in one soil. No harmful levels of sodium or of soluble salts have been found.

These sandy loams are of good fertility, with an occasional exception, and are well-drained. They are suitable for irrigation though the somewhat undulating surface often present in alluvial fans may complicate the irrigation layout. The patches of sand which occur within the sandy loams will also create difficulties.

ALLUVIAL LOAMS

These soils are commonest in the same parts of the valley as the alluvial sandy loams and are frequently intermingled with them. Thus areas mapped as sandy loams include some loams and those mapped as loams include some sandy loams. Again, as in the alluvial loams of Usangu, it is rare to find a soil which has a loam texture throughout the profile. Profile 257, described below, is a loam down to 35 cm. and a sandy loam or sand below this.

Analytical figures for 3 loam profiles, including profile 257, are given in table 13. Profile 257 is illustrated in figures 23 and 25.

PROFILE 257

Location	Mkula (sheet 1), ½ mile east of road.
Parent material	Alluvium.
Topography	Alluvial fan of Mkula river. Ground slightly undulating, slope about 2 per cent.
Drainage	Well-drained. Occasionally flooded in wet years.
Vegetation	Tall grass with scrub. Trees include Kigelia aethiopica, Acacia sp. and mangoes. The grass is burnt annually.
0 - 15 cm.	Black loam (10 YR 2/1, moist) with slight brown staining along roots. Weak, medium subangular blocky structure. Hard when dry; a few visible pores. Clear boundary.
15 - 35 cm.	Very dark grey-brown loam (10 YR 3/2, moist) with common reddish-brown fine mottles. Otherwise as above. Gradual boundary.
35 - 70 cm.	Brown sandy loam (10 YR 4/3, moist) with common, reddish-brown fine mottles. Structure as above, but not so hard. Clear boundary.
70 - 82 cm.	Dark yellow-brown coarse sand (10 YR 4/4, moist). No mottles. Soft (dry) and structureless. Abrupt boundary.
82 - 122 cm.	Dark brown sandy loam (10 YR 4/3, moist) with common reddish-brown fine mottles. Massive; slightly hard (dry) and porous. Increasing sand and gravel below 105 cm. Abrupt boundary.
122 - 190 cm.	Brown loamy sand (10 YR 4/3, moist) with common strong brown fine mottles. Soft, structureless.

The soils described as loams contain about 25 to 35 per cent of clay. These loams have a nearly neutral reaction, with a pH at the surface of about 6. One profile, M8, was strongly acid and had a pH of 4.6. This soil was in a swamp which had been cleared for paddy rice. A high acidity seems to be typical of some of these swamps. Profile M7, a sandy loam in a swamp not far away (see sheet 2 and fig. 22) showed a pH at the surface of 4.5.

The organic matter in these loams is high for a tropical soil, due to the strong growth of grass, etc., under natural conditions. For the samples analysed values from 4 to 8 per cent were recorded. In some of the soils the carbon/nitrogen ratio is high, suggesting a future need for nitrogenous fertiliser.

Available phosphorus is low in profile 257 but in other profiles was usually moderate to high in amount. Except in the strongly acid soil M8 the exchangeable calcium, magnesium and potassium are adequate to plentiful. There are no harmful accumulations of alkali or soluble salts.

These alluvial loams are the best all-round soils in the valley. It is unfortunate that their distribution tends to be patchy and that they often have a somewhat undulating surface. Differences in level of two or three feet in 50 to 100 feet may occur. It would be inadvisable to attempt to level them to ease the design of an irrigation scheme since this would be likely to expose underlying strata of sand and would result in losses of water.

ALLUVIAL CLAYS

The alluvial clays of the Kilombero Valley have been split into two groups:-

(1) Those which occur in the alluvial fans of the rivers and streams entering the valley. These have good fertility and structure and appear to have been deposited recently.

(2) Those which occur on the main flood plain outside the alluvial fans. These have a lower fertility and a poorer structure. They appear to be older clays affected by weathering since deposition. No doubt some of them still receive some additional clay from flood water but the amount is insufficient to counteract the weathering processes.

The first group, the recently deposited clays, have been further divided into:-

(a) Those regularly flooded and still being added to. This is the normal situation. (K on the maps)

(b) Those now rarely or never flooded owing to some recent change in the river system, but still retaining the properties of a recently deposited clay (Ke on the maps).

All profiles analysed have been of the normal (K) type. It is not to be expected that the Ke clays will differ in fertility. They have been distinguished on the maps because it should be possible to start their development without great expenditure on flood control.

RECENTLY DEPOSITED CLAYS

The recently deposited clays are found in relatively small patches along both sides of the Kilombero Valley, wherever tributary streams emerge from the hills. They have a level surface and usually lie slightly below the level of the adjoining sands, sandy loams and loams. They are very liable to be flooded from the tributary stream but being on the alluvial fans they are usually above the level of the Kilombero flood, so that often the flood drains away in a few days. However, they vary considerably in this respect and it is usually difficult, in the dry season, to discover just what happens during the rains. The thick growth of grass and reeds can restrict the flow of shallow sheets of water and there is often a strong backing-up effect on the tributary of the flooded Kilombero River. One profile is described below. Analysis of this and two others, P181 from Mtimbira (sheet 4) and L16 from Kidodi (sheet 1) are given in the tables.

PROFILE 170

Location — One mile west of Ifakara.

Parent material — Alluvium.

Topography — In an ill-defined valley, sloping to south.

Drainage — Subject to high water-table and to periodic flooding during the wet season.

Vegetation — Grass about 8 feet high (Hyparrhenia sp.) and herbs.

0 - 18 cm. — Grey-brown clay loam (10 YR 5/2, dry) with brown fine mottles below 10 cm. Medium subangular blocky structure. Fairly porous.

18 - 45 cm. — Grey-brown sandy loam with strong brown mottles, mostly along roots. A few iron concretions, probably originating elsewhere.

45 - 180 cm. — Grey silty clay (10 YR 5/1, dry) with common strong brown mottles increasing in number with depth. Coarse subangular blocky, becoming massive. Fairly porous at top, becoming less porous and very hard at bottom.

180 - 190 cm (+) — Grey sandy clay (10 YR 5/1, dry) with many brownish-yellow fine mottles. Medium subangular blocky. Very hard (dry). Some small black iron concretions.

This group of clays includes a few clay loams and the range in content of clay is from 35 to 60 per cent. Sandy strata are liable to occur within the profile, e.g. the 18 to 45 cm. layer of profile 170, due to changes in the stream courses in the alluvial fans.

The soils are usually slightly acid at the surface with pH values of 6 or 6.5, often rising to above 7 in the lowest horizons of the profile. Organic matter is quite high (3 to 7 per cent) but not quite as high as in the loams. The carbon/nitrogen ratio is often high, but not always. Available phosphorus is usually moderate, less than in the loams but higher than in the older clays.

Exchangeable calcium, magnesium and potassium are adequate to high. Exchangeable sodium tends to rise in the subsoil of some profiles but does not reach harmful levels in any of the profiles analysed.

These younger clays are excellent soils and are widely cultivated at present for paddy rice, using natural flooding with sometimes a little bunding and diversion of streams. Their fertility is not quite so high as that of the loams but their level surface will make irrigation easier, once flooding is controlled.

In the portion of the valley surveyed by Loxton, i.e. on the north side between the Kimbe and Lumemo Rivers, all clays are shown as recently deposited clay (K). This is because Loxton made no distinction in his soil maps. It is probable that the low-lying portions of those areas of clay, i.e. those nearer the Kilombero River, correspond better with the "Clays affected by weathering" of the writer's classification.

CLAYS AFFECTED BY WEATHERING SINCE DEPOSITION:

These weathered clays occupy the flood plain of the Kilombero and its major tributaries the Kihanzi, Mpanga, Mnyera and Ruhuji. They also occur to a lesser extent in the flood plain of the Msolwa river.

In these flood plains deposition is much slower than in the alluvial fans, due to the water carrying less sediment. The soil particles in the flood plain clays have therefore been subject to weathering for a longer period than the particles at the same depth in an alluvial fan clay. The older clays have a somewhat lower fertility and probably a lower reserve of unweathered minerals. In places, also, sodium has accumulated in the subsoil. Their structure is poorer though this may be an effect of a different vegetative cover and not purely of age as such.

One profile, P165, is described below. Analyses of this and 4 others are given in table 13.

PROFILE 165

Location	Kivukoni, near the ferry on the Ifakara-Lupiro road.
Parent material	Alluvium.
Topography	Flood plain of the Kilombero river. Gilgai relief; the pit was situated on top of a swelling (puff).
Drainage	Poor within profile and site is liable to flooding.
Vegetation	Rice stubble. Natural vegetation is tall grass.
0 - 15 cm.	Light yellowish-brown clay (2.5 Y 6/4, dry) with few brownish-yellow fine mottles. Subangular blocky structure; very hard when dry.

5 - 30 cm. Light yellowish-brown clay (10 YR 6/4, dry) with common, strong brown fine mottles. Otherwise as above.

30 - 55 cm. Light brownish-grey clay (2.5 Y 6/2, dry) with few, red fine mottles. Weak subangular blocky; fairly compact and very hard. (dry).

55 - 80 cm. Light brownish-grey clay (2.5 Y 6/2, dry) with common, strong brown fine mottles. Massive; very hard.

80 - 190 cm. Light grey clay (10 YR 6/1, dry) with many pale brown and brownish-yellow mottles. Massive and compact. Very hard.

The clay content of these older clays usually falls within the range of 40 to 75 per cent, i.e. extending to a higher clay content than the younger clays. Sandy strata in the profile are uncommon.

The weathered clays are somewhat more acid, at any rate at the surface, than the younger clays, this no doubt being due to the extra weathering and leaching to which they have been subject. Typically the pH at the surface is between 5 and 6, often rising in the subsoil. A few strongly acid profiles, such as M1 at Merera, are associated with swamps. This had a pH of 5.1 in the top foot, diminishing slightly to 4.8 in the third foot.

Organic matter is in the range 1.8 to 5 per cent, lower than in the recently deposited clays though there is a considerable overlap. Carbon/nitrogen ratios are moderate to high. Available phosphorus is nearly always low; this is, of course, measured chemically and should be taken as pointing to a need for fertiliser trials rather than a proof that fertilisers will be needed.

Exchangeable calcium and magnesium are adequate, except perhaps in the few strongly acid soils, but potassium is often low; again, this is not proof of potassium deficiency but rather a warning of the possibility. Exchangeable sodium is normally low but exceeded 15 per cent of total cations in the subsoil of two out of the 19 profiles examined. In profile 178 (see table) the sodium reached 21 per cent for the horizon below 80 cm. depth. In another profile (near Malinyi, figures not reproduced) the sodium was 13 per cent at the surface and reached 27 per cent for the 24 to 50 cm. horizon, going up to 30 per cent below 165 cm.

The incidence of alkali in these clays is obviously quite low but they will have to be looked out for during the detailed surveys preceding any irrigation scheme.

Profile 178, near Itete, lies in an area shown on the map as recently deposited clay. There is, of course, no clear boundary between recently deposited clays and those appreciably affected by weathering. The upper 30 cm. of profile 178 has many of the properties of a recently deposited clay but the compact and massive subsoil, with a high sodium and low phosphorus, make the soil a better fit in the group of weathered clays.

In spite of frequent difficulties over border-line cases, the distinction between the freshly deposited and the somewhat weathered clays seems worth maintaining. Our guide at Mtimbira said that the clays near the village, i.e. on the alluvial fan, can be brought to a good tilth in the first year of cultivation whereas the clays further out on the flood plain do not reach a satisfactory state until the second year of cultivation. This referred to hand cultivation in preparation for rice. Some years ago a tractor and plough worked at Mtimbira on the flood plain and was said to have produced a satisfactory tilth in the first year.

It is probable that the central portion of the Kilombero Valley, left uncoloured on the soil map, is largely occupied by these weathered clays but its inaccessibility and the limited time available prevented our visiting this area. If this is correct then these clays are certainly the major soil of the valley. It is evident from the aerial photos that this central area is much intersected by channels and there also seem to be occasional sand ridges.

The high clay content of most of the weathered clays and the compact nature of their subsoils will make for poor drainage in the soil and under irrigation the applications of water will have to be carefully controlled. Under the present regime the soils are, of course, under water for much of the wet season. Control of this flood water is the essential condition for irrigation. There is also the 40 inches or so of rain during the wet season which will flood the land during wet periods unless adequate surface drainage is provided.

However, assuming that complete water control is achieved these clays should be quite satisfactory for irrigated cropping. A stretch of one of these older clays is illustrated in figure 24.

CLAYS WITH PARTIAL SAND OVERLAY

These soils are only found in the Msolwa Valley but here they occupy a large proportion of the low ground. From a distance they look level (figure 27) but in fact the surface is somewhat uneven, with a difference in height of 2 to 3 feet between the ridges and the hollows.

On the ridges the topsoil is a loam or sandy loam but the clay content increases with depth and at 1½ to 2 feet the soil is a clay. In the depressions the sandy surface horizon is thinner or is absent.

It is still not clear how these soils have been formed. It will be noted that they only occur in the Msolwa valley and that they are associated with "Pale Sands" which, although sandier, have a similar undulating surface and increase in clay content with depth. The Pale Sands are thought to be derived, at least in the Msolwa valley, from sedimentary deposits of Karroo age. It seems probable that these clays are a mixture of Pale Sand with recent alluvial clay. The alluvial clay will have come from the flood waters of the Msolwa river and its tributaries and, earlier, from the Ruaha flood waters.

Earthworms are very numerous in these soils and build small columns of casts in the centres of tufts of grass. These columns are 6 to 9 inches high and spaced 2 feet or so apart. These worms will have thoroughly mixed the top feet or two of the soil and incorporated the recently deposited clay into the sand. There may also have been some downward movement of clay within the profile.

One profile is described below. Analyses of this profile L3 which has a sandy topsoil, and another (L10) with a heavier topsoil, are given in table 13.

PROFILE L3.

Location	Msolwa valley, about 7 miles ESE of Kiberege.
Parent material	Probably alluvial.
Topography	Level, with slight undulations of a foot or two in height.
Drainage	Poor. Flooded in wet season.
Vegetation	Grassland with occasional trees and many small columnar termitaria. Trees include Kigelia aethiopica, Combretum sp., small palms (Borassus sp. ?)
0 - 30 cm.	Very dark grey-brown sandy loam (10 YR 3/2, moist). Rusty staining along roots. Soft consistence.
30 - 60 cm.	Light brownish-grey coarse sandy clay (10 YR 6/2, moist). Common, fine, brown mottles. Hard when dry.
60 - 90 cm.	Light brownish-grey clay (10 YR 6/2, moist) with common fine strong brown mottles. Hard.

NB. Sampled with auger. This description is based on an examination of the auger samples.

These are somewhat acid soils, at least in the top foot of the profile. Organic matter is rather low (0.9 to 2.1 per cent) in the four profiles examined. Nitrogen is very low in profile L3. Available phosphorus is moderate to very low.

Exchangeable calcium and magnesium are moderate; potassium is low. The soils examined were all free from salt and all but one free from alkali. The fourth soil, from near Nangonji, had a high exchangeable sodium (25 per cent) in the 2nd and 3rd foot of the profile.

These soils carry a cover of tall grass, burnt annually, with scattered Kigelia aethiopica, Combretums and other small trees. They are flooded each wet season from the Msolwa and the other streams draining the escarpment to the west of the main road.

It will be seen that these soils are of only moderate fertility, though better than the Pale Sands. Their main disadvantage from an irrigation point of view, assuming that flood control has been achieved, is likely to be their uneven surface. Levelling the land would be most inadvisable. Not only would it expose a poor subsoil where the ridges have been planed off but it would leave a patchwork of clay subsoils and sand infillings in which control of water applications would be extremely difficult.

COMPLEX OF CLAY AND SAND RIDGES

The tributaries on the right bank of the Kilombero, from the Furua to the Luri have in the course of time brought down large volumes of sand and built up extensive alluvial fans. Usually only a small sector of each fan is occupied by the river at any one time. The other temporarily abandoned sectors are gradually covered with clay. The result is a network of sand ridges with clay in the intervening hollows.

These networks are shown on the map as a "complex of clay and sand ridges" (Cs) since it was not possible to show the clay and sand separately. The words "mostly clay" have been written across one area to indicate that there are few sand ridges in proportion to the clay but on the whole it would need a detailed soil survey to determine the relative proportions in each block of the complex.

No samples were taken from the soils of these complexes. The sand ridges resemble the sand ridges already described. The clays appear to be of the older, weathered type.

Another form of the complex borders the middle reaches of the Msolwa River. The Msolwa, as has already been mentioned, flows in the old bed of a larger river, presumably the Ruaha. When this bed was abandoned by the Ruaha the surface will have been an uneven sheet of sand. Since then most of the sand has been covered with a thick layer of clay. In the lower reaches of the Msolwa no sand is now visible but in the middle reaches the crests of former sand-banks still project through the clay.

OTHER ALLUVIAL COMPLEXES

In many areas where alluvial deposition is going on there is a mosaic of soils of various textures which could only be shown as complexes. As in the Usangu sheets, three complexes have been distinguished.

Xt: mainly light-textured alluvium; sands, sandy loams and loams.
Xh: mainly heavy-textured alluvium; loams and clays.
Xm: including both light and heavy alluvium.

The light-textured complex will contain an appreciable proportion of soils which are too sandy for irrigation. The heavy-textured complex should be satisfactory. The complex with both light and heavy-textured soils includes some sands which are too porous for irrigation.

NON-ALLUVIAL SOILS

Few of the ten non-alluvial soils shown on the map are suitable for irrigation. The "low-lying sands" are used in places for rice-growing by the existing population and could be irrigated easily. The "sandy clays" are also of some potential value. The other soils are in general unsuitable though they may be important for rain-grown crops. Brief descriptions of all the soils are given below.

(1) RED AND BROWN SOILS

The red and brown soils are the usual soil on well-drained slopes of the higher ground bordering the valley. Originally they were probably under rain forest but most of this has now gone and is replaced by miombo woodland or by cultivation. The forest soils are much prized by the local people and are said to be of high fertility. Probably the fertility largely resided in the humus accumulated during many years of forest cover. When the forest is cleared this rapidly decomposes, giving good crops for a few years. If the forest had been allowed to regenerate while the soil was still in good condition the fertility would have been restored. In practice cultivation continues until most of the humus has gone, leaving a poor sandy soil very liable to erosion. In these circumstances the forest does not regenerate but is replaced by miombo. The annual grass fires which occur in miombo effectively prevent any return of the rain-forest and prevent much accumulation of humus. The red and brown soils are in consequence mostly rather poor soils at the present time.

No forest soils have been examined but one profile was sampled in cultivated ground which had almost certainly previously been under miombo woodland. This profile, M14, is described on the next page and the analytical figures are given in the tables.

On sheets 1 and 3 of the Kilombero soil map the red and brown soils include the shallow stony soils (Z) which were distinguished later in the survey when sheets 2 and 4 were being compiled.

PROFILE M14

Location	Between Mpanga and Utengule, about ½ mile SE of Taveta turn-off.
Parent material	Granitic gneiss.
Topography	Hill-side. Slope about 5 per cent.
Drainage	Good.
Vegetation	Cotton field. Crop about 3 feet high and healthy.
0 - 15 cm.	Very dark brown sandy loam (10 YR 2/2, moist)
15 - 45 cm.	Dark red-brown sandy loam (5 YR 2/2, moist)
45 - 75 cm.	Similar but lighter in colour (5 YR 3/4, moist)

NB. Examined and sampled with auger.

This soil, which appeared to be typical of the red and brown soils under cultivation, is a rather acid sandy loam. The organic matter is low and the nitrogen very low. Available phosphorus is quite high and exchangeable calcium, magnesium and potassium are adequate. There are no accumulations of salt or alkali.

The main deficiency in these soils is likely to be nitrogen. The local practise in preparing land for a crop is to let the weeds grow for a few weeks at the beginning of the rains; quite a thick growth of grass results. The grass is then hoed into rows and covered with soil, thus creating a system of ridges and furrows. The crop is sown on the ridges and the nutrients liberated by the decomposing grass are easily

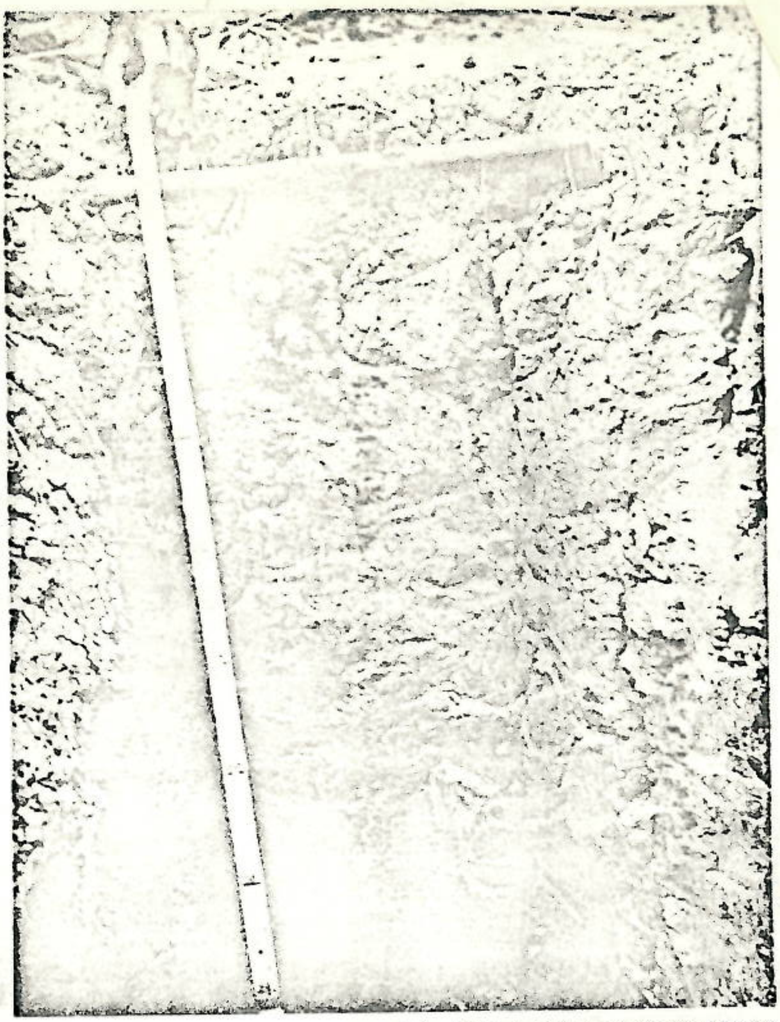

Fig. 33. Profile 235 in clay near Kimande, Pawaga. The scale is marked at 10 cm. intervals. (See also figure 34).

Fig. 34. Thornbush, chiefly Acacia kirkii, at the site of Profile 235. (See figure 33).

reached by the crop roots. The following year the ridges are split over the furrows, again a few weeks after the start of the rains, and the grass is thus once more buried in the ridges.

These soils are unsuitable for irrigation because of their topographic position and their sandy texture.

(2) GREY SANDY SOILS OF THE FOOTHILLS

These grey soils occur on lower slopes of hillsides, on the tops of broad ridges and in general wherever the slope of the ground is too slight for good drainage. The soils develop from the same Basement Complex gneisses as do the red and brown soils. They are mainly sedentary but those on lower slopes have probably received some colluvial sand.

Only one soil has been examined and this was situated near the red soil M14 but a little lower down the slope.

PROFILE M15

Location	Between Mpanga and Utengule, 50 yards down the slope from M14.
Parent material	Granitic gneiss.
Topography	Near foot of slope.
Drainage	Poor.
Vegetation	Miombo woodland; Brachystegia longifolia, Terminalia (? sericea) and tall grass.
0 - 22 cm.	Very dark grey loamy coarse sand (10 YR 3/1, moist)
22 - 45 cm.	Dark grey-brown coarse sand (10 YR 4/2, moist) with common dark brown mottles. Some iron concretions.
45 - 75 cm.	Grey-brown clayey coarse sand (10 YR 5/2, moist), with common dark red-brown mottles. Some soft yellowish-brown iron concretions.

NB. Examined and sampled with auger.

This soil is an acid loamy sand with very little organic matter and very low nitrogen. Available phosphorus is moderate. Calcium and magnesium are low but potassium is satisfactory. There are no accumulations of salts or alkali.

This is a soil of low fertility and suffers, in addition, from a periodic water-logging of the subsoil. It is unsuitable for cropping. In some parts of the valley grey sands are cultivated but probably only where the drainage is rather better than it is in the soil M15. The fertility level, i.e. amounts of organic matter, phosphorus, etc., in these cultivated sands is unlikely to be very different from that of M15. The soils are unsuitable for irrigation.

(3) LOW LYING SANDY SOILS SEASONALLY FLOODED

These are soils of level, low-lying land. In places, for example near Iteto and near Ngoheranga, they occupy the level floors of valleys running into the hills. Elsewhere they occupy the alluvial plain but are always adjacent to the hill slopes bordering the plain. A general view is given in figure 28.

The soils are probably colluvial, i.e. the soil particles have been washed down gradually from the neighbouring slopes, and not truly alluvial, i.e. carried from some distance in suspension in flowing water. The soil is therefore composed of particles which have already been weathered on the slopes and so do not contain the reserves of unweathered minerals present in the alluvial soils.

As well as being subject to periodic flooding these soils usually have a high water-table persisting on into the dry season. Consequently they have concretionary ironstone in the subsoil, though not always the massive variety present in profile 179. When they are normally flooded to a suitable depth they are used for rice and the local people say good crops are obtained.

One profile is described below. Analyses of this profile, and of M22 from near Kivukoni (sheet 3) are given in table 13.

PROFILE 179

Location	Mtimbira, on southern boundary of the settlement.
Parent material	Colluvium.
Topography	Level.
Drainage	Poor; flooded in wet season.
Vegetation	Rice stubble and weeds.
0 - 12 cm.	Dark grey loamy sand (10 YR 4/1, dry). Weak, medium crumb to single grain. Merging into:-
12 - 30 cm.	Grey-brown clayey coarse sand (10 YR 5/2, dry) with a few fine yellowish-brown mottles along roots. Weak, medium subangular blocky to massive. Slightly hard. Merging into:-
30 - 50 cm.	Grey clayey coarse sand (10 YR 6/1, dry) with common fine yellowish-brown mottles. Otherwise as above.
50 - 80 cm.	Light grey clayey coarse sand (10 YR 7/2, dry) with common fine pale brown mottles.
80 cm. (+)	Massive concretionary ironstone with light grey clayey coarse sand in interstitices.

The surface of these soils is sandy but the clay content increases in the subsoil. The topsoil is fairly acid, with a pH of 5 to 6; the subsoil can be either

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more or less acid. The organic matter is variable but usually low; it ranged from 0.7 to 3.9 in the four soils of this type which have been analysed. Nitrogen in the organic matter is usually low also. Available phosphorus is moderate to fairly high. Exchangeable bases are low in profile 179 but rather better in M22 and the other two soils analysed. There is no accumulation of salts or alkali.

These soils would be easy to irrigate and the heavier subsoils would prevent too great a loss of water. Some of the soils, such as P179, are of low fertility but others are better. In general they are inferior to the alluvial soils. Drainage will often be a problem. Termite mounds abound but they are usually of a small columnar type which can be fairly easily levelled.

(4) PALE SANDS

The term "Pale Sands" was adopted by Loxton for the sandy soils which occur in patches on the plain between Ifakara and Mgeta, on the north side of the Kilombero. Numerous sandy soils in other parts of the valley seem sufficiently similar to Loxton's Pale Sands to be included in the same group.

The profile of all these soils consists of one to two feet (30 - 60 cm) of grey loamy sand overlying a pale sandy clay. The surface of the ground is usually somewhat undulating and in the depressions the upper sandy layer may be thinner or be absent, the soil then being a sandy clay. Numerous large termite mounds add to the unevenness of the ground. Flooding is usually limited to the depressions but in places the higher ground is flooded also. It will be noted that the "Pale Sands" are rather like the "Clays with sand overlay" but with less clay.

In general these sands carry a thin deciduous woodland, usually miombo with Brachystegia longifolia dominant, but in places there is dense forest. The forest is particularly widespread in the Msolwa valley area (figure 29). No difference was detected between the sands under deciduous woodland and those under forest but it seems probable that the presence of the forest, which includes a number of evergreen trees and shrubs, indicates a water-table within root range for much of the dry season. The Pale Sands under forest have therefore been separated as a sub-group of the general type. Loxton also separated the Pale Sands with forest and put them in his class "Ground Water Forest Soils", but he included in this group other soils which were not Pale Sands. The present writer would have classed some of them as alluvial sandy loams.

Other Pale Sands, e.g. those at Kikwawila near Ifakara, when drawn on the map have the shape of alluvial fans. These perhaps consist of material washed down from Grey Sandy Soils of the Foothills and deposited in the plain. Or they may be old fans of alluvial sand or sandy loam which have been weathered for a long period since they received any fresh alluvium and have been converted into Pale Sands. The first theory seems the more probable though no doubt weathering is proceeding all the time. The patches of Pale Sand on the right bank of the Msolwa river, after it has turned south, are probably weathered alluvial sands originally deposited by the Ruaha river when it followed this course. The Msolwa follows a meandering course in the former bed of the Ruaha. The Pale Sands stand 5 or 6 feet above the level of the former bed and were apparently laid down as sandy levées along the bank of the former Ruaha.

A third group of Pale Sands consists of those surveyed by Loxton and those near Kivukoni, Mavimba and Iragua. These lie on very gently inclined slopes which are probably base levels of erosion. The underlying rock in the areas mentioned is Basement Complex gneiss which normally gives a soil with a sandy loam texture. These Pale Sands may have lost clay by either lateral or vertical eluviation. The colour is grey or pale brown rather than red because the slope is insufficient to allow rainwater to drain away laterally. This explanation for the formation of this sub-group of the Pale Sands would make them a special case of the Grey Sandy Soils of the Foothills.

The fourth group of Pale Sands is that which occupies almost all the country on the east bank of the Msolwa river, in the Selous Game Reserve. This sub-group has developed on sandstones of Karroo age.

Between the Msolwa and the Southern Highlands Escarpment, i.e. in the level plain through which the Msolwa river flows, there are extensive areas of Pale Sand, some under miombo (or similar) woodland (Ps) and some under forest (Pm). At Mangula the Pale Sand (here under forest) lies in places at an elevation of about 20 feet above the floor of the Njokomoni valley. It seems unlikely that this sand can be of alluvial origin. These Pale sands are probably also derived from underlying Karroo sediments although the presence of the Karroo west of the Msolwa had not previously been recognised.

The four sub-groups of the Pale Sands probably differ in some way from each other but it did not prove possible to find distinguishing features in the course of this reconnaissance survey. In the maps these sands are divided into three sub-groups:-

(1) Pale sands derived from Karro sediments.
(2) Pale sands with a high water-table, i.e. with forest.
(3) All other Pale Sands. In this sub-group are included the residual sands on erosion surfaces, the weathered alluvial sands and the transported sands forming fans; and also, probably, some derived from Karroo sediments but not recognised as such.

Profile descriptions follow for a soil from each subgroup. Analyses of these 3 profiles and another (P 253) are given in the tables.

(a) Pale sands derived from Karroo sediments

PROFILE L14

Location	Six miles east of Kidodi, on saw-mill track.
Parent material	Karroo sandstone (?)
Topography	Flat, with undulations a few feet in height.
Drainage	Impeded in lower part of profile.
Vegetation	Miombo woodland (Brachystegia longifolia) with many large termite mounds.

0 - 30 cm. Coarse sand, dark grey (10 YR 3/1, moist) at surface, brown (7.5 YR 5/2, moist) below.

30 - 60 cm. Pale brown coarse sand (10 YR 6/3, moist) with common yellow-brown mottles. Some iron concretions with MnO_2.

60 - 90 cm. Light grey very sandy clay (10 YR 7/2, moist) with common light yellow brown mottles. Some iron concretions (up to 10 mm. diam.) with much MnO_2.

NB. Examined and sampled with auger.

The surface horizon is slightly acid, with a pH of 6.4. The upper sandy layer is 2 feet thick, with sandy clay below. The soil is very low in organic matter (0.6 per cent) and low in all nutrients - nitrogen, phosphorus and potassium.

(b) Pale Sands with a permanent water-table

PROFILE L9

Location In the Magombera Forest, about one mile east of Mangula.

Parent material Sandy sediments.

Topography Level, with slight undulations of a few feet in height.

Drainage Impeded in lower horizons of profile.

Vegetation Rather thin forest, with some evergreen species in the lower storey.

0 - 30 cm. Very dark grey-brown loamy coarse sand (10 YR 3/2, moist).

30 - 60 cm. Grey very sandy clay (10 YR 5/1, moist). Common yellow-brown mottles.

60 - 90 cm. Light brownish-grey sandy clay (10 YR 6/2, moist). Many yellowish-brown and red mottles. Iron concretions (up to 5 mm. diam.) with slight MnO_2.

NB. Examined and sampled with auger.

This soil is more acid than L14 and has a slightly higher organic matter content (1.2 per cent). Otherwise the two soils are very similar. The forest above L9 was rather thin but the soil differed little from another soil under thicker forest; the organic matter in this second forest soil was no higher but the soil was less acid at the surface.

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(c) Other Pale Sands

PROFILE 168

Location	Kivukoni, about $\frac{3}{4}$ mile from the Kilombero river.
Parent material	Probably colluvial, from Basement Complex gneiss.
Topography	Flat; slight rise to south.
Drainage	Very poor; flooded from Kilombero river in wet season.
Vegetation	Rice stubble; formerly grass.
0 - 13 cm.	Grey brown loamy sand (10 YR 5/2, dry) with brown staining along roots. Weak subangular blocky to single grain structure.
13 - 35 cm.	Very pale brown sand (10 YR 7/3, dry). Weak subangular blocky to single grain.
35 - 180 cm.	Light brownish-grey sandy clay (2.5 Y 6/2, dry) with common fine pale yellow mottles. Weak subangular blocky to massive. Very hard and compact (dry). Iron and calcium carbonate concretions present, also MnO_2. Below 75 cm., becoming light grey (2.5 Y 7/2) without mottles.
120 - 130 cm.	Horizon of iron concretions, 2 to 30 mm. in diameter. Also some carbonate. In light grey sandy clay with much brownish-yellow mottling.
130 - 170 cm.	Pale yellow sandy clay (2.5 Y 7/4, dry) with many fine brownish-yellow and dark brown mottles. Compact and hard. Much quartz and feldspar gravel in layer 160 to 170 cm.
170 - 190 cm.(+)	Pale yellow clay (2.5 Y 7/4, dry) with many fine brownish-yellow and black mottles. Weak subangular blocky to massive. Compact and very hard.

This is a rather complex profile. Some of the clay is probably alluvial and the sandy material has been washed down on to the alluvium. The upper 35 cms. of this soil are little different from the other Pale Sands, except for a higher available phosphorus at the surface. Below 35 cm., however, there is a high exchangeable sodium which gives the soil an alkaline reaction and which would be harmful to some crops. There is also a slight, but not serious, accumulation of salts in the subsoil.

Other sands of this sub-group did not have the alkaline subsoil of profile 168. Organic matter ranged from 0.9 to 2.0 per cent. Available phosphorus was low to moderate, calcium low to moderate. Nitrogen and potassium very low.

Profile 253 (see fig. 26) is probably derived from Karroo sediments but might be weathered sandy alluvium.

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These Palo Sands are poor soils. Although some of them are used for rice under natural flooding, it would be difficult to keep them sufficiently watered if flooding were prevented. The forest growing on some of these sands contains useful timber trees and this forest is probably the best use to which the soils could be put. It might be possible to replace the miombo woodland, where it occurs, by some more useful species of tree but the presence of the miombo probably indicates poor water supply in the dry season.

In designing schemes for the utilisation of the Msolwa and Kilombero valleys possible injurious effects of water control on the forest should not be ignored. Prevention of flooding may cause a lowering of the water-table under the forest. This may in turn make the environment unfavourable for the timber trees present and so may lower the productivity of that area of land.

(5) SANDY CLAYS OF ENCLOSED BASINS (MBUGAS)

The floors of valleys tributary to the main Kilombero Valley are often occupied by a sandy clay. A similar sandy clay occurs widely on the north bank of the Kilombero between Ifakara and the Ruipa river, here the soil occupies wide depressions in a gently inclined erosion surface.

The soils have appreciable proportions of both coarse sand and clay. The coarse sand is probably washed down from the nearby higher ground and the clay is deposited from flood water. In some situations the coarse sand may be sedentary, i.e. derived from the underlying rock, with the clay deposited from flood water as before. The activities of termites, etc., mix the two materials.

The surface horizon varies from a sandy loam to a clay loam and is usually dark grey in colour, though it may be paler. The subsoil is heavier and is mottled, indicating poor drainage. Iron concretions are often present in the subsoil.

A soil from near Itete, in a narrow valley, had the following profile:-

0 - 15 cm.	Black loam.
15 - 30 cm.	Very dark grey sandy clay, with some iron concretions.
30 - 45 cm.	Similar, with brown mottling.

The vegetation was Combretum - Piliostigma scrub, with grass (Themeda triandra and Panicum sp.)

These sandy clays were described by Loxton (1953) who divided them into two groups, called the Mbuga Clay Pan and the Intermediate Mbuga Clay Pan soils. The following description of a Mbuga Clay Pan Soil is taken from Loxton's report.

PROFILE No. 107 (of Loxton)

Location About 8 miles W.N.W. of Ifakara.

Topography Flat (slope 0.2 per cent) with widely scattered large termitaria.

Drainage Very poor with very slow permeability. Flooded several inches deep in the wet season.

Vegetation Hyparrhenia grassland with widely scattered stunted Combretum, Piliostigma and Kigelia.

Ground water Deep.

0 - 25 cm. Very dark grey clay loam; slightly hard; moderately fine granular structure.

25 - 85 cm. Gritty grey clay; very coarse prismatic structure, very hard; common small iron concretions.

85 - 105 cm(+) Grey sandy clay; strong very coarse prismatic structure, very hard; common small iron concretions.

Analytical figures given in the report show a pH of 6.4 at the surface rising to 8.5 at 100 cm. depth. The organic matter is 3 per cent and the available phosphorus 2.1 mg/100g in the topsoil. Exchangeable calcium is 8.5 ma/100g at the surface and remains fairly high throughout the profile. There is no accumulation of soluble salts. Another profile was more acid, with less phosphorus.

The Intermediate Mbuga Clay Pan soil described by Loxton is very sandy to 50 cm. depth and is a sandy clay below this, with much concretionary ironstone below 70 cm. The soil had a much lower organic matter and exchangeable calcium than No. 107 but the other analytical figures were similar.

All these mbuga soils suffer from flooding under the present regime. Since they occur in the valleys of minor tributaries or, in the case of the soils described by Loxton, in depressions flooded by such tributaries, the control of the chief rivers in the valley will not have much effect on this flooding. The soils have a fairly good fertility but suffer from poor drainage in the subsoil. They are probably best utilised for rice-growing, with one crop a year under natural flooding.

(6) GREY SANDY CLAYS ON SLOPING GROUND

This soil was only found at one place, near Kanoro in the Msolwa Valley. It is a sandy clay, with mottling and with noticeable amounts of quartz and feldspar grains. It is rather similar to the sandy clays of the mbugas, just described, but lies on a slight slope and is not subject to flooding.

In most of the Kilombero Valley the "Grey Sandy Soils of the Foothills" lie between the red and brown soils of the slopes and the soil on the flats. At Kanoro, for some reason, the grey sandy soil is replaced by this grey sandy clay. The soils are probably equivalent in the weathering and other processes to which they are subject.

The difference between them represents the influence of the heavier texture of the soil at Kanoro.

One profile only has been examined. Analyses are given in the tables.

PROFILE L6

Location — Kanoro (near Kiberege), about ½ mile east of the road.

Parent material — Colluvium (?)

Topography — Foot of escarpment; gently undulating, with a rise of about 1 per cent to the west.

Drainage — Poor.

Vegetation — Combretum scrub. Wormcasts present on surface of soil.

0 - 30 cm. — Black loam (10 YR 2/1, moist) with a few brown mottles.

30 - 60 cm. — Very dark grey sandy clay (10 YR 3/1, moist) with many yellowish-brown mottles. Many grains of quartz and feldspar (ca. 2mm. across).

60 - 90 cm. — Grey sandy clay (10 YR 5/1, moist) with many yellowish-brown mottles. Quartz and feldspar grains.

NB. Examined and sampled with auger.

The soil is of reasonable fertility but being on a slope rising from the valley floor could not easily be irrigated. Drainage is rather slow and in places the soil has suffered from gully erosion.

(7) GREY SAND WITH CLAY SUBSOIL, ON SLOPING GROUND

This is another soil which was only found in one place; in this case near Kiswago on the south bank of the Kilombero (sheet 4). The profile, only examined with the auger, was:-

0 - 15 cm. — Dark grey-brown loamy coarse sand.

15 - 40 cm. — Grey-brown loamy coarse sand.

40 - 50 cm.(+) — Grey-brown clay, with mottling and some iron concretions.

The soil occurred on a broad low hill and carried a thin Combretum scrub with grass.

The soil differs from the "Grey sandy soils of the foothills" in the rapid change in texture at about 40 cm. depth. The drainage in the subsoil is obviously very poor and this is reflected in a poor stunted growth of the trees. The soil may have been a "Low-lying sandy soil" which has been eroded in consequence of a lowering of the base level of erosion in the vicinity.

No samples have been analysed but the soil appears to be of no agricultural value.

SOIL GROUPS USED BY LOXTON WHICH DO NOT FIT EXACTLY INTO THE SOIL CLASSIFICATION OF THIS REPORT

(1) FLOOD FLOW SOILS

Loxton classed as Flood Flow soils all alluvial soils falling between the coarse sands of river banks and the clays. The Flood Flow soils therefore include both the alluvial loams and the alluvial sandy loams of this present survey. Loxton regarded them as typically loams but it seems likely that they must include a considerable area of sandy loam. The analytical figures given by Loxton are similar to those already presented in this report for alluvial loams and sandy loams.

(2) FERRUGINOUS SANDS

This group of ferruginous sands incorporates five of Loxton's soil groups.

(1) Ruipa grey ferruginous clayey sands: drained phase.
(2) Ruipa grey ferruginous clayey sands: flooded phase.
(3) Idete grey clayey sands.
(4) Rondo ferruginous loamy sands.
(5) Mgeta loamy sands.

The first four of these groups consist of 30 to 60 cm. of grey or greyish-brown sand overlying a sandy clay. Iron concretions occur in the sandy clay below about 50 cm. depth. The Mgeta loamy sands have a shallower sand layer (about 15 cm.) above the clay and do not always have concretions in the subsoil, at any rate not in the top 100 cm. of the profile; mottles are present.

There was not time to re-examine these soils. The flooded phase of the Ruipa sand and the Idete sand are probably equivalent to the "low-lying sandy soils, seasonally flooded" of this present report. The drained phase of the Ruipa sand and the Rondo sand would probably have been classed as "Pale Sands".

Analytical figures given by Loxton show these four soils to be moderately to strongly acid, with a low organic matter and low exchangeable calcium. Available phosphorus is, however, moderate to fairly high. Loxton considers that the more level of these soils could be used for rice, using natural flooding, while the others are of marginal value for agriculture.

The two Mgeta loamy sand profiles presented by Loxton are moderately acid at the surface and alkaline in the subsoil. Otherwise they are similar to the other sands of this group. It is not clear to which soil group of the present report these soils belong.

Most of these sands are not suitable for irrigation. Those soils which are reasonably level and which have sufficient clay in the topsoil for the construction

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of bunds could be used but the proportion of such soils is probably small.

(3) GROUNDWATER FOREST SOILS

This group was distinguished by Loxton by the presence of forest. He regarded the soil as being a "Flood Bank" soil, i.e. an "Alluvial Sand" of this report, which had undergone appreciable weathering since deposition. The pattern of occurrence of these soils supports the suggestion of their alluvial origin. The soils are therefore rather different from the "Pale Sands with permanent water table" which are the main forest soils of the Msolwa Valley. Many of the latter are almost certainly of non-alluvial origin.

Loxton described the Groundwater Forest Soils as dark grey sandy loams with a grey sandy loam subsoil. They would therefore correspond with the alluvial sandy loams of this present survey, rather than with the alluvial sands. He regarded the soils as older than his Flood Bank soils because of a less obvious stratification in the profile. There seems to be no obvious reason why the forest should be confined to the more weathered soils. The forest will take perhaps 100 years to establish itself but this is s short period compared to the life of a soil profile.

Loxton recommended that these soils should be used for timber production or rubber plantations. The soils, being alluvial, should be more productive than the Pale Sands of the Msolwa valley and would appear to be similar to the alluvial sandy loam on which the Sanje rubber plantation is established.

The possibility of adversely affecting the forest by lowering the water-table, already mentioned in connection with the Pale Sands, applies here also.

(4) SHALLOW ALLUVIAL SOILS

This group includes four of Loxton's soils:-

Ruipa shallow alluvium.
Idete shallow alluvium.
Narabunga alluvium.
Namawala alluvium.

Only the first of these occupies any appreciable area. The following profile description is taken from Loxton's report (profile no. 36).

Location 1½ miles eastward from the Ruipa bridge, along the road.

Topography Nearly level (slope 0.2%) with scattered small termitaria.

Drainage Poor; slow permeability. Flooded during the rains.

Vegetation Themeda grassland, with scattered Combretum, Piliostigma, Afromosia and Annona.

0 - 15 cm.	Dark greyish-brown clay loam, moderate medium crumb structure; overlay.
15 - 35 cm.	Brown fine sandy clay loam; weak medium crumb structure; overlay.
35 - 75 cm.	Light grey sandy clay; hard, structureless and massive; common orange-brown mottlings and black iron concretions.
75 cm. (+)	Grey clay, very hard, structureless and massive; many iron concretions and orange mottlings.

The top 35 cm. consists of recent alluvium; the lower part of the profile is probably non-alluvial. Analytical figures show that the soil is moderately acid at the surface and almost neutral in the subsoil. There is a good level of organic matter (5%) and a moderate available phosphorus. Exchangeable calcium is rather low, particularly in the subsoil.

The thickness of the alluvial overlay is insufficient for this to be a good soil and the impermeable subsoil will make drainage difficult. The soil is best suited to rice, and perhaps other crops tolerant of poor drainage.

(5) FOOTHILL CATENA

The term "foothill catena" has been used to include the "eroded miombo catena", the escarpment foot colluvium" and the "soils of the escarpment foothills" of Loxton's reports.

In his report on Block A (Ifakara to the Chiwa-chiwa river) Loxton used the term "eroded miombo catena" for the soils of all the hilly country to the north of the area he had surveyed. This catena was said to include soils on steep and badly-eroded slopes and those of some large mbugas.

In the later report on Blocks B and C (Chiwa-chiwa to Kimbe rivers) Loxton distinguished an "escarpment foot colluvium" occurring at the base of steep rocky hills and "soils of the escarpment foothills" lying above the colluvium.

One escarpment foot colluvium profile, from near Njagi, consisted of 10 inches of grey sandy loam overlying 16 inches of reddish-brown loamy sand; below this was a dark reddish-brown sandy clay. This was a reasonably fertile soil and could be used for rain-grown crops. It is unsuitable for irrigation on account of its slope and sandy texture.

The "soils of the escarpment foothills" were stated by Loxton to include the following:-

(1) Skeletal soils of steep slopes.
(2) humic red earths under evergreen forest and secondary thicket.
(3) plateau soils under miombo.

The humic red earths and some of the plateau soils are included in the "red and brown soils of well-drained sites" (R) of this report. The remainder of Loxton's plateau soils come under the "grey sandy soils of foothills".

The humic red earths of the escarpment are cultivated in places by the Wahehe living at the top of the escarpment. The soils produce good crops but erosion is usually severe owing to the steepness of the slope.

None of these escarpment foothill soils is suitable for irrigation.

LAND CLASSIFICATION

The Kilombero soils have been classified on the same system as was used for the Usangu soils (see page 36). It is again assumed that complete flood control can be obtained. This is probably a greater assumption in the Kilombero than it was in Usangu owing to the higher rainfall in the Kilombero and the large number of streams entering the valley.

The proposed dam-sites on the Ruhuji, Mnyera, Mpanga and Kihanzi Rivers will control the main area of irrigable land in the centre of the valley. Flanking this central part of the valley are the "planes of erosion" described earlier, on which lies much useful land. Some of this useful land lies in detached pieces well above the level of the valley floor and could probably only be economically irrigated from the minor streams draining the slopes above these detached pieces of land. An example is the land between Kichangani and Kivukoni (sheet 3) which could only be irrigated by water from the Luri River. Such land has been shown as irrigable although it is doubtful whether all the minor streams which would have to be used to irrigate it are large enough, or have sufficient storage capacity, for a viable irrigation project.

The present occupation of the land has not been taken into consideration in assessing its suitability for irrigation. Large areas of land are cultivated by the local population around Ifakara, between the Ruipa and Mgeta Rivers in the Luri Valley and around Kidodi, Itete, Mtimbira and Malinyi. Rice is their main crop on the alluvial soils. European and Asian estates mostly lie between Kidatu and Ifakara; their total acreage is of the order of 20,000 acres

ASSESSMENT OF THE SOILS OF THE KILOMBERO VALLEY

The soils of the Kilombero Valley, as shown on the Soil Reconnaissance Map, have been grouped into six classes based on their suitability for irrigation assuming control of flooding and availability of irrigation water. The reasons for the assessments made are given below.

Sands in ridges, banks and water-courses (S and M)

Class 6. Too permeable and often standing above the surrounding land.

Sandy loams (A)

Usually Class 3. Sandy loams have rather a high permeability and an uneven surface; patches of sand often occur. Sandy loams in narrow strips usually include a considerable proportion of sand and have been put in either Class 4 or Class 6.

Loams (B)

Class 1. These soils have good texture and fertility and a favourable reasonably level surface.

Recently deposited clays (K and Kc)

Class 1. These are also excellent soils.

Clays affected by weathering (C)

These have a poorer structure and somewhat lower fertility than the recently deposited clays and are therefore put in Class 2.

Clays with partial overlay of sand (Cn)

These have an undulating surface and a variable depth of sand overlying the clay. Their fertility is also lower than the clays without sand. The construction of an irrigation system would be difficult and the soil is therefore down-graded to Class 4.

Complex of clay and sand ridges (Cs)

The proportions of clay and sand vary greatly from place to place and a detailed survey would be necessary to determine, for each area of this complex, whether irrigation would be economically practicable. The soil is therefore put in Class 5, requiring further investigation.

An area of this complex to the north-west of Iragua appears to have a relatively small proportion of sand ridge to clay and is almost certainly utilisable but the extent of this more favourable portion remains to be determined.

The "Meander Zone" of the Kilombero has also been put in Class 5 since this also contains a complex of clay and sand though here the sand is more often in channels than in ridges.

Alluvial complexes, predominantly light-textured (Xt)

This complex has been put in Classes 2, 3 or 4, depending on the proportions of sand present, as far as this could be judged during a reconnaissance survey. A complex of loam and sandy loam is Class 2 and one of sandy loam and sand is Class 4.

Alluvial complexes, predominantly heavy-textured (Xh)

Class 1. This complex consists of loam and recently deposited clay, both of which are good soils. Differences in surface level seemed insufficient to justify down-grading the complex to Class 2.

Complex of heavy and light alluvial soils (Xm)

This is mostly sandy loam and recently deposited clay. A proportion of sand appears in the complex and is the cause for its being down-graded to Class 2.

Red and brown soils of well-drained areas (R)

Grey sandy soils, ill-drained, of foothills (G)

Pale sands (Ps, Pw and P)

Grey sandy clays on sloping ground (H)

Grey sand with clay subsoil, on sloping ground (Gd)

Bare rock and shallow stony soils (Z)

All these soils are Class 6. They are unsuitable for irrigation on account of topography, texture or shallowness.

Low-lying sandy soils (L)

These have a suitable level surface for irrigation but a rather low fertility and probably impeded drainage. They are therefore put in Class 3.

Sandy clays of enclosed basins (mbugas) (D)

These are rather variable soils and often appear to have impeded drainage. In many cases it will be difficult to control flooding. The soils have been put in Class 3.

Complex of pale sand and low-lying sand (P + L)

This has been put in Class 5, requiring further examination. The Pale Sand is not suitable for irrigation and the Low-lying Sand is not a particularly good soil (Class 3 when it occurs alone).

Flood flow (F)

Class 2. Much of this soil is Class 1, alluvial loam, but a certain amount of sandier soil is usually present so the whole is put in Class 2.

Shallow alluvial soils (T)

Class 3. These soils have a suitable topography for irrigation but the depth of the more fertile alluvial layer is variable and the subsoil below this layer is poor and has a low permeability.

Ground-water forest soils (W)
Foothill catena (E)

Both Class 6. These soils are unsuitable for irrigation owing to their height above the valley floor. They also usually have too sandy a texture.

Sandy loam overlying clay (AC)

Class 3. The surface is somewhat uneven and usually more porous than desirable. The underlying clay should prevent too rapid a loss of water by drainage beyond root range.

Sandy loam overlying sand (AS)

Clay overlying sand (KS)

Both Class 6. A sand subsoil is not satisfactory for irrigation.

Clay overlying low-lying sand (KL)

The upper clay layer will contain a reasonable supply of plant nutrients and the low-lying sands (L) are poorly drained so will retain water. The soil is therefore put in Class 2.

Clay overlying sandy loam (CA and KA)

Class 4. This would be difficult to irrigate but is not so unsatisfactory as clay over sand. It is, therefore, put in the irrigable grade but in the lowest class of that grade.

ACREAGES OF IRRIGABLE LAND IN THE KILOMBERO VALLEY

Table 4 gives the acreages of the six Land Classes for the Kilombero Valley. Sheet 1 of the Land Suitability Maps has been divided into 1a, the land to the north of the Great Ruaha (the Msowero and Luhembe Valleys) and 1b, the remainder of the sheet (roughly the Msolwa Valley).

As for Usangu, classes 1 to 4 are included in the total "suitable for irrigation" and classes 5 and 6 in the total "unsuitable." These two totals do not include any unsurveyed land, but the final total does include the unsurveyed land. Most of the unsurveyed land lies in the central flood plain and here there is little doubt that the soil is mostly clay. A portion in the north-east will be affected by meanders of the Kilombero and will include a fair amount of sand.

A smaller part of the unsurveyed area consists of permanent swamps. These are probably largely clay but may include other soils. The unsurveyed area to the west of Msita (sheet 4) is all hilly and is not included in the table.

Class 6 includes a purely arbitrary amount of hill land round the boundary of the surveyed area. In the valley itself the proportion of class 6 land is much less

Table 4 Acreages of land of the different suitability classes in the Kilombero Valley

	Sheet 1a acres	Sheet 1b acres	Sheet 2. acres	Sheet 3. acres	Sheet 4. acres	Total of each class acres	%
Class 1, acres	9,700	18,100	13,900	26,600	72,600	140,900	9.8
Class 2, acres	3,600	53,800	140,000	179,100	159,300	535,800	37.2
Class 3, acres	11,200	20,300	51,700	72,400	73,000	228,600	15.9
Class 4, acres	100	52,900	200	1,100	6,700	61,000	4.3
Class 5, acres	-	19,400	900	64,200	64,500	149,000	10.4
Class 6, acres	7,300	40,600	94,800	143,200	37,500	323,400	22.5
Unsurveyed, acres (probably class 2)	-	-	119,000	129,600	26,600	275,200	-
Suitable for irrigation, acres	24,600	145,100	205,800	279,200	311,600	966,300	67.2
Unsuitable for irrigation, acres	7,300	60,000	95,700	207,400	102,000	472,400	32.8
Total, acres	31,900	205,100	420,500	616,200	440,200	1,713,900	-

1) Class 1 to 4 are suitable for irrigation, classes 5 and 6 are unsuitable.

2) None of the unsurveyed land is included in the total of land suitable for irrigation.

3) Sheet 1a is the land lying north of the Great Ruaha i.e. the Msowero and Luhembe Valleys. Sheet 1b is the remainder of sheet 1 from the Great Ruaha to the Kilombero River.

4) In calculating the percentages in the last column the unsurveyed area has been ignored.

mostly unoccupied and very suitable for irrigation. At present it is extremely inaccessible but it lies on the proposed rail route to Mbeya.

There is little water in the Sofi in the dry season and irrigation would depend on the finding of a suitable storage site above the Mission. The land between the road and Mselamiti could be irrigated from the Furua River once the flooding by the Sofi River is controlled, if the total water from the Sofi is insufficient for the whole 5,000 acres, as seems likely.

FURUA RIVER

About 5,000 acres of land, chiefly loams and sandy loams, could be irrigated from an intake about 3 miles above Malinyi on the Furua River. This stretch of land extends from this intake to Igawa, and northwards from Igawa until it reaches land flooded by the Kilombero. There are a number of sand ridges and a more detailed soil survey would be required before the area could be recommended. A dam would be required on the Furua River for all but a small project and no good sites for such a dam have yet been found.

MPANGA RIVER

A good dam-site has been found on the Mpanga River and has been surveyed (see Volume III of this report). With flooding controlled from this site a large area of irrigable land, from Mpanga downstream, would be obtained. It is difficult to estimate to what extent the Mnyera and Ruhuji Rivers would flood the lower-lying parts of this area if the Mpanga were prevented from flooding. It is therefore difficult to estimate the acreage of land which would be made available for irrigation by a dam on the Mpanga River only. It is probably in the order of 8,000 to 10,000 acres.

The soils are rather patchy near Mpanga village but there is a high proportion of class 1 land and plenty of room for expansion when the Mnyera and Ruhuji floods can be controlled.

Most of the suitable land in the immediate vicinity of Mpanga Mission is already under cultivation, rice being the main crop on the plain. Cotton is grown on the hill-sides. There is an adequate population, particularly at Utengule, to operate an irrigation scheme but communications with the "outside world" are difficult (see figure 19).

RUHUJI RIVER

About 7,000 acres of good land is available between Magini and Mkomaga. Control of flooding would be required and it is possible that control of the Ruhuji alone would be insufficient. There might have to be bunds to keep out Mnyera flood-water and some works in the lower reaches of the Ruhuji to prevent water from the Mnyera flowing up the Ruhuji. There is also a considerable area of sand. The site warrants consideration but it seems less attractive than most of the other sites suggested.

MNYERA RIVER

It is difficult to find land suitable for irrigation from the Mnyera which could be made irrigable by control of the Mnyera alone. It would seem that the Mnyera dam, a site for which has been surveyed, would only be justified as part of a comprehensive scheme for the whole Kilombero Valley.

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THE LOWER RUFIJI

INTRODUCTION

After leaving the Kilombero Valley at Boma ya Ulanga the Kilombero river flows south-east for about 40 miles. It then swings north-north-east and passes over the Shuguri Falls. At these falls it is joined by the Luwegu river, coming in from the south. Below the confluence the river is known as the Rufiji. 35 miles below the falls the Great Ruaha comes in on the west side. A few miles further on the Rufiji passes over the Pangani Rapids and then turns east through Stiegler's Gorge. At the end of the Gorge, at Mpanga, the valley widens and the river flows for the last 135 miles of its course (95 miles as the crow flies) through a flood plain sloping gently down to sea-level.

The soil survey is of this final flood plain, from Mpanga in the west to the end of the useful agricultural land on the river delta in the east. The seaward margin of the delta consists of salt flats, mangrove swamps and sandbanks and was not mapped.

Just below Mpanga the flood plain extends northwards in a large D-shaped area. This is a game reserve and is uninhabited and difficult of access. Most of it had to be left unsurveyed. On the opposite side of the river, south of Tindwa and west of Maba the ground was partly obscured by cloud in the only aerial photographs available. The soil boundaries in this area will be less reliable than those elsewhere.

In this western end of the plain the few people living there live on the river bank and access to the land back from the river is difficult. But from the Zombe-Kimburu footpath eastwards paths and tracks are relatively numerous, at least up to the beginning of the non-alluvial soils bordering the valley.

The field work of the reconnaissance soil survey was done in the latter part of 1954. The writer was helped for part of this period by R. H. Paxton, of the Tanganyika Agricultural Corporation, who produced the soil map for the northern half of the delta. The total area of soils shown on the map is about 700 square miles of which about 600 square miles are alluvial soils.

The map is based on photointerpretation, checked by traverses at intervals across the valley. Usually there were footpaths which could be followed. Profile pits were dug when necessary for the examination of the profile and the taking of samples. The pits were normally 6 feet deep. The soil descriptions incorporate work done later than the reconnaissance survey when the writer was examining possible sites for trial farms.

MAIN PHYSICAL FEATURES AND GEOLOGY

After leaving Stiegler's Gorge the Rufiji flows between hills for 10 miles. Then, at Mpanga, it leaves the hills and enters a flood plain about 5 miles wide and 75 miles long. East of this the flood plain widens into a delta which extends about 20 miles from east to west and 25 miles from north to south.

The flood plain and the delta consist almost entirely of recent alluvial deposits. This alluvium is bounded on both the north and south by soft sandstones and unconsolidated sandy deposits.

The hills to the west of Mpanga are shown on the Geological Map of Tanganyika (1959) included in volume VI of this Report as formed from Karroo sediments. On the left (north) bank of the Rufiji downstream from Mpanga there is first the large D-shaped area of alluvium mentioned above. Its northern boundary was not seen. Below this D, and opposite Kwangwazi, an escarpment of soft sandstone comes in from the north-west and forms the northern boundary of the flood plain right down to the delta. This escarpment is 20 to 30 feet high along most of its length though here and there, e.g. north of Rusende, it has been lowered by the erosion of streams tributary to the Rufiji.

On the right (south) bank of the flood plain there is a 20 to 30 foot escarpment for about 2 miles below Mpanga. The escarpment then turns south and forms the left bank of the valley of the Kondo River. To the east of the Kondo River there is no marked escarpment bounding the flood plain. The end of the alluvium is marked only by a rise of 4 or 5 feet on to fairly level coarse sandy deposits which the geological map shows as of Neogene age. This low-lying stretch continues to near Mayenge. South of Kipugira a channel coming from the south probably carries the wet season overflow from Lake Tungi or Utungi (Utenge on some maps).

Near Mayenge the land to the south of the flood plain begins to rise to the range of hills which runs south from Utete. Utete itself is 30 or 40 feet above the level of the valley. This higher ground is formed of Jurassic sandstones, according to the geological map. East of Utete the land gradually falls until at Mohoro there is no marked change in level between the alluvium and the adjoining sandy soils which rise slowly to the south and south-west.

The higher ground to both north and south of the Rufiji valley is cut here and there by the valleys of minor tributaries of the main river. The accumulation of alluvium in the Rufiji valley has dammed the exits of many of these minor streams and caused lakes to form.

THE ALLUVIUM OF THE RUFIJI VALLEY

The Rufiji valley below Mpanga can be divided into three sections, each differing from the others in the pattern of alluvial deposition.

(1) MPANGA TO MTANZA

The river bed in this section is very wide, up to a mile in places (figure 30). The river only fills this bed when in flood; in the dry season a great area of sand is exposed. The flood plain on the south side of the river consists mainly of former courses of the Rufiji and of associated sandy levées (raised banks). There is very little clay. On the north side of the river there is at least one old river bed probably containing sand. Inspection of the aerial photos suggests there may be rather more clay in the unexamined D-shaped area than on the south side of the Rufiji.

The Rufiji brings a heavy load of sediment down through Stiegler's Gorge. The average of four years measurement by the Hydrological section of the Rufiji Basin Team is 13,558,000 tons of suspended sediment per year; in addition there is the bed-load, which was not measured. At Mpanga the river reaches the flood plain and its velocity falls. Much of its sand load is deposited in the stretch between Mpanga and Mtanza and this raises the level of the river bed. In consequence the river frequently breaks its banks and forms a new course on lower ground. During less violent floods, when the river remains in its existing course, the spilling of the sand-laden flood water over the banks builds up extensive sandy levées. In addition, the sand in the river channel builds up into banks and diverts the main current from side to side of the channel, so that bank erosion is severe. These factors explain the main features of this section of the valley - the wide, sand-filled bed, the numerous abandoned beds and the extensive sandy levées.

(2) MTANZA to IKWIRIRI

Here the river is narrower and its course is less obstructed by sand banks. Nevertheless sudden changes of course do take place from time to time. For most of last century the Rufiji flowed along the north side of the plain through Rusendo and as far east as Mbingu, before crossing over to the south side. According to Telford (1928) it first broke through at Nyaringwe about 1873 and then again further upstream just below Nyasungwe in 1890.

The local people say there was formerly a large village at Beta on the north side of the old course and the clay land to the north (on which the Beta Trial Farm was eventually sited) was regularly flooded and produced good crops of rice. Since the river moved across to the Utete side of the valley the clay at Beta has ceased to be flooded and cultivation of rice, without artificial irrigation, has become impossible. It is evident that during its occupation of the northern channel the Rufiji had raised the level of the north side of the valley above that of the south side. In the stretch between Nyaringwe and Mayenge the river flows swiftly in a narrow channel. At Mayenge it reaches the lower south side of the flood plain; its velocity falls and the channel widens. The gradient across the flood plain is obviously greater than the longitudinal gradient at this point.

From Mayenge to Ikwiriri the proportion of clay to old river bed sand and sandy levée rises progressively. Fairly extensive levée deposits border the channel from Mtanza to Nyasungwe and also the old northern channel through Rusendo. But the 70 years during which the river has occupied the new course past Utete have not been sufficient for any extensive levée building. There has been a tendency for the formation of meanders below Mayenge but on the whole the river has kept close to the southern edge of the flood plain.

Below Mayenge there is little likelihood of any abrupt change of course for some centuries but above Nyasungwe there is a very real risk of the river breaking its southern bank and crossing to the southern side of the valley. It would in such an event probably rejoin its present course just above Mayenge. Telford (1928) believed that the next break would occur at Logelogo.

(3) IKWIRIRI TO THE SEA

By the time the river reaches Sule (south of Ikwiriri) it has lost much of its load of sand. Changes in course are by the gradual process of meandering and sudden break-outs are most unlikely. Either the level of the river bed is not rising or, if it is, this rise is slow and is compensated by the sinking of the whole delta under the weight of sediments being laid down on the seaward side of the delta.

Remains of former courses are still visible in the delta area. One such course leaves the present river at Kilindi and passes through Mohoro and Ndundu-tawa. There is a smaller channel, probably never more than a branch of the main river, also leaving at Kilindi and running through Ruhonde. These courses may be relics of the time when the delta did not extend so far to the east. The splitting up of the main channel, which now starts at Usimbe, may then have taken place at Kilindi.

In this third section of the lower Rufiji the soils are predominantly loams and clays. Sands rarely occur except in old river beds. Small, raised patches of sand are, however, found here and there. In particular there is a double ridge just east of Ndundu-tawa and a less regular series of patches further south. These appear to be old storm beaches dating from a time when the delta was much less extensive. Similar ridges are being formed at the present day on the eastern edge of the delta at Mbwera.

CLIMATE

The rainfall in the lower Rufiji valley tends to be bimodal in distribution. The "short rains" start in late November or early December. There is usually a drier interval in late January and early February and then the "long rains" start in late February and continue until early May. There is, however, much variation from year to year.

Near the coast the average annual rainfall is over 40 inches; for Mohoro it is 48 inches. Further inland the rainfall is less. The average for Utete is 36 inches and for Mtanza 27 inches. West of Mtanza there appears to be an increase and Stiegler's Gorge, 10 miles west of Mpanga, receives about 39 inches.

The agricultural system of the Lower Rufiji depends more on natural flooding than on direct rainfall so that the rain in the upper parts of the Rufiji Basin is as important to the local people as the rain immediately overhead. Nevertheless a poor rainfall year in the upper basin is usually a poor rainfall year in the Utete District also. In dry years, therefore, when there is little flooding, it is the Mtanza area of low rainfall which suffers worst from crop failures.

The lower Rufiji is practically at sea level and high temperatures may occur. The sun heats up the burnt grassland, rice stubbles and the bare sand in the bed of the river. The heated ground heats up the air currents moving across it and continues to do so until well after sunset. In 8 years temperature recordings at Utete screen temperatures of over 100°F have been recorded for each of the months from December to April. The highest reading was 112°F one January. The mean of the daily maximum and minimum temperatures averaged over a month has varied from 74° to 85°F.

SOILS

GENERAL DESCRIPTION

The soils in the flood plain are nearly all formed on alluvium deposited by the Rufiji. This alluvium varies in texture from a coarse sand to a clay and the pattern of its distribution is complex.

The simplest conditions for deposition, when the course of the river is stable, is for there to be coarse sand in the river-bed and a raised levée of fine sand along the river bank. With increasing distance from the river this levée diminishes in height and grades through sandy loam and loam to clay in the flat land beyond the levée. This is due to the gradual filtering out of the coarse particles from the flood water by the grass growing on the levée.

The picture is usually complicated by changes in the course of the river. If the river is tending to form meanders the bank on the outside of the bend will be eroded whilst on the inside of the bend finer material will be deposited over the coarse sand of the river-bed. Vegetation establishes itself on this finer material and traps both fine and coarse particles from the water flowing through it during floods; until eventually a new levée may be built up cutting off this inside bend from the new course of the river. Loam or clay may then be deposited inside this new levée.

Again, if the river moves to an entirely new course all the original course, including coarse sandy bed and the fine sands, sandy loams and loams of the levée, are gradually buried in clay.

The thickness of the alluvium is gradually increasing, presumably accompanied by some sinking of the whole delta area, so that alluvium is in places extending over non-alluvial ground bordering the flood plain.

The effect of all this is that if one digs a pit through the alluvium, at hardly any point will there be found a section uniform in texture. (The delta is an exception because here most of the alluvium deposited is clay). During a reconnaissance survey there is, however, rarely time to make deep investigations of the alluvium. In general auger borings were made to a depth of 18 inches to 2 feet. This eliminated much of the complexity and enabled most of the valley to be shown as sandy levée, loamy levée or clay. There still remained large acres where a change in texture took place in the top 18 inches and it became necessary to have such groups as "alluvial clay overlying coarse sand". There were also, of course, many small areas of such composite soils which were either not detected or were not large enough to show on a map at a scale of 1 in 125,000.

The non-alluvial soils bordering the valley are nearly all sandy. There are probably some differences in these sands since they are derived from parent materials of differing origin. However these soils are of no value for irrigation so no close examination of them was made. Low-lying areas within these sands often have a sandy clay soil but this could not be investigated in the time. Only in two or three places, where these non-alluvial sandy clays occurred within the alluvium of the valley, are they shown on the map.

The full list of soils distinguished on the map is given below:-

SOIL	MAP SYMBOL
Alluvial	
Coarse sands of river beds.	M
Sandy soils of river banks (mbaragwila)	B
Loams and heavier soils of river banks	Bc
Alluvial clay.	K
Alluvial clay mixed with sandy colluvial material	Ks

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Alluvial clay overlying sedentary sand.	KS
Alluvial clay overlying coarse sand	KM
Mbaragwila overlying coarse sand	BM
Alluvial clay overlying mbaragwila	KB
Saline soils	A
Complex of K and B not separable at map scale	K and B

Non alluvial

Sandy soils formed from sandstones, beach sands, etc.	S
Sandy clays, hardening or drying	P

DETAILED DESCRIPTIONS OF THE SOILS

COARSE SANDS OF RIVER BEDS

This soil is only shown on the map in abandoned river-beds, where a certain amount of vegetation has taken a hold. The sand in the present course of the Rufiji is not included.

The soil consists of almost pure sand often showing signs of current bedding. Sometimes narrow bands of loam or clay can be seen in the profile, indicating a period when the main current of the river had moved away and quiet conditions prevailed at the profile site. Horizons rich in river gravel also occur in most profiles.

There is always a certain amount of silt and clay mixed with the sand and when the channel ceases to carry flowing water there is increased deposition of finer alluvium from standing, or slowly moving flood water. Annual herbs and deep-rooting perennials become established and encourage further deposition.

The soil mapped as "coarse sand of river-beds" includes soils with up to 8 or 9 inches of a finer-textured overlay. When the thickness of the finer layer exceeded this the soil is shown as a composite one, e.g. alluvial clay overlying coarse sand (KM).

One pit was dug in the old bed of the Rufiji at Rusende. This channel still carries water in most years, when the Rufiji is in flood. There was a 10 cm. thick horizon of sandy clay at the surface and another thin band of clay at 40 cm. depth. The rest of the profile was sand or coarse sand, with water standing at 115 cm. depth. The vegetation was sparse grass and herbs, with a few shrubs.

The surface of these sands is normally somewhat undulating since a shallow river tends to concentrate its flow into a series of interlacing channels, leaving sand-banks between the channels. When the river dries up completely the incoming vegetation grows thicker in the channels than on the ridges, since the water-table is nearer the surface in the channels. This gives these old river-beds a somewhat net-like appearance on aerial photos, with dark lines of vegetation following the courses of the interlacing channels.

Another profile pit was dug about half a mile north of Rusende. This site had evidently been occupied by a loop of the river at some time in the past. The top

35 cm. was a dark grey clay loam. At 35 cm. there was an abrupt change to pale brown sand. Below 85 cm. there was a white current-bedded coarse sand with bands of river gravel. This continued to the bottom of the pit at 180 cm. depth.

The surface at this site still showed the undulations typical of these river-bed sands. The natural vegetation was grass with scattered trees and shrubs. The trees included Commiphora sp., Dalbergia melanoxylon, Acacia sp. and Hyphaenae palms.

This soil was classed as "alluvial clay overlying coarse sand". Although it supports a better plant cover than the pure sand it would still not be satisfactory for irrigated cropping. There is, for all practical purposes, only 35 cms. depth of soil since it would not be possible to maintain sufficient moisture in the sand. The crops would not flourish on 35 cm. of soil without watering at inconveniently frequent intervals.

SANDY SOILS OF RIVER BANKS (MBARAGWILA)

The Rufiji in flood carries a considerable load of fine sand, silt, clay and flakes of mica. This is kept in suspension by the turbulence of the river. When the river overtops its banks this suspended material is deposited on the adjoining land. The coarser particles are deposited nearest the river and successively finer particles further and further away.

The deposit on the actual river bank, often forming a belt several hundred yards wide along the river, is usually predominantly a micaceous fine sand, with lesser amounts of coarse sand, silt and clay. This is known by the local inhabitants as "mbaragwila". The greater part of the coarse sand transported by the river remains in the river bed while much of the silt and clay is carried in suspension across the mbaragwila and settles slowly at greater distances from the river.

These deposits of mbaragwila are most extensive (both in width and depth), and their texture is sandiest, in the western portion of the flood plain. Further east their extent decreases and their texture becomes heavier. In the delta area they are usually loams and in this survey have been grouped separately from the sandier mbaragwilas.

These mbaragwila deposits stand up above the rest of the alluvial deposits of the clay as raised banks or levées. Huts are usually sited on them and tracks usually follow them since they are less subject to flooding than other soils of the valley.

The flood water, when the river overtops its banks, does not usually flow as a uniform sheet but flows more rapidly, and more frequently, through low spots in the bank. The effect of this is that the mbaragwila is deposited unevenly, tending to form ridges at right angles to the river. Also the boundary of the mbaragwila furthest from the river, where it usually adjoins clay, is not the smooth line which it appears to be on the small-scale soil maps but is actually fretted, with tongues of one soil penetrating into the other.

The mbaragwila deposits are strongly stratified into layers of coarser and finer texture since different floods vary in violence and deposit different grades of material. The mbaragwila usually overlies clay. This clay represents the original land surface into which the river cut its channel when it moved into that particular course. In other cases there may be alternations of mbaragwila and clay, where the river has abandoned a course after laying down a certain amount of mbaragwila and has later returned to that course.

In the upper (western) part of the valley the thickness of the mbaragwila is often greater than 2 metres close to the river. Further away, of course, the thickness tends to diminish. In the profile described below, which was 400 yards distant from the river, the thickness of mbaragwila was just over one metre.

PROFILE R7

Location	Zombe, about 400 yards from the river bank.
Parent material	Alluvium.
Topography	Fairly flat; slope about 1 per cent.
Drainage	Flooded for part of most wet seasons. Well-drained in the dry season.
Vegetation	Grass; but cultivated in the past for cotton, maize, sorghum, etc.
0 - 10 cm.	Grey-brown fine sandy loam (2.5 Y 5/2, dry). Good crumb, porous, slight irregular vertical cracking. Many fibrous roots. Clearly defined from:-
10 - 18 cm.	Light brownish-grey somewhat clayey fine sand (2.5 Y 6/2, dry) micaceous. Massive, friable, slight vertical cracking. Fewer fibrous roots with slight rusty staining along roots. Clearly defined from:-
18 - 22 cm.	Grey-brown fine sandy clay (10 YR 5/2, dry) with about 5% strong brown mottles and some manganese staining. Stratified, with fine horizontal and vertical cracks. Moderate fibrous root. Clearly defined from:-
22 - 122 cm.	Stratified pale brown sand (10 YR 6/3, dry). Much coarse sand down to 43 cm., fine sand below; current-bedded below 85 cm. About 10% strong brown mottling at top, diminishing with depth. Massive but friable. Abrupt boundary.
122 - 150 cm.	Dark grey-brown fine sandy clay (10 YR 4/2, dry) with lenticular pale brown patches and some rusty mottles; slight manganese staining. Hard cloddy, with irregular mainly vertical cracks. Very few roots. Merging into:-
150 - 190 cm.	Very dark grey-brown clay (10 YR 3/2, dry) with about 25% brown to reddish-yellow mottles. Cloddy, with mainly vertical cracking. Slightly moist (early October).

This profile is approximately neutral in reaction, the pH varying from 7.2 at

1 metre depth (see table 14). There is a good organic matter content of 3½ per cent in the topsoil (organic matter = organic C x 1.72). Available phosphorus, as determined by dilute acid extraction, is high. Exchangeable calcium and magnesium are in good supply and potassium adequate. Sodium is low down to 1 metre depth and although there is a rise below this it does not reach a dangerous level. There is no accumulation of soluble salt, as is shown by the low conductivity figures.

The C/N ratio is rather high in the upper horizons, suggesting a deficiency of nitrogen, although this ratio is not a very reliable indicator of nitrogen status. These levée soils are very fertile when adequately supplied with water. The local inhabitants grow maize, beans, pumpkins, etc. on them during the wet season and paw-paws and mango trees are numerous. Cotton is widely grown also. It is sown on the lower-lying mbaragwila after the Rufiji flood has receded, i.e. towards the end of the rains. The roots follow the water-table as it sinks during the dry season and the crop is independent of rain.

Although these soils have a high inherent fertility they are not very suited to irrigation. In the first place their uneven surface will greatly increase the cost of installation of an irrigation system and will necessitate the use of small fields.

Secondly, they are often so sandy that water losses from canals and in the fields will be very high. The profile R7 would probably be reasonably satisfactory. In the top foot of the profile no horizon has less than 14 per cent of clay. Below this the profile is sandier but no horizon (at any rate no analysed horizon) has less than 11 per cent of clay. This together with the presence of a quantity of horizontally-bedded mica flakes, will probably be sufficient to prevent too rapid an escape of the water. Some other profiles examined, however, have been much more sandy. Thus profile R2, near Utete, had less than 10 per cent of clay in all horizons down to 80 cms., at which depth clay was reached; and profile P160, at Mtanza, showed only 2 per cent of clay between 70 and 200 cm. depth. Water losses in such soils would be far too high.

Since these mbaragwila soils are inherently the most fertile in the valley any irrigation scheme should endeavour to include as large an area of them as practicable. They will, however, have to be surveyed carefully beforehand so that only those with a reasonable water-holding capacity are incorporated. This survey will have to be in detail owing to the great variation which exists over quite short distances.

LOAMS AND HEAVIER SOILS OF RIVER BANKS

It has already been stated that the river levées in the delta area are of heavier texture than the levées of the higher reaches of the river. The levées of the delta are also less extensive both in width and height. The soil is still called mbaragwila by the inhabitants.

Only one profile pit was dug and this is described below:-

PROFILE R15

Location Mwengei.

Parent material Alluvium, fine-textured.

Topography Level.

Drainage Impeded. Not flooded from the river.

Vegetation Cultivated, with scattered trees, including:-
Mango
Kapok
Kigelia aethiopica
Vitex doniana

0 - 12 cm. Dark grey loam (10 YR 4/1, dry). Good crumb, fairly porous. Moderate amount of fibrous roots in the top 3 or 4 cms. Merging into:-

12 - 28 cm. Black fine sandy clay (10 YR 2/1, dry) becoming browner with depth. Medium cloddy; cracks up to 5 mm. wide. A few fibrous roots. Merging into:-

28 - 50 cm. Brown micaceous fine sandy clay (10 YR 5/3, dry) with greyish mottles. Medium cloddy; cracks up to 4 mm. wide; very few fibrous roots. Clear boundary.

50 - 85 cm. Pale brown fine sand with much brown and orange mottling. Massive, with a few fine vertical cracks. Merging into:-

85 - 165 cm. Dark brown clay (10 YR 3/4 dry) with 5% rusty mottles and some manganese staining. Very coarse clod, hard. No roots. Merging into:-

165 - 190 cm. Pale brown micaceous fine sand (10 YR 6/3, dry) with a few medium sized rust mottles. Massive but friable.

The profile was moist below 85 cm. (end of November).

In general fertility the soil is similar to that of the sandier R7 described above (see Table 14). In texture, however, it is much heavier. There is 27 per cent clay in the surface horizon and probably more than this in the next two horizons below, although they were not analysed. A sandy layer, with only 9 per cent clay, does intervene between 50 and 75 cm. depth but clay lies below that, down to 160 cm.

The sandy horizon between 50 and 75 cm. depth might cause some inconvenience in the construction of canals but this could be overcome without difficulty. It would not effect the usefulness of the land for cropping. In any case it is not a constant feature of these soils.

Topographically these soils are more suited to irrigation because their surface is more even than that of the sandier levées further upstream. Their total area is, however, quite small.

ALLUVIAL CLAY

Alluvial clay tends to occur at the bottom of saucer-shaped depressions. The raised rim of the saucer consists of the coarser alluvial deposits, i.e. the "mbaragwila" described in the previous two sections. The flood water entering the depression loses most of its coarser sediments while crossing the rim; the remaining fine, particles settle in the centre of the saucer to form heavy clay soils.

These clays are dark grey or dark grey-brown in colour. They crack widely on drying; the clay appears to be montmorillonitic though no identification of clay minerals has been done. There are some differences between the clays of the delta and those of the valley. The dividing line appears to fall near Ndundu. They are therefore described separately.

Mpanga to Ndundu

Ten profile pits were dug in clays between Mpanga and Ndundu. A typical profile is described below (R5), and a general view is given in figure 31. These clay deposits are not uniform and sandy strata are common within the profile. Profile R5 has a sandy layer between 100 and 135 cm. depth. The actual clay layers in this profile are fairly uniform, varying from 47 to 59 per cent of clay (table 14) but greater variations were often found. In only one horizon of one of these ten profiles did the clay content of a clay horizon exceed 60 per cent. This was the 75 to 125 cm. horizon of profile P207 (at Beta near Utete) which contained 65 per cent.

Rusty mottles occur in all horizons of these clay profiles except usually the top one. These mottles indicate bad drainage within the profile. Both the heavy texture and the seasonal high water-table (commonly actual submergence of the soil) are the cause of the poor drainage conditions and is not easy to foresee to what extent the drainage would be improved by lowering of the water-table by the damming of the river above Mpanga. However, the prevalence of sandy horizons in the clays above Ndundu and the not excessive percentages of clay in the clay horizons suggest that drainage would be satisfactory for most crops. Care would be needed in the application of irrigation water to avoid excessive watering.

Two of the ten clay profiles between Mpanga and Ndundu suffer from excess exchangeable sodium and are exceptions to the general statement just made. Drainage in these two clay soils would not be satisfactory without reclamation measures to reduce the sodium.

Profile 5 is an example of the eight clay profiles which were not affected by sodium.

PROFILE R5

Location	Rusende, 1000 yds. south of old course of Rufiji.
Parent material	Fine-textured alluvium.
Topography	Level. Flood plain of the Rufiji.
Drainage	Impeded. Flooded for part of wet season.
Vegetation	Grass, with scattered shrubs and a few trees (including Borassus palms). Much of the surrounding land is cultivated for rice.

0 - 8 cm.	Dark grey clay (10 YR 4/1, dry). Well-marked coarse crumb to small clod, hard. Moderate amount of fibrous root. Merging into:-
8 - 25 cm.	Dark grey-brown clay (10 YR 4/2, dry) with slight rusty mottling in lower part. Coarse blocky, hard. Irregular cracks, mainly vertical. A few fibrous roots. Merging into:-
25 - 38 cm.	Brown fine sandy clay (10 YR 5/3, dry) with 15% dark brown to yellowish-red mottles. Massive, with irregular cracks. A few fibrous roots. Merging into:-
38 - 75 cm.	Dark grey-brown clay (10 YR 4/2, dry) with 10% yellow mottles (10 YR 8/6). Coarse subangular blocky structure. No fibrous roots. Merging into:-
75 - 100 cm.	Dark brown clay (7.5 YR 4/2, dry) with 20% yellowish-red mottles. Massive, with irregular cracks. Merging into:-
100 - 135 cm.	Brown clayey sand (7.5 YR 5/4, dry) with dark brown and white mottles. Massive and compact.
135 - 200 cm.	Very dark brown clay (7.5 YR 3/2 to 4/2, dry) with 20% reddish-yellow mottles. Little cracking but with a tongue of sand descending from the previous horizon to below 200 cm.

Moist below 40 cm. depth (early October).

This soil is slightly on the acid side of neutral (pH 6, rising to 7 at 100 cm. depth). There is a moderate amount (2½%) of organic matter and a moderate level of available phosphate. Exchangeable calcium and magnesium are high; potassium is high in the surface horizon and moderate below. There is no excessive level of sodium and no accumulation of soluble salts.

Profile 207 (at the Beta trial farm) was similar to R5. The exchangeable sodium in the subsoil is rather higher in 207 but does not reach harmful levels; the available phosphorus is rather low in 207. Profile 207 is heavy-textured down to a depth of 180 cm.; below this there is fine sand.

The two profiles with excess exchangeable sodium were R8 at Zombe and R11 near Nyawiru. In these the top 20 cms. or so of the profile are similar to those of R5 but below this the soil is strongly alkaline, with pH values above 9 at about 100 cm. depth. Below this the pH declines slightly.

The alkalinity is due to a high level of sodium in the exchange complex. It is usually considered that crops will be affected if the exchangeable sodium exceeds 15 per cent of the total exchangeable bases. The exchangeable sodium percentage (ESP) and clay content of several horizons of profile R8 are given over the page.

Table 5. Exchangeable sodium and clay percentages for Profile R8

Depth (cm.)	pH	ESP	Clay %
0 - 8	6.4	5	50
8 - 16	5.9	6	52
22 - 50	7.0	23	56
70 - 90	9.6	44	13

The effect of the high sodium will be to restrict root growth of many crops to the top 22 cms. of the soil profile and, in conjunction with the high clay content of the 22 - 50 cm. horizon, to impede drainage. The soil is satisfactory for rice and is, in fact, used for this crop by the people of Zombe. For most other crops it would require some ameliorative measures.

There is no calcium carbonate in the 22 to 50 cm. horizon, though there is some in the lower horizons. Gypsum applications would therefore be necessary to reduce the sodium.

Profile R11, near Nyawiru, appears to be similar to R8, with pH values up to 9.2 (for 100 - 140 cm. depth), though the exchangeable sodium was not measured. There was no free calcium carbonate at any level in this profile.

These alkaline soils probably occur where the water-table is near the surface for a considerable part of the year. Evaporation of water ascending from the water-table would explain the high sodium levels. In mid-October R8 had a water-table at 150 cm. depth. In R11 the soil was moist below 170 cm. depth in November but there was no standing water down to 220 cm. depth.

To summarise, the alluvial clays between Mpanga and Ndundu are in general suitable for irrigated cropping. They have good reserves of plant nutrients and are free from salt. A proportion, however, are affected by an excess of sodium and without amelioration are only suitable for rice.

Of 10 pits dug 2 were affected by sodium. This suggests that about 20 per cent of the area of clay might be affected but obviously not much reliance can be put on this figure.

Below Ndundu

Nine pits were dug in alluvial clay below Ndundu. On the whole the clay is heavier in texture than that above Ndundu and sandy strata are less frequent. Clay contents of 60 to 70 per cent are common and 3 out of the 9 profiles consisted of continuous clay to at least 2 metres depth.

The land below Ndundu is, roughly, the delta of the Rufiji. It is not surprising that most of the clays in this area are affected by high exchangeable sodium or by salt or by both. Profile R17, at Kingongo II, is typical of these delta clays. A general view is given in figure 32.

PROFILE R17

Location	Kingongo II, about 900 yds. north-east of village.
Parent material	Fine-textured alluvium.
Topography	Level; on the delta of the Rufiji.
Drainage	Impeded. Rain-water is ponded on the site but flooding from the river does not occur.
Vegetation	Grass and herbs. Rice is cultivated nearby.
0 - 12 cm.	Very dark grey clay (10 YR 4/1, dry). Good crumb structure; cracking slightly on drying. Many fibrous roots. Merging into:-
12 - 30 cm.	Very dark grey clay (10 YR 4/1, dry) with 15% brown and yellowish-red mottles. Angular blocky; very hard. Cracks up to 15 mm. wide. Moderate amount of fibrous root. Merging into:-
30 - 96 cm.	Very dark grey clay (10 YR 3/1, dry) with 15% red to strong brown mottles. Otherwise as above. Merging into:-
96 - 140 cm.	Very dark grey clay (10 YR 3/1, dry) with 15% red to brownish-yellow mottles. Angular blocky; hard. Very few roots. Salt crystallising on walls of pit. Merging into:-
140 - 190 cm.	Very dark grey clay (10 YR 3/1, dry) with 15% yellowish-red to pale yellow mottles. Plastic and very sticky. Salt water oozing in below 180 cm. No roots.

It will be observed that this profile is clay throughout; the actual clay content of the different horizons varies from 54 to 70 per cent (see tables 6 and 14). The pH is 6.3 at the surface, declining to 4.2 below 140 cm. depth. (The reason for the acidity of the subsoil is not clear; it is possible that it is due to the oxidation of sulphides in the soil sample to sulphuric acid after the sample has been taken and that the soil is not so acid in the natural condition.)

As well as having a high proportion of sodium in the exchange complex of the subsoil this profile also has appreciable amounts of salt below a depth of 60 cm. (Table 6). Crops differ in their sensitivity to salts but the more sensitive crops are affected when the conductivity of the saturated extract exceeds a value of 2.

Table 6. Exchangeable sodium and clay percentages and conductivity of the saturation extract for profile R17.

Depth (cm)	pH	ESP	Clay %	Conductivity of S.E. (millimhos/cm)
0 - 12	6.3	3	56	-
30 - 60	5.7	15	70	-
60 - 96	4.7	-	-	6.3
96 - 140	4.5	32	61	7.4
140 - 190	4.2	32	54	9.4

Both the ESP and the salt content reach harmful levels at a depth of 60 cm., or thereabouts. When the pit was dug salt water oozed in at a depth of 180 cm. Amelioration of the soil will not be possible unless this water-table can be lowered. The land may not be sufficiently above sea-level for this to be done. If the water-table can be lowered then gypsum applications will be needed to displace the excess sodium.

In other respects the soil is satisfactory. The organic matter and potash contents are good and the available phosphorus is moderate.

Profile R24, at Mchikichi on the north bank of the river is similar to R17 in that there were no sand strata in the 2 metres depth of the pit but the soil was less affected by sodium or salt. The ESP only exceeds 15 at depths of over 100 cm. and the soluble salts do not reach serious levels at any depth.

Profile R20, north of Ruhende, was notable for its solonetzic structure. The top 8 cm. of the soil was rather loose and at 8 cm. depth there was a sharp transition to round-topped columns.

The exchangeable sodium percentages and clay contents are given in table 7. There were no serious accumulations of salts. The soil was rather lighter in texture than the other clays, except for the 95 to 120 cm. horizon.

Table 7. Exchangeable sodium and clay percentages for profile R20

Depth (cm)	pH	ESP	Clay,%
0 - 8	6.9	7	24
8 - 22	8.1	13	33
22 - 50	8.6	18	32
55 - 70	8.1	19	19
95 - 120	8.6	32	63

The ESP's for R20 are rather lower than those of R17. However the local people say that rice does not yield satisfactorily in the vicinity of R20, whereas it grows well around R17. If this difference in rice yield is due to soil differences the most likely factor would seem to be the high pH values of profile R20 below a depth of 8 cm. The levels of organic matter and available phosphorus are good.

Another profile examined, though the figures are not included in table 14, was

R25 on Usimbe Island. The pit was dug on the edge of a large block of rice-fields which give good yields of rice. Some figures are given in table 8.

This profile is acid, like R17. Sodium is high below 25 cm. depth; there is a considerable accumulation of salt in the surface horizon of this profile and lesser amounts in the subsoil. The water-table was deeper than 180 cm. (late November) but the rather sandy horizon below 120 cm. was wet. The high sodium and salt values are probably due to the evaporation of water ascending from a saline water-table. Since Usimbe Island is surrounded by salt water it is possible that nothing can be done to lower this water-table.

Table 8. Exchangeable sodium and clay percentages and conductivity of the saturation extract for profile R25.

Depth (cm)	pH	ESP	Clay %	Conductivity of S.E.
0 - 25	4.8	6	69	12
25 - 85	4.7	21	63	1
120 - 180	4.4	25	24	4

The figures indicate that rice has a considerable resistance to salt in the soil.

Two other profiles in the delta area, R19 near Mohoro and P159 near Ndundu, were free from accumulations of sodium or salt but the evidence suggests that most of the clays of the delta are affected to some extent. The range of possible crops is therefore limited unless ameliorative measures can be applied. In many cases a lowering of the water-table would have to be the first step and it is doubtful whether this will prove possible.

ALLUVIAL CLAY MIXED WITH SANDY COLLUVIAL MATERIAL

This soil occurs chiefly in the upper part of the valley, near Mpanga. The material from which the soil develops is a mixture of coarse sandy material derived from the surrounding sandstones and of alluvial clay.

Only one profile pit was dug in this soil; it is described below (R 10). The uppermost 18 cm. are mainly alluvial clay though there is some admixture of coarse sand which gives the clay a rather gritty feel. The sand grains also help to bind the soil into a hard mass which will be abrasive to implements when dry. Below 18 cm. there is less clay and the material is either colluvium washed down from nearby higher ground or is perhaps weathered sandstone more or less in situ. Analytical figures are given in Table 14.

PROFILE R10

Location — Nyakisiku. 500 yds. south-east of bridge over Kondo river.

Parent material — Alluvium overlying weathered sandstone (?).

Topography — Level. Flood plain of Rufiji river.

Drainage Very poor. Site subject to flooding from river.

Vegetation Grass, with scattered trees and shrubs. Trees include Acacia sp. and Hyphaenae sp.

0 - 8 cm. Very dark grey clay (10 YR 3/1, dry). Coarse crumb to fine sub-angular blocky; very hard. Cracks to 2 cm. wide. Many fibrous roots. Merging into:-

8 - 18 cm. Very dark grey clay (10 YR 3/1, dry). Coarse subangular blocky; very hard. Wide cracks. Moderate fibrous root. Clear boundary.

18 - 85 cm. Dark grey coarse sandy clay (10 YR 4/1, dry) with 10% strong brown mottles and some manganese staining. Some white inclusions (? kaolin). Massive, very hard, compact. A few irregular cracks to 0.5 cm. wide. Few fibrous roots. Merging into:-

85 - 100 cm. Grey (10 YR 5/1, dry), strong brown (7.5 YR 5/8) and white mottled clay, with manganese staining. Some carbonate. Massive, very hard, compact. Irregular vertical and horizontal cracking. Very few roots. Merging into:-

100 - 180 cm. Similar to above with increased concretionary carbonate (2 to 8 mm.) No roots. Moist below 165 cm. (mid-October).

The upper 18 cm. of this profile are similar to the alluvial clays already described, apart from the slight amount of coarse sand. The clay content is 50 to 60 per cent, the reaction is slightly acid, there is a high organic matter content (5½ per cent) and a fair available phosphorus level.

From 18 to 100 cm. depth the texture is a sandy clay. The pH rises slightly and a few carbonate concretions appear towards the 100 cm. level. The available phosphorus is lower than in the topsoil and the organic matter is of course lower also. Marked mottling indicates poor drainage in this part of the profile. The poor drainage is probably due to a combination of a seasonal high water-table and a horizon of impervious material below 100 cm.

This impervious material extends from 100 cm. depth to at least the bottom of the pit (180 cms.) and consists of an alkaline sandy clay with marked rusty mottling and much concretionary calcium carbonate. There is a rise in conductivity also, showing some accumulation of soluble salts, but this does not reach a serious level.

This profile R10 consists essentially of about 100 cm. of reasonably fertile soil overlying an impervious alkaline stratum. Irrigated cropping should be possible if water applications are strictly controlled so that water-logging does not occur in the top 100 cm.

Although there are 100 cm. of good soil in profile R10 there is no reason to suppose that this figure prevails throughout the mapped area of this soil. It is almost certain that in a proportion of the area there will be less than 100 cms. of good soil above the impermeable material. There will probably be a complete range between only a few centimetres overlying the impermeable layer, when the soil will grade into the hard sandy clays described below, and two or more metres, when it will grade into the alluvial clays.

Where the depth to the impermeable layer is less than 100 cms. the soil will probably only be useful for rice. The local people say that rice grows well on this soil.

SALINE SOILS

Much of the sea-ward side of the delta is occupied by saline soils. These soils support mangroves, salt marsh or are sometimes bare of vegetation.

No detailed examination was made of these soils but the following figures for pH and conductivity were obtained for surface samples of soil from a bare patch of soil and from a grassed area 10 feet away:-

Vegetation	pH	Conductivity of 1:5 suspension. (millimhos/cm.)
Bare	5.0	3.00
Grassed	5.2	0.85

The rice plant will stand a considerable amount of salt and at one site a rice crop was seen which was irrigated twice daily, at each high tide. The water was no doubt brackish water backed up by the rising tide and not full-strength sea-water.

The salt-marsh vegetation probably includes species of value to grazing animals and the mangroves are of economic importance. Nevertheless, this land is of low agricultural value and is not suitable for irrigation.

SANDY SOILS FORMED FROM SANDSTONES, BEACH SANDS, ETC.

The Rufiji valley is bounded on the north and south by sands and soft sandstones of Karroo, Jurassic, and Neogene age (according to the Geological Map). These all produce sandy soils of low fertility.

No profile pits were dug and no samples have been analysed. A rubbish pit at Utete showed about 12 inches of pale reddish-brown loamy sand resting on a sparse stoneline of water-worn quartz stones about 2 cm. in diameter. Below was a pale grey weathering sandstone. The quartz stones were noted elsewhere as being a constituent of the sandstone. The uppermost sandy layer is often more than 12 inches thick and there may have been loss by erosion at the site just described. In poorer-drained sites the soil is grey, without reddish tints.

Sorghum, cassava and sometimes cotton are grown on these sandy soils. The present trend appears to be to give up cultivation on these soils and to concentrate on the more fertile alluvial soils.

In low-lying sites in the sandy country there are grey sandy clays which harden on drying. They were not examined or sampled but are probably less alkaline than the sandy clay (profile R12) described below. They were not distinguished from the sandier soils of the higher ground in this survey.

At Mbwera there are a series of curved and nearly parallel ridges of coarse sand. These appear to be successive storm beaches left by a receding sea. They are planted with coconuts. There are also a number of isolated patches of sand lying on an arc passing slightly to the west of Ndundu-tawa. These are probably remnants of earlier storm-beaches. They lie four or five feet above the surrounding alluvium.

None of these sandy soils is suitable for irrigation.

SANDY CLAYS HARDENING ON DRYING

In two or three places in the Rufiji valley there are grey sandy clays which become very hard on drying, without shrinking or cracking. Only one pit was dug, R12 near Mayange.

The stretch of soil in which this pit was dug is mostly level and below the higher peak levels of the Rufiji floods. At one point, however, it rises to a low hillock which is above even the highest flood levels. This hillock and the presence of considerable quartz gravel in profile R12 show that this soil is not alluvial. It is formed on a piece of the local sandstone (? Jurassic) which has been nearly levelled by erosion and which will eventually be buried by alluvium brought down by the Rufiji.

PROFILE R12

Location	About one mile south-east of Mayenge.
Parent material	Jurassic sandstone, or derived colluvium.
Topography	Level.
Drainage	Very poor; soil almost impervious. Flooded from river occasionally but not deeply.
Vegetation	Thin grass, with scattered trees and shrubs, including Hyphaenae sp.
0 - 3 cm.	Dark grey sandy loam (10 YR 4/1, dry). Massive, hard. Many fibrous roots. Clear boundary.
3 - 10 cm.	Brown clayey sand (10 YR 5/3, dry) with strong brown mottles at top of horizon, descending in tongues into a grey sandy clay in lower part. Massive; hard. Few fibrous roots. Merging into:-
10 - 17 cm.	Grey-brown sandy clay (10 YR 5/2, dry) with many coarse quartz grains. Some concretionary iron and manganese. Very hard; not cracking on drying.
17 - 45 cm.	Grey-brown sandy clay (10 YR 5/2, dry) with a few, fine rusty mottles. Concretionary calcium carbonate (to 5 mm.), iron and

manganese; coarse quartz grains. Massive and very hard, not cracking on drying. No roots.

45 - 190 cm. Similar. Carbonate concretions to 15 mm. Iron concretions (with manganese) to 5 mm. Coarse quartz grains to 3 mm. Becoming less hard in lower part of horizon.

This soil is most unsuitable for cropping. It is very impervious to water, is strongly alkaline (pH value of 10 at a depth of 2 feet), has a high salt content and has a high proportion of sodium in the exchange complex. The high salt content and the high exchangeable sodium are probably the result of long-continued evaporation at the soil surface of water rising from a water-table within the profile. The water-table was not reached in this pit (dug to 180 cm. in October) but it is probably much higher when the Rufiji is in flood.

If the water-table can be kept low by control of the level of the Rufiji it should be possible to improve this soil by prolonged leaching with water alone, since the soil contains free calcium carbonate. The process is likely to be lengthy owing to the present impervious nature of the soil.

A few years ago several acres of this soil were tractor-ploughed and planted with rice. It was said by the local villagers that the rice appeared to grow normally but gave a poor yield. The soil soon reverted to its hard, impervious state.

COMPOSITE PROFILES

Changes in the course of the Rufiji have often resulted in changes in the kind of alluvium deposited at a particular point. Any of the kinds of alluvial soils already described are liable to be buried by another kind. A number of these "composite soils" are shown on the map, e.g. clay overlying mbaragwila, mbaragwila overlying sand, etc.

For practical reasons, if the upper layer of a composite soil was thicker than 18 inches, the lower layer was ignored and the soil was classed as belonging to the group to which the top 18 inches belonged. If the upper layer was less than 6 inches in thickness, it was ignored and the soil placed in the group to which the lower layer belonged. A composite soil shown on the map indicates, therefore, between 6 and 18 inches of the upper soil overlying an unspecified depth of the lower. There is a fair amount of latitude about these thicknesses since each auger boring had to represent a considerable area of land in which the thickness of the soil layers may vary appreciably.

A few soils which had three different kinds of alluvium in the top 18 inches were fitted into the two-layer soil which they seemed most closely to resemble.

The buried layer in a composite profile usually retains most of its original properties, including sometimes a higher organic matter content than the overlying soil. This is illustrated in profile R2, for example, (p.90 and table 14) where a sandy horizon lying at a depth of 45 to 80 cms. has less than a tenth of the organic matter of the clay horizon immediately below. (R2 is not, however, classed as a composite profile because the boundary between the upper sand and the lower clay is at a greater depth than 18 inches).

A full description of one type of composite profile, clay overlying sandier material, is given below. This particular combination may be difficult to irrigate successfully.

PROFILE 158

Location	Two miles east of Ndundu, on bank of Rufiji.
Parent material	Alluvium.
Topography	Level.
Drainage	Flooded for part of the wet season. Water table at 115 cm. in mid-July.
Vegetation	Tall grass (Hyparrhenia sp.) with scattered trees.
0 - 15 cm.	Very dark brown clay loam (10 YR 2/2, moist) with a few, fine orange mottles. Strong, fine crumb; very hard when dry. Merging into:-
15 - 30 cm.	Very dark grey clay (10 YR 3/1, moist) with 10% fine orange mottles. Strong, coarse subangular blocky; very hard when dry. Merging into:-
30 - 45 cm.	Fine sandy clay mottled dark grey (10 YR 4/1, moist) and yellow-brown (10 YR 4/4) with fewer, fine, strong brown mottles. Weak, medium granular. Friable and more porous than above. Merging into:-
45 - 75 cm.	Brown clayey fine sand (10 YR 5/3, moist) with medium, dark yellow-brown mottles. Massive, but very friable and porous. Merging into:-
75 - 115 cm.	Dark grey-brown clayey fine sand (10 YR 4/2, moist). More mottling than previous horizon. Water standing at 115 cm.

Soils such as this, and soils with an even thinner layer of clay overlying sand, can be cropped under the existing regime because during the wet season, when the crop is grown, the water-table rises in the sandy lower layer and maintains the upper clay layer in a moist condition. The crop can obtain sufficient nutrients from the top horizon of clay, even when the under-lying sand is of low fertility.

If, however, the Rufiji were controlled and the water-table were kept at a low level, all the water for the crop would have to come from surface applications, irrigation water alone in the dry season and irrigation water and rain in the wet season. This water will pass only slowly through the clay but, on reaching the underlying sand, will drain rapidly to greater depths, possibly out of root range of the crop. The profile as a whole will be able to store only a small amount of water within the crop's root-range. To keep the crop adequately supplied may necessitate watering at inconveniently frequent intervals.

LAND CLASSIFICATION

The same classification is used in the Lower Rufiji Land Suitability Maps as was used in those of Usangu and the Kilombero. Once again it is assumed that complete control from flooding by the river has been obtained. At present almost the entire valley is flooded in years of high rainfall.

The Land Suitability Maps are an attempt to show the suitability of the soils for irrigation. The west end of the flood plain is much dissected by old river-beds; parcels of good land lying amongst stretches of sand may prove to be too isolated for economic development. On the whole, however, there are few inaccessible areas of good land and nearly all suitable land appears to be capable of incorporation in an irrigation system for the valley.

The sandy levées presented some difficulty in classification since they range from coarse sand at the top of the bank, nearest the river, to a loam at their boundary farthest from the river. The solution adopted was to separate a strip 200 to 300 yards wide on the side next to the river (or old river-bed) and put this in Class 5, as not recommended until further examination has shown it to be suitable for irrigation. This strip should include most of the coarser-textured soils of the levée too porous for irrigation and also possibly out of command of the supply canals. The remainder of the levée has been put in Class 1 since it includes the fertile alluvial loams.

It should be realised that the boundary down the middle of the levée will in most cases be more irregular than that shown. In places, where the river regularly overtops its banks, the sandy zone will be wider than 200 to 300 yards; in between such places it will often be much less. It is hoped that the dividing line, while not showing the exact boundary between the two parts of the levée, will divide it into approximately the right proportions of land suitable and unsuitable for irrigation. Below Mpanganya in the present course of the Rufiji, and in the delta area, there is little deposition of sand on the river banks so the levées have been put wholly in Class 1.

A considerable area of the better soils of the valley is used at present by the local people, particularly in the eastern part of the valley, below Utete. The chief crop is rice, grown during the wet season and watered by the natural floods. In the delta this flooding comes from ponding of rain-water but in the rest of the valley the flooding is mainly from the river. In years of low rainfall there is little flooding and the crop is a failure, particularly in the low rainfall belt around Mtanza.

Cotton is also grown, especially in the upper part of the valley. The seed is sown on the lower ground on the levées as the flood water recedes and the plants tap the descending water-table for their water supplies. The crop receives little direct rain since it is not planted until near the end of the rains.

The introduction of flood control would destroy the present agricultural system except on the delta, and irrigation would have to be introduced simultaneously with the beginning of the flood control.

ASSESSMENT OF THE SOILS OF THE LOWER RUFIJI VALLEY

In assessing the soils for their suitability for irrigation it has been assumed that flood control will be achieved. In most of the valley this will result from control of the Rufiji River and its tributaries but surface drains will be needed on the delta to take away excess rain-water.

The reasons for the assessments made of the soils shown on the soil maps are given below.

Coarse sands of river beds (M)

Class 6 - unsuitable for irrigation owing to high permeability and uneven surface.

Sandy soils of river banks (B)

It has already been explained, earlier in this section, that these soils have been divided into two classes in the land suitability maps. In the western half of the valley a strip 200 to 300 yards wide on the side nearest the river (or former river) has been considered as Class 6, unsuitable for irrigation, on account of sandiness and an uneven surface. The remainder of the soil area in the western half of the valley, and all the soil area in the eastern half, has been put in Class 1. These soils are highly fertile, of good water-holding capacity and are well-drained.

Loams and heavier soils of river banks (Bc)

These are Class 1, like the better parts of the soil of the preceding paragraph.

Alluvial clay (K)

From Mpanga down to Ndundu, where the delta begins, these clays are put in Class 1. They are of good fertility, contain strata of sand to assist the drainage and rarely contain any salt or alkali.

On the delta the clays are not so well-drained and tend to be slightly affected by salt or alkali. These are put in Class 2.

Small areas of clay on the delta believed to be more seriously affected by salt are put in Class 5, as requiring further attention.

Alluvial clay mixed with sandy colluvial material (Ks)

This clay has a poorer structure than the pure alluvial clay so is downgraded to Class 2.

Alluvial clay overlying sedentary sand (KS)

This has been put in Class 4. The underlying sand does not seem to be very permeable, otherwise the soil would have been in Class 6.

Alluvial clay overlying coarse sand (KM)

Mbaragwila overlying coarse sand (BM)

These two soils are both unsuitable for irrigation, Class 6, since the underlying sand is very porous and they have an uneven surface.

Alluvial clay overlying mbaragwila (KB)

Class 2. The mbaragwila in the subsoil has a reasonable water-holding capacity, but the change in texture down the profile is a disadvantage so the soil is down-graded from the Class 1 of the deep alluvial clay.

Complex of alluvial clay and mbaragwila (K + B)

Each component would be Class 1 on its own but in a complex, in which moreover there are usually slight surface undulations, the soil is downgraded to Class 2.

Saline soils (A)

Sandy soils formed from sandstones etc. (S)

Sandy clays hardening on drying (P)

All these soils are Class 6, unsuitable for irrigation, on account of salinity, alkalinity, low water-holding capacity etc.

ACREAGES OF IRRIGABLE LAND IN THE LOWER RUFIJI VALLEY

Table 9 gives the acreages of the six Land Classes in the Lower Rufiji Valley. The figure for "irrigable land" comprises Classes 1 to 4. Classes 5 and 6 are considered as non-irrigable.

In measuring the area of each class most of the saline soils of the delta and most of the sandy non-alluvial soils bordering the valley were excluded since these soils are of no value for irrigation and since the area of these soils shown on the soil map gives no indication of their actual extent.

From the isohyets shown on the Land Suitability Map it will be seen that the soils of Sheet 1 receive 30 inches of rain a year or less. On Sheet 2 the rainfall ranges from about 30 inches in the west to 40 inches in the east. On Sheet 3 the rainfall is over 40 inches. The positions of the isohyets are approximate only and in any case are average figures and variations will occur from year to year.

Table 9. Acreages of land of the different suitability classes in the Lower Rufiji Valley

	Sheet 1	Sheet 2	Sheet 3	Total of each class acres	%
Class 1, acres	61,100	78,000	39,600	178,700	42.8
Class 2, acres	1,600	8,700	95,100	105,400	25.3
Class 3, acres	-	-	-	-	-
Class 4, acres	-	-	5,000	5,000	1.2
Class 5, acres	20,900	6,100	1,900	28,900	6.9
Class 6, acres	45,500	23,800	29,900	99,200	23.8
Water	18,500	10,200	5,600	34,300	-
Suitable for irrigation, acres	62,700	86,700	139,700	289,100	69.3
Unsuitable for irrigation, acres	66,400	29,900	31,800	128,100	30.7
Total land area, acres	129,100	116,600	171,500	417,200	100.0

For Usangu and the Kilombero the acreages of the individual soils, as distinguished on the soil maps, have not been calculated owing to the large amount of labour which this would have entailed. These figures were, however, obtained for the Lower Rufiji and are given below. The saline soils of the delta, the sandy soils formed from sandstones and beach sands and the sandy clays hardening on drying are not included.

Table 10. Acreages of the various soils in the Lower Rufiji Valley

	acres
Coarse sands of river beds (M)	36,600
Sandy soils of river banks (B)	101,800
Loams and heavier soils of river banks (Bc)	8,800
Alluvial clay (K)	179,900
Alluvial clay with colluvial material (Ks)	5,300
Alluvial clay overlying sedentary sand (KS)	1,300
Alluvial clay overlying coarse sand (KM)	23,400
Mbaragwila (B) overlying coarse sand (BM)	11,300
Alluvial clay overlying mbaragwila (KB)	14,500
Complex of K and B	900

DEVELOPMENT OF IRRIGATION IN THE LOWER RUFIJI

In wet years practically the whole of the irrigable land in the Lower Rufiji is flooded. The present population depend on the natural flooding for their rice and cotton crops and prevention of flooding would destroy their agricultural system. Irrigation in the Lower Rufiji is therefore all or nothing.

Control and storage would be obtained by a dam at Stiegler's Gorge (see Volume III of this Report). Irrigation would be most appreciated in the low rainfall zone in the upper part of the valley but here the population is low. On the delta there is a high population but, with over 40 inches of rain a year, little demand for irrigation.

A fairly compact area of irrigable land exists between Kwangwazi and Mtanza. From Logo-Logo downstream the irrigable land is practically continuous.

PAWAGA

INTRODUCTION AND MAIN FEATURES

The area covered by the Pawaga soil reconnaissance map includes the lower reaches of the Little Ruaha River and the valley of the Great Ruaha River from just above its confluence with the Little Ruaha to its confluence with the Kisigo River. The writer visited the area in 1957 but lack of time prevented him from making any general reconnaissance. The soil map and most of the soil descriptions have been produced by C.A. Waldron, of the Tanganyika Department of Agriculture.

The flood plain of the Great Ruaha is about 2 miles wide above its confluence with the Little Ruaha but increases to about 7 miles wide at the confluence and for a few miles below. There is no definite point at which the two rivers meet. The Little Ruaha splits up into a number of channels and loses its individuality before reaching the Great Ruaha.

Below the area of confluence of the Little and Great Ruaha the flood plain gradually decreases in width to under 2 miles but increases again where the Kisigo River comes in from the west. The width here is not known as the northern boundary has not been determined.

The ground rises gently from each side of the flood plain. On the south-east this gentle rise ends in a steep escarpment rising to the Uhehe highlands. On the north-west side of the valley the rise leads to rather featureless undulating country at no great altitude above the valley floor.

The Great and Little Ruaha are permanent rivers. The Kisigo drains a dry part of Tanganyika and is only seasonal.

After its junction with the Kisigo the Great Ruaha turns east and enters a gorge at Mtera, a few miles further downstream. To the north of the river between the Kisigo and Mtera there is a tract of flat country called the Logi (or Chipogoro) plain. This plain extends about 20 miles northwards from the river and is about 12 miles wide at its southern end but rapidly diminishes to about 8 miles wide further north. The plain is traversed from north to south by the seasonal rivers the Bubu and the Fufu which drain an area with a 20 inch or less annual rainfall.

Time did not permit any examination of the Logi plain. It seems probable that there will be a considerable extent of alkaline and saline soils on the plain, as there are in the Pawaga area, but some investigation to confirm this purely theoretical deduction is desirable.

GEOLOGY

In the Uhenge highlands to the south-east of Pawaga and in the country to the north-west of the area there are predominantly foliated granitic rocks, with dyke rocks which are mostly dolerites and pyroxene appinites (E.G. Haldemann, verbal communication). The soils of the lower slopes bordering the flood plain are probably developed from colluvial material but this is in turn derived from the rocks outcropping further up the slope. On the low hills in the valley, such as that on which Kimande stands, the soils appear to be directly derived from the same granitic and dyke rocks, judging from outcrops of each which are visible at Kimande. The alluvium of the flood plain will be mainly derived from rocks in the higher reaches of the Little and Great Ruaha Rivers.

CLIMATE

Pawaga lies in the rain shadow of the Uhehe highlands and suffers a low and erratic annual rainfall. The average at Kimande is 16 inches but this has varied in 10 years of records between 7.34 and 22.54 inches. This rain falls in the period December to April.

The altitude of the Pawaga plain is only 2,300 feet above sea level and high temperatures prevail, particularly in the period October to December. There are no temperature records from Pawaga but readings have been made at Mtera, just outside the area, for 2 years. In this time 98°F has been recorded on several occasions and 99°F once.

ALLUVIAL SOILS

Waldron has divided the alluvial soils into two groups, the Recent Alluvial Soils and the Old Alluvial Soils. The present vegetation was the basis of this division. The "Recent" soils support a fairly good vegetative cover, with numerous well-grown Acacias and evergreens. On the "Old" soils the vegetation is sparser and consists largely of stunted Acacias and halophytes such as Salvadora persica.

Recent Alluvial Soils

These occupy belts one to two miles wide along the present courses of the Great and Little Ruaha Rivers. At the junction of these rivers there is a widening to an area about 5 miles wide and 7 miles long. There is another widening at the confluence of the Kisigo and Great Ruaha Rivers but only part of this area is covered by the soil map.

The recent alluvium consists of a complex of soils with textures ranging from sand to clay. The sand occurs as long narrow strips, often standing one to two feet above the surrounding land, as in Usangu and the Kilombero Valley. No analyses are available but the soils are almost certainly similar to the alluvial sands, sandy loams, loams and recent clays of Usangu and the Kilombero.

A rather badly-organised irrigation scheme exists at Kimande. Rice is grown under natural flooding, with supplementary irrigation from a furrow when required. A new scheme is now being planned by the Water Development and Irrigation Department. This will be further up the Little Ruaha. Crops other than rice are grown in the vicinity of Kimande and Isere on higher sites not subject to flooding, or only occasionally flooded. The higher sites tend to have the sandier soils. Patches of Acacia forest, again usually on the higher sites in the alluvium, supply timber and shade in what is on the whole an arid and inhospitable tract of country.

Control of the Little Ruaha would produce a considerable area of land suitable for irrigation but in the absence of a topographic survey it is impossible to furnish any estimate of just how much. Probably control of the Little Ruaha would free less than half the total area of recent alluvium from floods and the Great Ruaha would also have to be controlled to free the remainder.

Even when freed from floods a proportion of this recent alluvium will be too sandy, or too dissected by old channels, for irrigation. The remainder, and greater part, will be very suitable and is the best land in the area covered by the soil map.

Older Alluvial Soils

Nearly all the older alluvial soils lie on the left (west) bank of the Great Ruaha. Waldron, basing his opinion on the vegetation, considers that the soils are probably saline. The soils are generally clays and sandy clays and gave him more the impression of "Plains Soils" or "Hardpan soils" than alluvium. They are more compacted and intractable than those of the "Recent" alluvium. In the absence of any further information it is impossible to assess these soils with any certainty. They will almost certainly require reclamation.

The topography is level and favourable but the land is much dissected by old water-courses.

NON-ALLUVIAL SOILS

Red and brown sands and sandy loams

Light brown and grey sands and sandy loams

These sandy soils are found on the hill slopes bordering the valley and on isolated low hills within it, the soil being formed from the underlying granitic rock. In places some movement of the soil may have taken place but the soil is always somewhat raised above its surroundings. The red and brown soils occur on the better-drained sites and the light brown and grey soils where the drainage is poor.

The fertility of these soils is probably low but no profiles have been examined or samples analysed. The red and brown soils are likely to be the more fertile but are on higher ground and so topographically unsuited to irrigation. The light brown and grey soils are more likely to be under command by the irrigation water but will be the poorer soils and are likely to be affected by salt and alkali in places.

These soils cannot be considered as suitable for irrigation. Waldron considers that they are best utilised for grazing. Where topography allows, water spreading might be introduced to improve the grass growth.

Dark grey clays with some admixture of coarse sand

Waldron describes these soils as dark grey to almost black compact clays, with often a fair amount of quartz particles but not sufficient to justify the term "sandy clay". They may have been alluvial in origin but if so have been considerably altered since formation.

The soils generally occur at the foot of slopes, just above the alluvium. With one small exception this soil is all in a strip on the right bank of the Ruaha, stretching for about 15 miles downstream from Kimande.

Samples from several profiles examined by Waldron were analysed by the Government Chemist in 1958. All these soils showed excessive salinity and many were alkaline as well. As might be expected, the worse soils are those lower down the slope. Figures for two of the profiles are given in Table 11. Pit II represents the saline/alkali soils and pit XI the less alkaline but still saline soils from higher up the slope.

Table 11. Conductivity and exchangeable sodium percentages (ESP) for two clay profiles in the Pawaga area

Depth (inches)	pH	Conductv. of S.E. m.mho/cm.	$CaCO_3$	Exch. capacity m.e.%	Exch. sodium m.e.%	ESP
Pit II						
0 - 12	8.0	5	slight	59	21.8	37
12 - 24	8.0	14	"	80	22.3	28
24 - 36	8.2	11	"	79	23.1	29
36 - 48	8.7	10	"	63	21.7	34
Pit XI						
0 - 24	8.4	0.5	slight	31.3	0.9	3
24 - 34	8.7	0.8	"	30.9	3.6	12
34 - 46	7.6	8	"	30.0	4.8	16
46 - 58	7.8	9	"	30.4	5.8	19

The soils contain calcium carbonate and could theoretically be reclaimed by leaching alone. With their high clay content this leaching would be a slow process, particularly for soils like pit II with a high exchangeable sodium. The higher-lying soils such as pit XI only require the removal of soluble salts and are slightly sandier in texture; they could be more easily reclaimed. The proportion of the less alkaline soils in the group as a whole would have to be determined before any recommendations could be made.

Topographically these soils, which lie on a slight slope and are above the Ruaha flood level, are well suited to irrigation though the cross-drainage of water running off the Southern Highlands escarpment to the south-east will create engineering problems. With their high clay content, however, they will never be easy soils to work. Their present fertility status is probably low, owing to their poor vegetation cover and to overgrazing, and would require building-up before the soils would give good results. Owing to the unproven possibility of reclamation these soils must be classified as class V land.

Light brown and grey sandy clays

These light-coloured sandy clays are a common soil in the area examined. Sometimes they are overlain by a shallow layer of sandier material (a red, brown or grey sand or sandy loam); also soils intermediate in texture between these sandy clays and grey sandy loams (BG on the map) are fairly common. These soils are probably alluvial in origin and lie below the sands and sandy loams on the slopes and above the clays at the foot of the slope.

The profile described below was examined and sampled by the writer in 1957 and was one of six in a 500-acre plot about half a mile to the east of Kimande. This area is shown as B1/A on the map but the dark clay (A) was not reached in any of the pits. The soil is illustrated in figs. 33 and 34.

PROFILE 235

Location	About ½ mile south of Kimande.
Parent material	Alluvium.
Topography	Flood plain. Flat with minor undulations (? gilgai)
Drainage	Very poor. Site subject to flooding.
Vegetation	Dense thornbush, chiefly Acacia kirkii. Much bare ground between and under the trees.
0 - 15 cm.	Grey clay loam (10 YR 5/1, moist). Strong, medium sub-angular blocky; hard when dry. Few pores. Grading into:-
15 - 35 cm.	Grey clay (10 YR 5/1, moist). Coarse subangular blocky; very hard when dry. Grading into:-
35 - 100 cm.	Grey clay (10 YR 5/1, moist). Weak, coarse subangular blocky to massive; very hard and compact. A few white concretions. Grading into:-
100 - 170 cm.	Grey clay (10 YR 5/1, moist) with a little strong brown staining along roots. Massive and compact; very hard. Common white concretions (not calcareous, perhaps gypsum). Grading into:-
170 - 190 cm.	Light grey clay (10 YR 6/1, moist) with common fine pale brown mottles. Weak, fine subangular blocky; compact and hard. White concretions as in preceding horizon.

Most of the six profiles sampled were both saline and alkaline (see analysis of profile 235 in table 15). The salt is the more serious and in profile 235 is present in harmful amounts from 35 cm. depth downwards; the exchangeable sodium exceeds 15 per cent of the total cations at 170 cm. depth. The soil has very little organic matter (0.6%) but a fairly good available phosphorus. Calcium and potassium are adequate. There is calcium carbonate throughout the profile and leaching would improve the soil; but with 50 per cent clay and about 10 per cent sodium in most of the profile the rate of leaching would be very low.

Profile 232 (table 15) was the best of the six profiles and this soil was used occasionally by the local people for rice-growing. The soil is slightly lighter in texture (30% clay) and contains no harmful amounts of sodium or of salts. Organic matter is still very low (0.85%).

A proper evaluation of this soil would need a much more extensive network of samples. But on the evidence available most of the area marked B1 on the map is affected by salts and by alkali in the subsoil; the soil is very impermeable and improvement of the soil would be a slow process. Even after leaching the soil will be intractable until the organic matter has been built up.

To the north of the Great Ruaha there is a considerable area of light-coloured sandy clay shown as "B" by Waldron, i.e. not obviously affected by salt or alkali. If this estimate is correct, these soils should be better than those near Kimande but there are no analyses to confirm this.

There is a fairly common variant of these sandy clays which Waldron describes as "a grey to light grey sandy clay with often a dense covering of quartz stones on the surface and within the top 12 inches. The stones are subangular and up to 5 inches across". A pit near Kimande was examined by the writer in 1957. The stones suggested that the soil was sedentary or only partly colluvial. At Kimande the soil occurred on the lower slopes of a low hill capped by sandy loams. The rocks outcropping appeared to include both the granitic and the dyke rocks and the difference in texture between the sandy loams and the sandy clays might be the result of differences in parent rock. More likely, however, the difference is due to a catenary development with perhaps some movement of clay particles from the sandy loams to the sandy clays below them.

These soils are all shown as B 1 S by Waldron implying that they are saline. This is confirmed for the profile at Kimande (profile 236, see table 15) which is saline from 30 cm. downwards and alkaline from about 100 cm. downwards.

To summarise, on the evidence available most of these light brown and grey sandy clays require some measure of reclamation. Even when reclaimed they will be difficult to work unless the organic matter can be increased. Experiments would be required to discover whether reclamation would be economic and in the meantime the soils must be considered class V land.

Brown and red-brown sandy clays

No analyses are available for these sandy clays but Waldron considers they are likely to be less affected by salinity than the light brown and grey sandy clays. This estimate is based on the vegetative cover, which includes fewer halophytes than that on the lighter-coloured soils. No assessment of their potentiality can be made until some samples have been examined.

Sandy clay loams

These are indicated on the map by the symbol DC. Again no analyses are available but the soils are less likely to be affected by salt and alkali than the sandy clays. They have, moreover, a more favourable texture if leaching is required.

The soil usually lies on gentle slopes and is thus suitable topographically for irrigation. Though rather high above the valley floor it could be commanded from the Little Ruaha River. The numerous drainage lines and gullies running across occurrences of this soil will be a complication in laying out an irrigation scheme.

Once again, no assessment of irrigation potentiality can be made until some analyses become available.

METHODS USED IN THE EXAMINATION AND ANALYSIS OF THE SOILS

Profile descriptions

The meanings of the terms used in the soil profile descriptions are those of the U.S. Soil Survey Manual (1951). The colour names and symbols are those of the Munsell Colour Charts. Textures are judged by the feel of the moist soil in the field. The terms used to describe the extent of mottling are as follows:-

few - less than 2 per cent of total surface.

common - between 2 and 20 per cent of total surface.

many - over 20 per cent of total surface.

For describing the size of individual mottles the terms are:-

fine - less than 5 mm. in diameter.

medium - between 5 and 15 mm in diameter.

coarse - over 15 mm in diameter.

For other terms the reader is referred to the U.S. Soil Survey Manual.

Methods of analysis

pH value

Determined with a glass electrode on a 1:2.5 suspension of the soil in water. The suspension is allowed to stand for one hour, with occasional stirring, before measurement.

Organic carbon

Walkley and Black's wet oxidation method. A correction factor, assuming 80 per cent recovery, is applied.

Total Nitrogen

By Kjeldahl digestion, with selenium as catalyst. The clays are given a preliminary soaking in distilled water, according to Bal's modification of the method.

Available phosphorus

By extraction with 0.3 normal hydrochloric acid. A 1:2.5 mixture of soil and acid is shaken for 2 to 3 minutes and then filtered. The phosphorus in the filtrat is determined colorimetrically. The result is only a rough indication of the avail able phosphorus but other simple methods have not been shown to be better.

Exchangeable cations

The soil is extracted with normal ammonium acetate having a pH of 7.0. 250 ml. of extractant are used for 10 g. of the heavier soils or 20 g. of the sandier soils. If salts are present in the soil these are removed by washing with 40 per cent alcohol before extraction. In the solution obtained by the extraction calcium and magnesium are determined by precipitation with ammonium oxalate and 8-hydroxyquinoline, respectively manganese by oxidation with periodate and sodium and potassium with an EEL flame photometer.

The cation exchange capacity is determined by distillation of a suspension of the ammonium-saturated soil with magnesium oxide. This gives satisfactory results with kaolinitic soils but gave too low a result with some of the Rufiji Basin soils, probably because of fixation of the ammonium ions within the lattice of the clay. This is one possible reason for the total cations often exceeding the exchange capacity. The other is that the capacity was determined on the soil saturated with ammonium at pH 7.0, whereas the total cations were extracted from the soil at its original pH, which was often higher than 7.0. The exchange capacity at pH 7 is less than that at pH 8, for example.

In the case of calcareous soils, calcium and magnesium were extracted with normal sodium chloride, using two successive extractions and subtracting the figures obtained for the second extraction from those for the first.

The percentage saturation is, of course, the proportion of the exchange capacity which is occupied by the metallic cations.

It was not possible to complete the exchangeable cation determinations on all the soils in time for this report but it is not thought that the missing figures, when obtained, will affect any of the conclusions reached.

Stones and Gravel

This is the material retained by a 2mm. sieve, after removal of organic material. All determination other than "stones and gravel" is done on the material passing the 2 mm sieve. The soil is lightly pounded before sieving to break up soil clods. The softer iron and calcium carbonate concretions get broken up in the process but the harder ones are included in "stones and gravel".

Mechanical Analysis

The International Pipette Method is used. The particle-size grading is thus:-

Coarse sand	2 - 0.2 mm.	apparent	diameter
Fine sand	0.2 - 0.02 mm.	"	"
Silt	0.02 - 0.002 mm.	"	"
Clay	less than 0.002 mm.	"	"

The figures are expressed as percentages of the air-dry soil. Dispersion is obtained by 6 hours shaking of the soil with sodium oxalate solution. Occasionally, as in the lower horizons of profile 253, this fails to secure dispersion, apparently due to light cementation with iron oxides. In such cases the silt and clay are separated by repeated sedimentation and pouring off the remaining suspension, with sodium carbonate for dispersion. In between successive sedimentations the soil is rubbed with a brush.

Calcium carbonate is determined by volumetric measurement of the CO_2 evolved on adding acid. A Collins' Calcimeter was used.

Conductivity

In all samples the conductivity of a 1:5 suspension in water is first determined as a sorting test. If a high value is obtained the conductivity of the saturation extract is then determined. The figure is expressed as millimhos per centimetre at $25^{o}C$.

GLOSSARY

Catena

Between the crest of a hill and the valley bottom there is often a succession of soils, each being affected in some way by those above it and in turn affecting those below it. This succession usually repeats itself on all similar slopes over a considerable area, so long as geological, climatic and other factors remain the same. Such a succession is known as a catena.

Cations

These are electropositive ions occurring in soil solutions and attached to soil colloids. The term "exchangeable cations" refers to those attached to the colloids and has a similar meaning to the older term "exchangeable bases" but includes exchangeable hydrogen ions.

Exchangeable sodium percentage (ESP)

This is the exchangeable sodium of a soil, expressed as a percentage of the total exchangeable cations. In this report, following the recommendations of the U.S. Soil Salinity Laboratory, soils with an ESP of over 15 are considered to be alkali soils.

Gilgai Relief

This is a term describing a form of micro-relief which sometimes occurs in clay soils subject to periodic wetting and drying. In the form in which it was seen in Usangu and the Kilombero Valley it consists of numerous roughly circular depressions, several feet in diameter. These depressions are separated by a network of ridges, giving a honeycomb pattern in plan. The height of the ridges above the bottoms of the hollows varies from a few inches to a foot or so.

Libaragwila

This term is used by the Warufiji (the inhabitants of the Lower Rufiji Valley) to describe recent deposits of micaceous fine sand and silt left by the river when in flood. It contains many unweathered mineral particles and is very fertile.

Miombo

This is a light deciduous woodland dominated by trees of the genus Brachystegia. There is a ground flora of grass and herbs which is burnt in the dry season. Wherever it is mentioned in this report the miombo had the tree B. longifolia as the dominant species. Brachystegia boehmii was sometimes associated with the B. longifolia.

Pediment

Weathering processes in dry climates produce hills, or ranges of hills, with relatively steep upper and middle slopes but with a sharp change below this to a long gentle descent to the valley bottom. The effect is similar to that of an inverted cup standing on an inverted saucer. The saucer is the pediment. The pediment is often somewhat dissected by water-courses originating on the steeper slopes and running across the pediment more or less radially with respect to the hill.

A SUMMARY OF THE PHYSICAL PROPERTIES OF SOILS AT FOUR LOCALITIES IN THE RUFIJI BASIN

as measured by the Physics Division of E.A.A.F.R.O.

Reconnaissance samplings were taken to check the suitability of soil types described by Mr. B. Anderson. In most cases the cores were taken from the pits whose profiles he has described in detail.

Lower Rufiji

Mtanza (Near Utete)

The very complex pattern of heavy soils and coarse sands included some areas of soils good for rice growing, as was demonstrated by local practice and confirmed from core studies. There were, however, shallow horizons of tight clay associated with heavily channelled coarse sands, indicating strong lateral drainage. Since this would present difficulties in irrigation and render the area unsuitable for the quantitative watering studies for which it had been selected, these soils were not further investigated.

Bohoro Flats

Rujewa Trial Farm

Urunda Pilot Plot (Bohoro No. 2) 1956

Pit No.	Depth	Percolation Rates (Inches per hour through 3-inch cores under 1/2 inch static head)	Moisture Content at Field Capacity (% oven dry wt. at 1/3 atm. tension)	Maximum Moisture Content (% oven dry wt. at 20 cm. tension)
I	0-3 in.	0.8 Fair	31	37
	At 3 ft.	5.3 Good	41	46
	Bare soil, with some ephemeral grasses; overgrazed. The surface soil is a sandy silt over a subsoil of uniform silt loam, interrupted by horizons of coarse sand. The whole profile is freely drained with many root channels. Suitable for citrus and for many annual crops. Unsuitable for rice.			
II	0-3 in.	4.6 Good	37	46
	At 3 ft.	2.8 Good	40	44
	Overgrazed bare soil near dry riverbed. Silty clay loam with horizons of sand and fine gravel. Freely drained throughout. Crops as for I.			
III	0-3 in.	0.1 Poor	32	43
	At 3 ft.	2.6 Good	23	34
	At 4 ft. 6 in.	4.3 Good	29	35

Under heavy grass cover, overgrazed and trampled. 15 inches of silty clay,

Pit No.	Depth	Percolation Rates (Inches per hour through 3-inch cores under 1/2 inch static head)	Moisture Content at Field Capacity (% oven dry wt. at 1/3 atm. tension)	Maximum Moisture Content (% oven dry wt. at 20 cm. tension)
III cont.	severely puddled by cattle, overlying 20 inches of silty fine sand with orange mottlings. Below this there is tough cracking brown clay. A possible rice soil, but drainage will be rather high. Cropping and tillage will need care to avoid puddling.			
IV	0-3 in.	1.9 Fair	32	39
	At 1 ft. 6 in.	0.6 Fair	12	16
	At 2 ft. 6 in.	0.3 Poor	15	18
	Under vigorous 6 ft. tall Chloris gayana and Sorghum verticilliflorum Stapf. Six inches of heavy plastic grey-brown clay over 2 ft. of a stiff sandy loam containing much unweathered coarse grit. This soil is of high potential value for field crops other than rice; crop sequence will need care to maintain surface infiltration rates.			
V	0-3 in.	0.6 Fair	36	38
	At 3 ft.	0.3 Poor	22	24
	Under vigorous grasses (6 ft. tall Hyparrhenia sp., Sorghum sp. and Chloris gayana). A uniform brown clay freely penetrated by roots for the 6 ft. seen. This soil type is very suitable for rice and appears favourable for cotton.			

Mbarali Irrigation Scheme

Three soil types, selected by Mr. Brian Anderson, were core-sampled:-

I. Neutral Clays

II. Grey-Brown Loams

III. Alkaline Clays

I. "Neutral Clays" (Profiles 214 and 219). These are variable stratified heavy grey loams or sandy loams overlying compact mottled sandy clays. Aeration is rather poor, roots penetrated only 2 to 3 feet; but percolation rates are quite adequate to 6 ft. Surface infiltration rates are high. The profiles are not saline but sodium values begin to reach harmful levels at 5 ft. A wide range of soil properties were observed between the profiles of this soil type.

Depth of Soil Horizon	% Total sand	% Clay + Silt	Bulk Density (Kg/litre)	Free Draining Pore Space (% Total Volume)	Percolation Rates (in Inches/hour)	Storage Capacity for available water (Field Cap. to Wilt. Point)(0.3 atm. to 15 atm. tension).
0 - 6"	22 to 52	44 - 71	0.95 - 1.46	5 - 20	9 to 17	0-3 ft. 2½ to 3 ins.
6" - 1'6"	27 to 61	36 - 57	1.25 - 1.45	4 - 17	7 to 9	
1'6" - 3'3"	38 to 63	31 - 67	1.32 - 1.51	9 - 12	4 to 5	3-6 ft. 2 to 3½ ins.
3'3" - 6'3"	46 to 64	37 - 52	1.18 - 1.68	4 - 11	0.6 to 3.7	

Effects of Cattle Trampling. Profile 214 was taken in an area heavily trampled by cattle while Profile 219 was in soil having little or no trampling.

Rainfall Test. Applying a severe artificial storm of 1 inch of rain in 6 mm. drops in 10 minutes, while drainage tension was maintained in the cores, gave the substantial differences shown below. Percolation rates were also strongly effected, but the sandy topsoil retained effective transmission rates even after trampling. This soil will lose its infiltration rates rapidly if unskilfully handled.

	Little Trampling	Heavy Trampling
Mean Rainfall Acceptance	77%	53%
Mean Percolation (0-3 in. cores)	17.5 ins/hr.	9.2 ins/hr.

11. "Grey-Brown Loam" (Profile 217). The most important soil for irrigation in this area. This shows some granular structure from plant root effects in the first foot, and some mottling in the first 3 feet. From 3 to 6 feet it is darker, structureless and compact. Analytical data from the T.A.C. laboratories at Nachingwea show no dangerous levels of sodium or salinity in the first 4 – 5 feet. Below this there is an increasing presence of sodium ions. Infiltration rates are adequate for irrigation. Aeration is fair and roots were observed to a depth of 5 feet.

Depth of Soil Horizon.	% Total Sand	% Silt + Clay	Bulk Density (Kg/litre)	Free Draining Pore Space (% Total Volume)	Percolation Rate (Inches/hour)	Stored Water available to crops (in inches)		
							1 Day after Irrigation (50 cm. tension)	4-5 Days after Irrigation (1/3 atm. tension)
0-5 in.	29	66	1.27	10.1	5.2	0-3 ft	3.6	2.8
5 in. - 2 ft.	16	80	1.19	11.0	3.3			
2 ft. - 5 ft.	23	74	1.28	7.5	2.0	3-6 ft	4.4	3.6
5 ft. - 6 ft.	46	51	1.46	4.7	0.4			

Rainfall acceptance varied from fair to poor (60% to 30% acceptance of a 1-inch "storm" falling in 10 minutes.)

111. "Alkaline Clay" (Profiles 218 and 221) Variable stratified grey and brown clays and clay-loams over massive alkaline sandy clays. Root penetration poor and vegetation not vigorous.

Depth of Soil Horizon.	% Total Sand	% Silt + Clay	Bulk Density (Kg/litre)		Free Draining Pore Space (% Total Volume)		Percolation Rates (in Inches/Hour)		Storage Capacity for available water at Field Capacity (1/3 atm.)
			218	221	218	221	218	221	
0 - 1 ft.	10-56	39-83	1.07	1.41	14	12	4.5	4.3)	0-3 ft. 2½ ins.approx
1 - 3 ft.	25-54	42-69	1.73	1.43	8	8	0.5	2.6)	
3 - 5 ft.	-	-	1.49	1.24	5	8	4.0	1.7)	3-6 ft. 2½ ins.approx
5 - 6 ft.	64	33	1.42	1.41	6	4	0.4	0.8)	

These clays have poor rainfall acceptance at the surface.

General Conclusions. Where sodium values are low enough to permit safe development the infiltration and percolation values will not be limiting factors in irrigation.

All of these soils tend to set very hard when dry. The high proportion of fine sand tends to give low surface infiltration rates when puddled, and some of the area will need skilful farming. The areas with sandy topsoils will, however, be easy to irrigate. Control of irrigation rates to avoid a rise in water table from alkaline subsoils may be critical, but the area is well supplied with drainage channels. The cheap and simple radiation integrator is the best available indicating device for this control.

With losses due to sand-beds, and the rather long minor canals which may be required to bring water to the areas of better soil, distribution losses will tend to be high. After further study of the catchment areas, and a recent air observation of increased cattle damage in the Chimala catchment, I still consider that this scheme will be limited by dry weather flows rather than by any soil difficulties.

Western Bohoro Flats (North of Utengule Village)

Site A. (U.3). 7 miles N.E. of Utengule. Highly impervious silty clay-loam, rock-hard when dry and very difficult to wet, even under vacuum. Surface showed extremely low rates of acceptance of heavy rainfall.

Site B. (U.4). 9 miles N.E. of Utengule. This soil is very similar to that of Site A, but has a slightly higher water retention value and rather better rainfall acceptance. It is very impervious.

Mean Values for core measurements.

Depth	Moisture Content at Field Capacity (% over dry wt. at 1/3 atm. tension)	Inches available water between Field Capacity and Wilting Point (1/3 and 15 atm.)
0 - 6 inches	32.8	1.18
6 in. - 1 ft. 6 in.	30.9	1.37
1 ft. 6 in. - 2 ft. 6 in.	28.9	1.24
2 ft. 6 in. - 3 ft. 6 in.	27.0	1.86
Total in 3½ feet.		5.65 inches

These soils are physically suitable for skilful rice cultivation. Local tribesmen are already growing over 2,000 acres of rice using extremely primitive techniques and very low seeding rates.

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TABLE 12 - ANALYSES OF SOILS FROM THE USANGU PLAIN

Pro-file No.	Horizon cm.	pH	Organic C %	Total N %	C/N	Avail. P. mg. %	Exchangeable cations m.e./100 g. soil: Ca	Mg	Mn	K	Na	Total	Capacity	Satn. %	Stones and gravel %	Mechanical Analysis. % of fine earth fraction: Coarse sand	Fine sand	Silt	Clay	Moisture	$CaCO_3$	Conductivity: 1:5 ext. m-mhos	Satn. ext. m-mhos	Lab. No.
ALLUVIAL SAND																								
P220	0-15	7.0	0.42	0.038	11	1.9	3.8	2.0	tr.	0.23	0.11	8.0	6.0	100	0.6	54.1	27.2	6.3	9.5	1.2	nil	0.016	-	N1441
	15-35	7.3	0.35	0.022	16	1.7	5.1	2.7	nil	0.11	0.18	9.8	8.9	100	0.3	55.8	20.5	6.5	13.6	2.0	nil	0.013	-	1442
	35-90	7.6	0.12	-	-	4.3	4.0	1.8	tr.	0.09	0.17	9.4	6.5	100	2.5	70.7	17.2	3.5	6.9	1.1	nil	0.017	-	1443
	90-120	8.9	0.00	-	-	2.0	1.8	0.3	tr.	0.02	0.07	2.2	1.5	100	9.5	96.2	2.9	0.3	0.6	0.3	nil	0.034	-	1444
P243	0-15	7.3	0.62	0.054	11	14.0	6.8	1.5	0.04	2.1	0.3	10.7	11.3	95	0.2	9.4	68.6	10.8	8.7	2.1	nil	0.025	-	N1829
	15-40	7.6	0.42	0.041	10	13.5	5.9	2.7	0.01	2.3	2.3	13.2	11.4	100	0.1	-	-	-	-	-	0.04	0.027	-	1830
	40-70	8.0	0.26	-	-	16.8	-	-	-	-	-	-	-	-	3.8	-	-	-	-	-	nil	0.026	-	1831
	70-102	8.8	0.09	-	-	11.0	2.3	0.4	0.02	1.2	1.1	5.0	4.2	100	0.0	11.4	73.1	11.0	3.4	1.0	nil	0.030	-	1832
	102-127	9.2	-	-	-	6.5	4.4	0.6	n.d.	3.9	6.8	15.7	15.3	100	0.7	5.1	42.9	27.0	20.9	3.4	0.12	0.134	1.3	1833
	127-160	9.4	-	-	-	2.8	-	-	-	-	-	-	-	-	37.9	-	-	-	-	-	0.03	0.065	-	1834
	160-200	8.9	-	-	-	2.0	8.8	1.8	0.00	1.7	18.7	31.0	17.1	100	0.0	4.9	23.2	34.8	29.8	4.2	nil	0.109	-	1835
ALLUVIAL SANDY LOAM																								
P225	0-15	6.5	0.73	0.072	10	1.0	6.6	3.5	0.18	0.47	0.30	11.1	12.4	90	0.0	32.8	27.2	15.5	21.9	2.5	nil	0.041	-	N1552
	15-30	6.9	0.64	0.051	13	1.1	-	-	-	-	-	-	-	-	0.0	32.0	26.1	7.5	31.3	3.0	nil	0.034	-	1553
	30-60	6.7	0.23	0.030	8	1.3	6.0	6.5	0.06	0.10	0.24	12.9	9.5	100	0.0	42.9	29.7	8.8	16.0	2.1	nil	0.031	-	1554
	60-88	6.9	0.03	-	-	1.4	-	-	-	-	-	-	-	-	0.0	51.6	29.8	6.3	9.9	1.5	nil	0.039	-	1555
	88-140	7.3	0.28	0.022	13	1.1	9.5	5.9	0.04	0.14	1.55	17.1	14.9	100	0.0	28.3	15.3	19.3	29.8	3.6	nil	0.087	-	1556
	140-190	8.1	-	-	-	1.1	-	-	-	-	-	-	-	-		Similar to horizon 88-140 cm.						0.084	-	1557
	240-300	7.4	-	-	-	1.3	13.9	9.9	0.03	0.66	4.6	29.1	31.9	91	0.0	0.7	6.7	22.8	66.2	7.9	nil	0.194	-	1558
P247	0-20	6.8	1.57	0.155	10	2.5	6.8	4.4	0.15	1.18	0.43	13.0	12.5	100	0.0	5.7	37.0	27.5	23.4	2.2	nil	0.054	-	N1934
	20-50	7.1	0.62	0.078	8	0.3	5.8	4.2	0.02	0.42	0.37	10.8	9.8	100	0.0	-	-	-	-	-	nil	0.037	-	1935
	50-80	7.3	0.64	-	-	0.7	-	-	-	-	-	-	-	-	0.0	12.0	47.0	17.0	18.5	1.9	nil	0.065	-	1936
	80-100	8.4	0.28	-	-	0.4	6.4	2.4	0.04	0.45	3.1	12.4	8.7	100	0.0	-	-	-	-	-	nil	0.329	4.0	1937
	100-150	8.9	-	-	-	0.6	4.2	1.4	n.d.	0.48	11.1	17.2	11.1	100	0.0	0.4	15.4	43.5	33.1	2.9	0.14	0.684	8.3	1938
	150-200	9.5	-	-	-	0.5	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	0.11	0.947	9.7	1939
B5	0-30	6.6	1.27	0.099	13	1.3	8.3	3.1	0.10	0.65	0.3	12.5	14.2	88	0.0	2.0	36.1	30.8	26.5	2.6	nil	0.018	-	N1789
	30-60	6.7	0.87	-	-	1.5	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	nil	0.019	-	1790
	60-90	7.0	0.37	-	-	0.4	4.1	2.4	0.06	0.32	0.65	7.7	9.4	82	0.0	3.2	40.5	29.3	22.6	2.3	nil	0.021	-	1791
ALLUVIAL LOAM																								
P242	0-20	6.6	1.14	0.089	13	0.5	9.7	2.7	0.21	0.83	0.54	14.0	17.4	80	0.4	7.8	11.4	36.0	37.8	4.0	nil	0.034	-	N1823
	20-35	6.6	0.65	0.053	12	1.3	-	-	-	-	-	-	-	-	1.0	-	-	-	-	-	nil	0.035	-	1824
	35-45	6.9	0.22	0.018	12	10.8	4.6	1.1	0.06	0.19	0.50	7.5	7.3	100	3.2	34.9	43.5	7.5	11.9	1.9	nil	0.022	-	1825
	45-55	7.1	0.41	-	-	2.6	7.7	2.0	0.03	0.46	1.07	11.3	12.7	89	0.8	19.9	33.5	19.3	23.2	3.0	nil	0.042	-	1826
	55-75	7.1	-	-	-	1.5	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	nil	0.031	-	1827
	75-110	7.2	-	-	-	1.2	4.3	1.0	0.02	0.43	0.94	6.7	7.5	89	7.1	59.1	17.0	9.3	13.1	1.8	nil	0.036	-	1828
J7	0-15	5.9	1.84	0.154	12	0.40	12.5	5.0	0.26	0.87	0.93	19.6	23.4	84	0.0	4.1	17.1	23.8	51.8	4.9	nil	0.053	-	N2209
	15-40	5.9	0.39	0.055	7	0.40	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	nil	0.025	-	2210
	40-75	6.5	0.36	-	-	0.45	7.3	3.0	0.10	0.32	0.76	11.5	12.9	89	0.0	1.0	32.0	36.3	24.1	3.1	nil	0.031	-	2211
	75-105	7.5	-	-	-	1.05	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	nil	0.064	-	2212
	105-130	7.5	-	-	-	1.10	6.6	1.8	0.05	0.34	0.35	9.1	9.5	96	0.0	4.2	46.7	24.8	24.4	2.0	nil	0.037	-	2213
RECENT ALLUVIAL CLAY																								
M14	0-30	5.4	1.46	0.104	14	0.23	9.4	3.7	0.11	0.64	0.92	14.8	19.2	77	0.0	0.1	1.1	27.8	66.6	3.8	nil	0.039	-	N2158
	30-60	5.3	0.64	-	-	0.10	8.2	3.4	0.11	0.15	0.87	12.7	18.0	71	0.0	0.2	1.5	29.8	67.3	4.5	nil	0.037	-	2159
	60-90	5.6	-	-	-	0.10	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	nil	0.057	-	2160
M20	0-30	6.0	1.77	0.106	17	0.23	7.7	2.3	0.04	0.43	0.43	11.9	13.9	86	0.0	14.5	21.2	21.3	39.9	3.8	nil	0.035	-	N2176
	30-60	6.0	0.38	0.055	7	0.05	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	nil	0.041	-	2177
	60-90	7.1	0.32	-	-	0.10	13.2	2.6	n.d.	0.32	1.5	17.6	16.2	100	0.0	13.9	18.0	15.0	47.9	4.3	0.13	0.067	-	2178
	90-140	7.9	-	-	-	0.15	-	-	-	-	-	-	-	-	0.4	-	-	-	-	-	1.15	0.230	1.3	2179
	140-180	7.3	-	-	-	0.23	-	-	-	-	-	-	-	-	0.1	7.6	15.0	16.8	54.9	5.2	1.14	1.13	4.9	2180
	180-230	7.3	-	-	-	0.25	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-	0.35	0.699	-	2181
	230-260	7.4	-	-	-	0.12	17.7	1.5	0.03	0.45	0.52	20.2	14.8	100	0.0	1.3	1.0	22.0	70.1	6.0	nil	0.586	3.8	2182

TABLE 12 (CONTINUED) - ANALYSES OF SOILS FROM THE USANGU PLAIN

Profile No.	Horizon cm.	pH	Organic C %	Total N %	C/N	Avail. P mg. %	Exchangeable cations m.e./100 g. soil: Ca	Mg.	Mn	K	Na	Total	Capacity	Satn. %	Stones and gravel %	Mechanical Analysis. % of fine earth fraction: Coarse sand	Fine sand	Silt	Clay	Moisture	$CaCO_3$	Conductivity, 1:5 ext. m-mhos	Satn. ext. m-mhos	Lab No.
OLDER ALLUVIAL CLAYS																								
(a) Usually above flood level																								
P226	0–20	5.7	1.30	0.141	9	0.03	11.6	8.0	0.22	1.57	0.47	21.9	29.6	74	0.0	2.3	8.5	24.5	57.0	6.6	nil	0.036	-	N1599
	20–40	4.7	0.81	0.085	10	0.10	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.038	-	1600
	40–75	5.3	0.48	0.068	7	0.07	8.4	6.4	0.22	0.28	0.57	15.9	22.7	70	0.0	0.8	9.5	40.0	45.3	5.4	nil	0.039	-	1601
	75–130	6.1	0.46	-	-	0.15	-	-	-	-	-	-	-	-	0.0	Similar to horizon above						0.032	-	1602
	130–150	6.8	0.18	0.017	10	0.30	7.8	3.2	0.05	0.23	0.53	11.8	11.9	99	0.0	9.7	57.9	10.0	19.5	1.7	nil	0.029	-	1603
	150–200	6.7	-	-	-	0.32	-	-	-	-	-	-	-	-	0.0	15.5	69.5	3.5	9.3	1.4	nil	0.026	-	1604
	230–275	7.0	-	-	-	0.37	16.0	6.6	0.02	0.31	1.33	24.3	25.3	96	0.0	4.0	17.2	32.5	41.5	5.6	nil	0.058	-	1605
	275–305	7.1	-	-	-	0.52	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.056	-	1606
	305–350	8.0	-	-	-	1.05	16.4	7.4	0.02	0.34	1.55	25.7	24.1	100	0.0	5.0	39.2	14.3	37.9	5.3	nil	0.051	-	1607
P223	0–15	7.2	0.98	0.077	13	0.9	12.8	9.0	0.08	0.36	1.1	23.3	24.9	94	0.0	0.9	15.9	33.5	47.2	5.6	nil	0.054	-	N1542
	15–50	6.8	0.75	0.065	12	0.9	9.9	5.0	0.05	0.65	2.3	17.9	19.9	90	0.0	-	-	-	-	-	-	0.110	-	1543
	50–100	6.6	0.47	-	-	0.8	16.2	9.8	0.03	0.63	2.5	29.2	36.9	79	0.0	2.2	10.6	21.5	59.8	7.1	nil	0.283	2.4	1544
	100–150	7.3	0.45	-	-	1.3	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.241	-	1545
	150–190	7.1	-	-	-	1.5	14.7	11.8	0.03	0.70	3.8	31.0	33.0	94	0.0	2.7	11.6	19.0	60.0	7.2	nil	0.296	1.9	1546
B9	0–30	6.1	1.19	0.095	13	0.3	12.2	7.6	0.05	1.12	2.5	23.4	32.0	73	0.1	4.5	8.0	12.3	69.6	7.3	nil	0.039	-	N1750
	30–60	6.2	0.71	-	-	0.4	14.0	6.7	0.06	0.99	2.5	24.1	31.6	76	0.1	-	-	-	-	-	-	0.025	-	1751
	60–90	6.6	0.48	-	-	0.4	-	-	-	-	-	-	-	-	0.1	0.1	5.5	9.8	70.7	8.1	nil	0.045	-	1752
K7	0–30	6.0	0.83	0.120	7	0.1	3.7	3.4	0.24	0.32	0.68	8.3	13.8	60	0.0	1.8	2.0	46.8	48.5	3.4	nil	0.021	-	N1858
	30–60	6.5	0.62	-	-	0.2	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	nil	0.043	-	1859
	60–90	7.8	-	-	-	1.9	13.2	8.8	0.03	1.31	2.42	25.8	24.2	100	0.0	2.8	4.8	22.0	65.9	5.1	nil	0.069	-	1860
U5	0–30	7.4	0.77	0.063	12	0.4	19.7	5.2	0.01	2.3	2.0	29.1	22.4	100	0.0	2.8	11.4	21.3	56.8	6.5	nil	0.059	-	N1889
	30–60	7.8	0.57	0.059	13	0.7	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	nil	0.071	-	1890
	60–90	8.0	-	-	-	1.3	22.5	5.5	0.01	2.6	3.4	34.0	26.9	100	0.0	0.4	7.5	20.0	58.8	8.5	nil	0.093	-	1891
(b) Subject to prolonged flooding and treeless																								
B7	0–30	5.8	2.07	0.218	10	0.5	7.4	3.7	0.20	0.74	0.81	12.9	27.1	48	0.0	1.0	10.6	22.3	52.9	6.3	nil	0.015	-	N1744
	30–60	5.5	0.69	-	-	0.1	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	nil	0.014	-	1745
	60–90	6.1	-	-	-	0.1	10.6	7.2	0.18	0.99	1.03	20.0	25.1	80	0.0	0.5	9.6	17.0	65.3	6.4	nil	0.020	-	1746
B15	0–30	6.4	0.91	0.097	9	0.2	5.9	2.5	0.07	0.67	0.76	9.9	13.7	72	0.1	3.1	5.4	35.3	55.0	3.4	nil	0.027	-	N1810
	30–60	7.4	0.37	-	-	0.1	-	-	-	-	-	-	-	-	0.4	-	-	-	-	-	nil	0.048	-	1811
	60–90	8.0	-	-	-	0.6	11.1	4.5	0.01	1.70	2.23	19.5	19.1	100	0.3	7.3	17.1	16.3	55.0	4.8	nil	0.074	-	1812
U10	0–30	5.8	0.97	0.128	8	0.1	3.9	3.4	0.00	0.67	1.52	9.5	22.2	43	0.0	1.1	11.2	21.3	55.6	5.8	nil	0.024	-	N1904
	30–60	5.8	0.33	-	-	0.1	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	nil	0.030	-	1905
	60–90	5.9	-	-	-	0.1	11.6	5.7	0.00	1.15	1.36	19.8	22.5	88	0.0	1.0	5.7	13.5	74.3	5.8	nil	0.027	-	1906
U22	0–30	6.0	1.66	0.145	11	0.1	11.7	4.7	0.23	1.9	0.92	19.4	25.1	77	0.0	2.1	11.5	30.0	52.3	5.9	nil	0.025	-	N2256
	30–85	6.4	0.39	0.045	9	0.3	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	nil	0.033	-	2257
	85–120	7.8	0.06	-	-	3.8	16.3	4.2	0.01	3.7	3.7	27.9	22.6	100	0.1	6.4	33.0	30.0	28.8	1.5	tr.	0.058	-	2258
	120–155	7.5	-	-	-	0.6	12.1	4.0	0.00	3.7	4.2	24.0	25.8	93	0.0	4.3	37.4	29.0	28.6	1.1	0.12	0.048	-	2259
	155–215	8.2	-	-	-	0.7	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	0.06	0.063	-	2260
	215–260	8.6	-	-	-	1.2	-	-	-	-	-	-	-	-	0.1	6.6	6.5	28.3	49.9	8.2	0.02	0.149	-	2261
U24	0–30	7.6	0.57	0.036	16	0.1	31.2	7.6	0.02	-	-	-	43.7	-	0.0	0.9	3.4	14.3	72.1	9.8	0.29	0.091	-	N2268
	30–90	8.3	0.50	0.033	15	0.3	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	0.111	-	2269
	90–150	8.2	0.36	-	-	0.3	26.7	8.1	0.02	-	-	-	43.9	-	0.2	0.8	1.2	11.3	78.0	10.1	0.45	0.287	-	2270
	150–215	7.9	-	-	-	0.3	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-	0.28	0.225	-	2271
	215–260	7.6	-	-	-	0.7	24.1	9.1	0.02	-	-	-	41.8	-	0.0	0.5	3.8	16.8	70.6	10.4	0.25	0.395	-	2272
U3	0–30	7.4	1.04	0.083	13	0.2	20.9	11.2	0.01	3.5	10.0	45.6	37.5	100	0.0	0.2	2.3	7.8	70.9	10.0	nil	0.069	-	N1898
	30–60	7.7	0.88	-	-	0.5	15.3	15.0	n.d.	4.2	4.2	38.7	38.3	100	0.0	0.1	1.8	4.5	77.6	11.3	0.07	0.126	-	1899
	60–90	8.2	-	-	-	0.7	15.0	11.6	n.d.	4.2	7.6	38.4	44.4	87	1.4	-	-	-	-	-	0.24	0.181	-	1900
M15	0–30	6.6	0.83	0.059	14	0.2	41.8	4.5	0.05	0.90	4.2	51.5	34.6	100	0.0	8.3	7.3	10.5	62.9	10.1	nil	4.83	31.6	N2161
	30–60	7.0	0.63	-	-	2.6	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-	nil	6.26	37.7	2162
	60–90	6.9	-	-	-	2.8	42.8	1.4	tr.	1.41	18.5	64.1	36.6	100	0.0	2.8	6.3	15.8	68.7	9.2	nil	7.85	30.4	2163
J6	0–30	7.0	1.00	0.065	15	0.5	22.3	8.1	-	-	-	-	37.3	-	0.0	0.9	3.0	4.3	82.9	10.9	0.05	0.060	-	N2206
	30–60	7.9	0.87	-	-	0.6	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	0.12	0.097	-	2207
	60–90	8.4	-	-	-	0.6	-	-	-	2.5	6.3	22.1	38.6	-	0.1	0.5	3.0	5.8	82.6	8.7	0.46	0.137	-	2208
U17	0–30	6.9	1.00	0.053	19	0.1	32.8	13.1	0.07	2.5	3.0	51.5	46.5	100	0.0	0.1	1.5	3.0	84.9	11.4	nil	0.032	-	N2241
	30–60	7.3	0.77	-	-	0.4	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.053	-	2242
	60–90	7.8	-	-	-	1.1	15.3?	14.4	n.d.	2.4	6.8	39.1	-	-	0.0	0.5	5.0	0.8	82.9	12.6	0.50	0.181	-	2243

TABLE 12 (CONTINUED) - ANALYSES OF SOILS FROM THE USANGU PLAIN

Profile No.	Horizon cm.	pH	Organic C %	Total N %	C/N	Avail. P mg. %	Exchangeable cations m.e./100 g. soil: Ca	Mg	Mn	K	Na	Total	Capacity	Satn. %	Stones and gravel %	Mechanical analysis. % of fine earth fraction: Coarse sand	Fine sand	Silt	Clay	Moisture	$CaCO_3$	Conductivity: 1:5 ext. m-mhos	Satn. ext. m-mhos	Lab. No.
OLDER ALLUVIAL CLAYS (Continued)																								
(c) Subject to flooding, with trees																								
B6	0-30	6.3	0.88	0.107	8	0.2	17.0	7.4	0.07	1.7	2.4	28.6	29.1	98	0.0	1.2	10.5	20.8	61.1	6.4	nil	0.060	-	N1741
	30-60	7.1	0.43	0.070	6	0.5	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.058	-	1742
	60-90	8.1	-	-	-	1.1	14.7	10.3	n.d.	2.4	3.8	31.2	33.3	94	1.4	0.7	4.1	22.8	66.1	7.1	0.18	0.096	-	1743
B18	0-30	6.1	1.18	0.116	10	0.1	4.1	2.4	0.13	0.54	0.98	8.2	13.8	59	0.2	8.4	13.0	27.5	46.9	3.3	nil	0.023	-	N1817
	30-55	6.3	0.38	-	-	0.1	-	-	-	-	-	-	-	-	0.7	-	-	-	-	-	-	0.021	-	1818
	55-75	6.8	-	-	-	0.1	3.9	2.0	0.03	0.38	1.44	7.8	8.8	90	6.9	43.2	9.9	13.5	32.4	2.2	nil	0.030	-	1819
U13	0-30	6.6	0.82	0.068	12	0.3	12.9	7.8	0.01	1.6	1.3	23.6	31.1	76	0.0	1.1	3.7	16.0	71.7	8.0	nil	0.059	-	N1913
	30-60	6.8	0.67	-	-	0.4	-	-	-	-	-	-	-	-	0-0	-	-	-	-	-	nil	0.065	-	1914
	60-90	7.4	-	-	-	1.0	16.6	7.5	0.01	2.6	1.8	28.5	31.9	89	0.0	0.9	3.0	15.8	72.2	8.8	nil	0.066	-	1915
M9	0-30	5.8	1.88	0.074	25	0.7	11.7	3.3	0.10	0.38	1.2	16.7	25.8	65	0.0	1.5	10.5	20.3	60.7	5.8	nil	0.025	-	N2143
	30-60	6.1	1.10	-	-	0.1	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.019	-	2144
	60-90	6.4	-	-	-	0.1	13.0	3.9	0.10	0.30	1.5	18.7	19.1	98	0.0	0.1	24.7	21.5	51.4	4.8	nil	0.026	-	2145
(d) Alkaline alluvial clays																								
B12	0-30	8.7	0.63	0.051	12	0.7	-	-	-	1.9	4.1	-	25.7	-	0.7	12.9	16.8	16.0	48.8	6.2	0.04	0.130	-	N1759
	30-60	8.5	0.52	-	-	1.1	20.3	4.4	0.03	3.6	9.4	37.7	34.5	100	1.5	2.5	8.5	17.8	63.2	8.2	nil	0.151	-	1760
	60-90	8.6	-	-	-	1.5	-	-	-	-	-	-	-	-	2.5	-	-	-	-	-	0.36	0.138	-	1761
P215	0-15	7.4	0.88	0.080	11	0.8	10.1	8.2	0.03	0.45	1.7	20.5	17.7	100	0.0	9.5	30.1	17.8	36.5	4.4	nil	0.069	-	N1410
	15-40	8.2	0.73	0.068	11	0.6	10.7	5.8	tr.	0.24	3.2	19.9	19.8	100	0.0	7.5	28.2	18.5	41.8	4.9	nil	0.078	-	1411
	40-80	8.5	0.46	0.034	13	4.1	-	-	-	-	-	-	-	-	0.0		Similar to horizon 80-120 cm.					0.104	0.9	1412
	80-120	8.5	0.31	0.023	13	6.8	10.7	5.2	0.01	0.17	4.4	20.5	17.7	100	0.0	10.2	37.6	17.0	31.7	4.2	nil	0.082	-	1413
	120-160	8.9	0.27	-	-	6.5	-	-	-	-	-	-	-	-	0.4		Similar to horizon 80-120 cm.					0.128	0.8	1414
	160-190	9.4	0.11	-	-	3.4	14.7	5.7	0.01	0.80	4.9	28.1	16.5	100	1.0	28.0	25.6	9.5	33.1	4.2	nil	0.342	0.9	1415
P249	0-15	6.4	0.79	0.084	9	0.2	9.4	3.7	0.03	2.5	1.5	17.1	19.0	90	0.4	8.6	16.6	26.5	44.5	5.2	nil	0.063	-	N1944
	15-40	7.2	0.48	0.058	8	0.2	-	-	-	-	-	-	-	-	0.4	-	-	-	-	-	nil	0.086	-	1945
	40-90	8.4	0.14	-	-	3.5	12.7	5.0	n.d.	2.6	7.6	27.9	21.2	100	11.3	4.9	10.0	31.0	45.9	6.7	0.33	0.136	-	1946
	90-140	8.7	-	-	-	2.0	-	-	-	-	-	-	-	-	12.7	-	-	-	-	-	0.98	0.152	-	1947
	140-190	8.9	-	-	-	1.6	13.7	2.9	n.d.	2.7	7.5	26.8	22.2	100	13.6	5.6	10.4	30.3	44.2	6.3	0.90	0.206	0.9	1948
B14	0-30	8.7	0.52	0.054	10	1.1	6.3	2.2	0.36	7.7	8.8	25.4	25.7	99	1.2	9.6	14.7	18.5	51.3	5.7	0.38	0.094	-	N1807
	30-60	9.1	0.14	-	-	0.4	2.4	0.4	0.05	8.3	17.1	28.3	22.5	100	1.7	4.8	22.1	16.5	50.2	6.8	0.44	0.218	0.7	1808
	60-90	9.5	-	-	-	0.3	-	-	-	-	-	-	-	-	1.2	-	-	-	-	-	0.37	0.240	1.2	1809
(e) Clays hardening on drying																								
M17	0-30	6.1	0.66	0.055	12	0.1	9.9	4.1	0.07	0.38	1.2	15.7	18.1	87	0.4	16.3	14.4	14.5	50.4	4.5	nil	0.042	-	N2167
	30-60	6.0	0.49	-	-	0.1	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-	nil	0.070	-	2168
	60-90	7.1	-	-	-	1.9	17.2	3.8	0.02	0.71	1.9	23.6	28.6	83	0.1	5.8	9.1	17.3	63.6	5.9	nil	0.159	-	2169
ALLUVIAL SANDY SOILS AFFECTED BY ALKALI																								
P262	0-15	7.8	0.68	0.057	12	0.18	5.5	3.6	0.03	0.26	4.0	13.4	13.3	100	0.4	30.6	25.3	13.2	27.6	3.0	nil	0.150	-	N2289
	15-30	7.4	0.50	0.040	13	1.30	9.6	3.5	n.d.	-	-	-	17.1	100	0.2	-	-	-	-	-	0.05	1.34	11.2	2290
	30-80	9.0	0.22	-	-	2.00	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-	0.32	1.24	4.7	2291
	80-160	9.6	-	-	-	1.23	-	-	-	-	-	-	-	-	1.4	13.5	23.2	22.0	38.1	5.2	1.11	0.882	2.3	2292
	160-190	9.5	-	-	-	0.28	-	-	-	-	-	-	-	-	0.5	-	-	-	-	-	1.39	0.688	5.7	2293
	190-225	9.4	-	-	-	0.25	4.6	1.5	n.d.	0.38	7.1	13.5	11.9	100	1.5	21.0	28.6	11.5	35.9	3.8	1.93	0.561	13.9	2294
	225-240	9.2	-	-	-	0.60	-	-	-	-	-	-	-	-	0.2	-	-	-	-	-	0.03	0.077	-	2295
J4	0-30	5.7	0.68	0.047	14	0.10	2.0	1.3	0.11	0.22	3.2	6.8	7.5	91	0.7	45.1	16.0	12.5	23.9	2.1	nil	0.017	-	N2200
	30-60	7.6	0.64	-	-	0.93	3.5	1.7	0.05	.45	7.9	13.6	10.7	100	0.5	40.5	18.5	8.3	29.9	3.0	nil	0.034	-	2201
	60-90	7.4	-	-	-	1.10	-	-	-	-	-	-	-	-	1.0	-	-	-	-	-	nil	0.639	9.9	2202
SOILS FORMED FROM LAKE-BED																								
P241	0-3	6.8	0.27	-	-	14.5	-	-	-	-	-	-	-	-	0.0		Coarse sand					0.046	-	N1718
	3-28	6.5	1.73	0.167	10	1.6	8.5	4.6	0.55	4.7	0.9	19.3	29.3	66	0.0	0.8	16.1	17.8	56.0	5.9	nil	0.029	-	1719
	28-50	6.6	0.63	0.074	9	0.1	9.3	4.6	0.05	1.5	1.5	17.0	28.9	59	0.0	1.4	16.4	24.5	44.9	6.9	nil	0.034	-	1720
	50-85	7.5	0.29	-	-	2.8	8.8	9.0	0.03	3.1	2.4	23.3	22.2	100	0.0	1.3	37.4	37.0	16.1	5.9	nil	0.038	-	1721
	85-112	7.5	-	-	-	6.5	-	-	-	-	-	-	-	-	0.0		Sand				0.08	0.025	-	1722
	112-185	7.5	-	-	-	1.3	8.2	6.2	0.06	3.8	2.0	20.3	19.7	100	0.0	1.3	16.1	59.3	12.1	5.1	nil	0.018	-	1723
	185-208	7.1	-	-	-	1.1	-	-	-	-	-	-	-	-	0.0		Similar to horizon 112-185 cm.				nil	0.018	-	1724
	208-240	7.9	-	-	-	0.6	12.0	8.8	0.09	3.1	3.6	27.6	27.7	100	0.0	2.3	8.9	21.0	61.6	5.7	nil	0.054	-	1725
B4	0-30	7.7	0.38	0.046	8	3.7	8.5	3.4	0.04	6.1	5.8	23.8	21.4	100	0.3	3.5	18.8	51.3	17.5	4.4	nil	0.095	-	N1735
	30-60	8.1	0.24	0.031	8	6.5	15.5	2.2	0.02	9.1	11.4	38.3	32.5	100	0.4	-	-	-	-	-	nil	0.089	-	1736
	60-90	8.8	0.14	-	-	18.0	6.8	2.8	n.d.	8.8	12.5	30.9	31.7	98	0.6	2.7	17.0	34.8	37.9	7.0	0.51	0.162	-	1737

TABLE 12 (CONTINUED) - ANALYSES OF SOILS FROM THE USANGU PLAIN

Profile No.	Horizon cm.	pH	Organic C %	Total N %	C/N	Avail. P mg. %	Exchangeable cations m.e./100 g. soil: Ca	Mg	Mn	K	Na	Total	Capacity	Satn. %	Stones and gravel %	Mechanical analysis. % of fine earth fraction: Coarse sand	Fine sand	Silt	Clay	Moisture	$CaCO_3$	Conductivity: 1:5 ext. m-mhos	Satn. ext. m-mhos	Lab. No.
SOILS WITH SODIUM CARBONATE																								
P248	0-20	7.9	1.34	0.120	11	9.5	4.3	2.0	n.d.	1.[illegible]	1.3	9.3	12.1	77	0.5	26.5	33.6	22.3	16.0	1.8	0.12	0.060	-	N1940
	20-40	9.5	0.48	-	-	0.4	2.7	1.2	n.d.	1.6	2.7	8.2	8.5	97	0.5	8.0	50.8	23.8	16.7	1.5	0.13	0.106	-	1941
	40-80	10.1	0.20	-	-	0.2	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	0.45	0.160	-	1942
	80-120	10.3	-	-	-	0.3	1.3	0.4	n.d.	1.1	12.4	15.2	-	-	0.0	1.7	17.6	45.5	32.3	2.9	0.56	0.460	3.3	1943
B17	0-30	10.1	0.34	0.050	7	0.7	0.7	0.4	n.d.	4.2	13.6	18.9	16.9	100	0.0	63.0	7.3	12.3	14.0	4.6	0.76	0.060	-	N1815
	30-60	9.6	0.23	-	-	0.4	3.7	0.7	n.d.	5.4	9.0	18.8	17.2	100	0.5	1.9	10.1	41.0	40.3	9.1	0.48	0.239	-	1816
NON-ALLUVIAL SOILS																								
(a) Alkaline red and brown soils																								
P240	0-20	9.0	0.51	0.054	9	0.8	12.9	6.5	0.03	0.8	2.4	22.6	18.5	100	-	24.7	37.9	9.8	23.8	3.4	0.16	0.155	-	N1713
	20-50	9.2	0.39	0.039	10	2.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.56	0.358	2.6	1714
	50-100	9.3	0.25	-	-	3.8	8.1	5.0	0.03	1.7	5.9	20.7	20.8	100	-	21.5	38.6	11.8	23.9	3.9	0.71	0.586	5.9	1715
	100-150	9.3	-	-	-	3.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.93	0.500	5.2	1716
	150-185	9.3	-	-	-	3.7	3.5	4.6	0.04	0.4	4.1	12.6	12.5	100	-	19.1	44.8	7.3	23.6	3.5	1.55	0.542	6.3	1717
(b) Grey sandy soils of foothills																								
P263	0-20	6.8	0.56	0.043	13	0.1	1.3	0.4	0.03	0.16	0.34	2.2	2.2	100	5.2	67.5	23.2	5.5	2.6	0.4	nil	0.041	-	N2296
	20-42	9.1	0.13	0.015	9	0.2	1.5	0.3	0.01	0.19	5.91	7.9	6.1	100	5.5	55.8	22.4	5.3	15.6	1.5	nil	0.247	-	2297
	42-80	10.0	0.02	-	-	0.5	-	-	-	-	-	-	-	-	12.6	-	-	-	-	-	0.03	0.442	6.3	2298
	80-115	10.0	-	-	-	0.7	0.3	0.1	n.d.	-	-	-	-	-	7.0	52.7	30.1	9.5	7.0	1.1	0.05	0.388	9.0	2299
	115-125	9.7	-	-	-	0.5	-	-	-	-	-	-	-	-	5.4	-	-	-	-	-	tr.	0.388	12.3	2300
	125-190	9.1	-	-	-	0.7	0.2	0.1	n.d.	-	-	-	-	-	5.0	51.8	28.3	11.0	8.1	1.1	tr.	0.062	-	2301
(c) Cemented sandy soils																								
P246	0-10	6.3	0.81	0.065	12	0.3	5.2	1.4	0.16	0.73	0.30	7.8	9.1	79	4.4	33.0	26.0	14.3	23.9	2.3	nil	0.059	-	N1929
	10-30	6.9	0.27	0.030	9	0.7	-	-	-	-	-	-	-	-	6.3	-	-	-	-	-	nil	0.039	-	1930
	30-60	7.5	0.19	-	-	1.5	12.9	1.6	0.01	1.32	0.43	16.3	14.1	100	n.d.	33.4	19.2	8.3	36.0	3.7	nil	0.054	-	1931
	60-100	8.2	0.12	-	-	3.8	-	-	-	-	-	-	-	-	5.3	-	-	-	-	-	0.61	0.088	-	1932
	100-130	8.5	-	-	-	2.8	11.9	1.3	n.d.	1.86	7.6	22.7	8.1	100	18.1	34.3	27.6	16.8	12.3	3.5	0.48	0.088	-	1933
M3	0-30	5.7	0.35	0.038	9	0.1	1.8	0.7	0.04	0.10	0.98	3.6	5.6	64	0.7	43.2	18.8	15.0	20.4	1.4	nil	0.035	-	N2127
	30-55	5.4	0.24	-	-	0.1	2.8	0.8	0.04	0.14	2.17	6.0	7.8	77	0.5	-	-	-	-	-	-	0.100	-	2128
M8	0-30	5.9	0.5	-	-	0.1	1.5	2.2	0.04	0.27	1.4	5.4	7.6	71	1.1	37.2	32.2	7.8	18.4	2.1	nil	0.03	-	N2140
	30-60	5.1	0.4	-	-	0.1	-	-	-	-	-	-	-	-	0.8	-	-	-	-	-	nil	0.17	-	2141
	60-90	5.3	-	-	-	0.7	8.0	5.4	0.03	1.02	2.0	14.5	16.3	89	0.7	22.4	24.5	9.0	40.2	4.5	nil	0.55	4.8	2142
(d) Clays of the pediment catena																								
K8	0-30	7.6	0.69	0.065	11	1.7	15.6	6.5	0.01	0.71	2.3	25.1	21.8	100	0.8	13.7	21.4	21.0	40.5	4.0	nil	0.063	-	N1861
	30-60	8.4	0.50	-	-	2.5	9.1	6.6	n.d.	0.99	2.6	19.3	21.5	90	1.6	8.1	25.0	18.8	42.3	5.3	0.69	0.116	-	1862
(e) Alkaline clay																								
P239	0-15	8.1	0.86	0.071	12	3.2	15.6	9.1	0.03	0.80	3.4	28.9	30.6	-	0.2	1.6	22.5	15.3	46.9	7.2	0.04	0.059	-	N1707
	15-30	8.4	0.73	0.063	12	2.7	15.0	12.2	n.d.	0.74	3.9	31.8	37.2	-	0.1	3.3	20.4	21.0	47.3	7.3	0.08	0.081	-	1708
	30-60	8.7	0.67	-	-	2.8	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	0.29	0.090	-	1709
	60-90	8.7	0.60	-	-	3.6	15.0	11.4	n.d.	0.90	10.3	37.6	41.8	-	0.2	5.5	12.4	16.8	57.3	8.4	0.42	0.100	-	1710
	90-135	8.8	-	-	-	3.9	-	-	-	-	-	-	-	-	0.7	-	-	-	-	-	0.76	0.155	-	1711
	135-185	8.8	-	-	-	3.1	15.1	11.6	n.d.	1.41	11.1	39.2	44.9	-	0.4	10.8	6.7	11.8	57.5	8.6	0.35	0.138	-	1712
(f) Pale sands of gentle slopes																								
P250	0-15	5.4	0.33	0.037	9	0.1	0.5	0.3	0.02	0.35	0.17	1.3	2.1	62	0.8	51.0	40.2	4.0	4.0	0.5	nil	0.024	-	N1949
	15-35	4.7	0.19	0.025	8	0.1	0.22	0.07	0.00	0.33	0.08	0.7	1.7	41	1.3	-	-	-	-	-	nil	0.015	-	1950
	35-65	5.0	0.12	-	-	0.0	-	-	-	-	-	-	-	-	1.8	-	-	-	-	-	nil	0.016	-	1951
	65-110	7.0	0.01	-	-	0.1	2.8	0.5	0.02	1.5	0.43	5.2	5.7	93	10.2	46.2	40.5	6.3	4.1	1.7	nil	0.028	-	1952
	150-170	8.3	-	-	-	0.2	2.5	0.4	0.02	1.5	1.13	5.6	4.8	100	6.0	-	-	-	-	-	nil	0.045	-	1953
U20	0-30	7.1	0.41	0.042	10	1.6	7.9	0.7	0.02	0.18	3.5	12.3	10.9	100	1.9	46.9	3.2	7.8	41.8	2.8	nil	1.27	11.3	N2250
	30-60	7.1	0.20	-	-	19.3	14.4	0.5	0.04	-	-	-	13.9	100	2.9	40.8	2.1	11.3	44.6	3.9	0.02	2.12	12.9	2251
	60-90	6.9	-	-	-	40.4	-	-	-	-	-	-	-	-	3.4	-	-	-	-	-	nil	1.27	21.3	2252

TABLE 13 - ANALYSES OF SOILS FROM THE KILOMBERO VALLEY

Profile No.	Horizon cm.	pH	Organic C %	Total N %	C/N	Avail. P mg. %	Exchangeable cations m.e./100 g. soil: Ca	Mg	Mn	K	Na	Total	Capacity	Satn. %	Stones and gravel %	Mechanical analysis. % of fine earth fraction: Coarse sand	Fine sand	Silt	Clay	Moisture	$CaCO_3$	Conductivity: 1:5 ext. m-mhos	Satn. ext. m-mhos	Lab. No.
ALLUVIAL SAND																								
P177	0-15	4.7	1.99	0.148	13	16.6	3.6	0.9	0.15	0.46	0.08	5.2	14.6	36	0.8	43.3	24.8	8.8	18.3	2.3	nil	0.026	-	N1028
	15-30	4.5	1.12	0.066	17	0.9	2.0	0.5	0.14	0.18	0.11	2.9	9.2	32	1.3	50.9	22.9	6.8	16.1	2.0	nil	0.032	-	1029
	30-55	5.2	0.60	0.051	12	1.2	-	-	-	-	-	-	-	-	4.3	-	-	-	-	-	nil	0.059	-	1030
	55-130	6.6	0.08	0.004	20	0.8	1.0	0.3	0.03	0.14	0.08	1.5	2.0	75	43.8	92.0	4.1	1.0	2.5	0.4	nil	0.034	-	1031
	130-230	6.7	-	-	-	1.2	-	-	-	-	-	-	-	-	30.6	-	-	-	-	-	nil	0.018	-	1032
L13	0-30	6.3	1.82	0.112	16	4.3	10.4	3.3	0.05	0.65	0.33	14.7	15.0	98	0.0	4.9	65.7	9.5	13.7	2.6	nil	0.050	-	N2010
	30-60	6.6	0.39	-	-	7.0	3.8	1.5	0.08	0.18	0.19	5.8	6.8	85	0.0	5.8	79.0	5.5	7.1	1.2	nil	0.036	-	2011
	60-90	6.7	-	-	-	10.0	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	nil	0.040	-	2012
ALLUVIAL SANDY LOAM																								
P255	0-10	6.5	1.38	0.092	15	11.0	14.2	3.8	0.13	0.54	0.27	18.9	21.2	89	0.5	23.5	46.2	11.5	15.3	3.2	nil	0.053	-	N2026
	10-25	6.2	1.00	0.059	17	4.3	6.5	2.7	0.10	0.29	0.43	10.0	12.8	78	0.7	20.1	52.1	10.5	15.0	2.5	nil	0.125	-	2027
	25-75	6.6	0.69	-	-	1.4	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-	-	0.025	-	2028
	75-95	6.7	-	-	-	1.3	6.9	3.9	0.02	0.19	0.41	11.4	13.0	88	0.0	20.8	44.9	15.3	17.0	4.1	nil	0.028	-	2029
	95-120	6.6	-	-	-	0.2	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.053	-	2030
	120-200	6.3	-	-	-	2.0	6.2	3.2	0.12	0.11	0.48	10.1	10.0	100	0.0	25.5	51.0	6.8	15.6	2.6	nil	0.130	-	2031
L15	0-30	6.7	2.20	0.141	16	2.8	13.5	3.8	0.02	0.67	0.38	18.4	17.0	100	0.2	30.0	29.9	10.8	23.7	3.6	nil	0.047	-	N2052
	30-45	6.5	0.65	-	-	0.8	5.5	5.0	0.00	0.34	0.17	11.0	8.6	100	1.0	44.3	28.3	7.3	17.1	2.5	nil	0.019	-	2053
	45-75	6.5	-	-	-	2.4	-	-	-	-	-	-	-	-	23.0	-	-	-	-	-	-	0.025	-	2054
M9	0-30	4.8	1.40	0.081	17	0.7	0.8	0.2	0.07	0.28	0.24	1.6	7.3	22	0.0	46.6	29.8	0.5	21.3	2.2	nil	0.03	-	N2331
	30-60	4.8	0.98	-	-	0.4	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.03	-	2332
	60-90	4.8	-	-	-	0.3	0.7	0.2	0.03	0.18	0.22	1.4	2.9	48	0.0	47.8	32.5	10.0	9.9	0.8	-	0.03	-	2333
ALLUVIAL LOAM																								
P257	0-15	6.2	3.57	0.252	14	0.3	13.0	5.4	0.07	0.74	0.14	19.4	24.0	81	0.0	11.2	27.3	20.8	30.5	5.3	nil	0.051	-	N2037
	15-35	6.0	1.64	0.110	15	0.1	6.0	3.7	0.05	0.45	0.41	10.6	17.6	60	0.0	-	-	-	-	-	-	0.022	-	2038
	35-70	5.9	0.88	-	-	0.1	-	-	-	-	-	-	-	-	0.2	-	-	-	-	-	-	0.028	-	2039
	70-82	6.0	-	-	-	0.1	-	-	-	-	-	-	-	-	2.1	-	-	-	-	-	-	0.026	-	2040
	82-105	6.0	-	-	-	0.1	3.0	2.7	0.04	0.23	0.21	6.2	9.0	69	0.4	26.4	42.5	11.0	15.3	2.4	nil	0.031	-	2041
	105-122	6.2	-	-	-	0.0	-	-	-	-	-	-	-	-	3.5	-	-	-	-	-	-	0.032	-	2042
	122-190	6.4	-	-	-	0.0	3.8	3.2	0.02	0.06	0.33	7.4	7.1	100	0.1	13.9	55.8	10.5	13.4	2.3	nil	0.014	-	2043
L19	0-13	6.3	4.68	0.269	17	4.6	18.5	7.6	0.04	1.06	0.76	28.0	30.5	92	0.9	7.6	31.7	18.0	33.1	6.0	nil	0.030	-	N2064
	13-25	6.1	2.41	0.114	21	0.6	11.1	4.8	0.03	0.38	0.35	16.7	19.1	87	0.0	-	-	-	-	-	-	0.020	-	2065
	25-40	5.6	1.53	0.096	16	0.7	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.022	-	2066
	40-55	6.4	0.64	-	-	0.9	5.2	3.1	0.02	0.11	0.14	8.6	7.6	100	0.1	12.3	57.9	8.3	18.6	2.4	nil	0.020	-	2067
	55-85	6.6	0.41	-	-	0.4	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.016	-	2068
	85-95	6.8	-	-	-	0.0	9.5	3.8	0.01	0.27	0.08	13.7	18.0	76	0.0	3.6	29.3	22.0	38.5	5.6	nil	0.017	-	2069
	95-120	6.9	-	-	-	0.1	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.019	-	2070
	120-150	7.5	-	-	-	0.1	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	nil	0.020	-	2071
	150-180	7.2	-	-	-	0.1	2.2	2.8	tr.	0.03	0.63	5.7	3.7	100	0.6	36.1	39.0	6.3	21.3	2.0	nil	0.022	-	2072
M8	0-30	4.6	3.54	0.292	12	1.7	1.8	0.6	0.05	0.32	0.22	3.0	15.5	19	0.1	-	-	-	-	-	nil	0.06	-	N2328
	30-60	4.5	0.81	-	-	1.3	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	nil	0.04	-	2329
	60-90	5.0	-	-	-	0.7	1.1	0.7	0.02	0.18	0.16	2.2	4.6	48	0.3	-	-	-	-	-	nil	0.03	-	2330
RECENT ALLUVIAL CLAY																								
P170	0-10	5.8	2.96	0.185	16	1.0	12.3	5.9	0.13	0.64	0.49	19.5	27.8	70	0.1	7.5	12.5	31.8	40.1	5.9	nil	0.023	-	N992
	10-18	5.6	2.30	0.153	15	0.6	8.1	4.8	0.06	0.21	0.38	13.6	23.3	58	0.1	9.8	8.7	29.0	45.7	5.8	nil	0.019	-	993
	18-45	5.4	0.81	0.053	15	1.1	4.1	2.1	0.06	0.11	0.37	6.7	12.6	53	0.7	47.3	13.9	12.5	21.2	3.7	nil	0.020	-	994
	45-90	5.3	1.45	0.090	16	0.4	9.1	4.2	0.12	0.13	0.71	14.3	24.2	59	0.1	4.0	10.1	28.0	51.1	5.7	nil	0.023	-	995
	90-180	6.2	0.18	0.011	16	0.2	-	-	-	-	-	-	-	-	0.0	11.1	14.3	21.0	48.9	5.5	nil	0.059	-	996
	180-190	7.5	-	-	-	0.2	8.3	5.2	tr.	0.13	0.87	14.5	14.7	99	0.0	21.2	21.0	13.8	40.9	4.1	nil	0.059	-	997
P181	0-10	6.2	3.52	0.158	22	0.6	19.4	8.7	0.18	1.07	0.54	29.9	34.3	87	0.0	9.3	15.1	21.3	45.4	6.0	nil	0.071	-	N1047
	10-30	5.8	1.46	0.101	14	0.4	12.7	6.7	0.16	0.51	0.49	20.6	24.5	83	0.0	11.3	11.6	17.8	53.7	5.6	nil	0.063	-	1048
	30-50	5.7	0.69	0.062	11	0.4	5.0	5.2	0.07	0.24	0.46	12.0	13.7	88	3.1	44.0	10.1	9.8	32.0	3.8	nil	0.081	-	1049
	50-70	5.6	0.64	-	-	0.2	-	-	-	-	-	-	-	-	1.9	-	-	-	-	-	-	0.069	-	1050
	70-100	5.7	-	-	-	0.1	8.8	5.7	0.07	0.10	0.43	15.1	18.9	80	0.1	5.6	18.3	20.5	49.3	5.1	nil	0.063	-	1051
L16	0-30	6.2	1.83	0.114	16	0.5	12.6	7.6	0.06	0.32	0.58	21.2	23.9	89	0.2	13.3	18.3	16.8	44.0	6.2	nil	0.032	-	N2055
	30-60	7.4	0.73	-	-	0.0	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	nil	0.035	-	2056
	60-90	7.9	-	-	-	0.0	21.0	4.3	0.02	0.06	2.28	27.7	22.5	100	2.3	13.9	29.2	10.5	41.4	6.9	nil	0.126	-	2057

TABLE 11 (CONTINUED) - ANALYSES OF SOILS FROM THE KILOMBERO VALLEY

Profile No.	Horizon cm.	pH	Organic C %	Total N %	C/N	Avail. P mg. %	Exchangeable cations m.e./100 g. soil: Ca	Mg	Mn	K	Na	Total	Capacity	Satn. %	Stones and gravel %	Mechanical analysis. % of fine earth fraction: Coarse sand	Fine sand	Silt	Clay	Moisture	$CaCO_3$	Conductivity: 1:5 ext. m-mhos	Satn. ext. m-mhos	Lab. No.
OLDER ALLUVIAL CLAY																								
P165	0-15	5.6	1.45	0.109	13	0.1	4.5	2.1	0.03	0.16	0.38	7.2	12.5	58	0.1	6.5	10.0	19.5	60.8	5.3	nil	0.020	-	N959
	15-30	5.8	0.91	0.078	12	0.0	4.4	2.3	0.01	0.13	0.43	7.3	12.5	58	3.3	3.9	10.0	17.8	64.6	5.5	nil	0.021	-	960
	30-55	5.6	0.83	0.064	13	0.1	4.4	2.2	0.01	0.12	0.49	7.2	13.4	54	1.3	3.7	8.6	13.3	68.3	5.2	nil	0.020	-	961
	55-80	6.1	0.44	0.040	11	0.0	-	-	-	-	-	-	-	-	0.0	3.5	6.6	9.0	76.4	5.5	nil	0.068	-	962
	80-115	5.6	0.63	0.036	18	0.0	5.1	2.8	0.00	0.10	0.82	8.8	13.5	65	0.2	2.3	8.6	12.5	71.7	4.9	nil	0.023	-	963
	115-190	6.1	0.22	0.023	10	0.0	8.4	5.3	0.05	0.11	1.69	17.5	22.4	78	0.3	2.7	6.9	9.5	76.4	5.5	nil	0.323	-	964
P178	0-13	6.0	2.47	0.162	15	0.5	12.8	5.4	0.04	0.26	0.71	19.2	23.3	82	0.3	14.8	16.2	23.0	38.8	6.1	nil	0.030	-	N1033
	13-30	6.6	1.19	0.083	14	0.1	10.8	7.3	0.02	0.11	1.5	19.7	20.7	95	0.3	4.8	15.0	19.3	55.0	6.1	nil	0.047	-	1034
	30-80	7.8	0.86	0.062	13	0.1	14.6	9.2	0.02	0.14	3.2	27.1	23.9	100	0.0	11.5	14.4	15.0	54.8	6.6	nil	0.139	1.0	1035
	80-180	8.4	0.38	0.025	15	0.2	13.0	7.0	0.01	0.17	5.2	25.4	24.6	100	0.6	12.4	13.0	11.8	56.4	6.5	nil	0.169	0.8	1036
L2	0-30	5.6	2.14	0.147	15	0.2	7.9	4.4	0.03	0.48	0.65	13.5	18.5	73	0.0	0.8	9.4	12.3	69.2	6.1	nil	0.064	-	N1978
	30-60	5.8	0.78	0.086	9	0.0	5.7	3.4	tr.	0.13	0.76	10.0	14.1	71	0.0	-	-	-	-	-	-	0.070	-	1979
	60-90	6.1	-	-	-	0.0	5.6	2.9	0.00	0.10	0.65	9.3	12.5	74	0.0	2.6	11.8	10.3	70.5	5.4	nil	0.031	-	1980
M11	0-30	5.1	1.55	0.122	13	0.5	7.7	3.6	0.12	0.56	0.87	12.9	18.3	71	0.0	1.4	8.2	25.8	57.9	5.9	nil	0.03	-	N2337
	30-60	5.2	0.83	-	-	0.1	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.04	-	2338
	60-90	6.5	-	-	-	0.1	10.7	4.3	0.07	0.21	0.98	16.3	15.8	100	0.0	-	-	-	-	-	-	0.06	-	2339
M16	0-30	5.1	2.33	0.140	17	0.4	4.1	1.4	0.22	0.52	0.41	6.7	16.6	40	0.0	-	-	-	-	-	-	0.05	-	N2352
	30-60	4.3	1.14	-	-	0.1	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.02	-	2353
	60-90	6.5	-	-	-	0.1	13.1	3.2	0.02	0.16	0.71	17.2	16.3	100	0.0	-	-	-	-	-	-	0.04	-	2354
CLAY WITH PARTIAL SAND OVERLAY																								
L3	0-30	5.4	1.03	0.052	20	0.5	1.5	0.8	0.09	0.13	0.08	2.6	5.4	48	0.0	33.1	43.3	6.5	14.0	1.2	nil	0.021	-	N1981
	30-60	5.2	0.24	0.018	13	0.1	1.2	0.8	0.01	0.26	0.15	2.4	3.0	80	0.4	38.7	40.9	3.5	15.3	1.0	nil	0.141	-	1982
	60-90	5.8	-	-	-	0.0	2.1	1.8	0.01	0.10	0.33	4.3	6.4	67	0.3	22.9	25.6	7.0	40.7	3.3	nil	0.019	-	1983
L10	0-30	5.6	1.28	0.013	12	0.3	2.8	1.9	0.03	0.06	0.35	5.1	11.1	46	0.0	21.0	35.6	6.3	31.2	2.9	nil	0.021	-	N2002
	30-60	5.9	0.56	-	-	0.1	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.019	-	2003
	60-90	6.1	-	-	-	0.1	3.4	2.3	0.02	0.06	0.45	6.2	9.4	66	0.8	21.1	26.2	4.5	44.3	3.5	nil	0.035	-	2004
NON-ALLUVIAL SOILS																								
(a) Red and brown soils																								
M14	0-15	5.8	0.98	0.056	17	2.0	3.5	1.2	0.16	0.68	0.10	5.6	6.4	88	0.0	-	-	-	-	-	-	0.07	-	N2346
	15-45	5.4	0.60	-	-	1.4	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.03	-	2347
	45-75	5.3	-	-	-	0.5	0.8	0.4	0.20	-	-	-	3.4	-	0.0	-	-	-	-	-	-	0.03	-	2348
(b) Grey sandy soils of foothills																								
M15	0-22	5.6	0.52	0.029	18	1.3	1.1	0.4	0.10	0.34	0.07	2.0	2.3	87	0.1	-	-	-	-	-	-	0.04	-	N2349
	22-45	5.1	0.22	-	-	0.3	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-	-	0.03	-	2350
	45-75	5.0	-	-	-	0.1	0.5	0.25	0.03	0.15	0.11	1.0	1.4	71	0.1	-	-	-	-	-	-	0.03	-	2351
(c) Low-lying sands, subject to flooding																								
P179	0-12	5.3	0.71	0.037	19	0.98	1.5	0.3	0.21	0.16	0.11	2.3	3.8	61	0.1	30.3	52.6	4.3	10.3	0.9	nil	0.047	-	N1037
	12-30	4.7	0.36	0.024	15	0.19	0.6	0.1	0.02	0.05	0.08	0.9	2.8	32	0.1	35.8	45.9	4.0	13.2	0.8	nil	0.016	-	1038
	30-50	4.6	0.30	0.025	12	0.15	0.4	0.1	0.02	0.05	0.13	0.7	3.1	23	0.0	45.0	30.3	2.8	20.2	1.2	nil	0.026	-	1039
	50-80	4.7	0.11	-	-	0.04	0.3	0.0	0.01	0.06	0.16	0.5	3.0	18	0.4	-	-	-	-	-	-	0.035	-	1040
M22	0-30	5.5	1.26	0.088	14	0.5	3.4	1.5	0.03	0.27	0.23	5.4	7.0	77	0.2	-	-	-	-	-	-	0.05	-	N2370
	30-53	5.5	0.26	-	-	0.1	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	0.03	-	2371
	53-90	6.1	-	-	-	0.1	2.5	1.2	tr.	0.05	0.30	4.1	4.2	98	0.5	-	-	-	-	-	-	0.02	-	2372
(d) Pale sands, from Karroo sediments																								
L14	0-30	6.4	0.35	0.021	17	0.4	1.2	0.6	0.02	0.08	0.14	2.0	1.4	100	0.0	46.8	43.7	4.8	4.4	0.4	nil	0.020	-	N2049
	30-60	5.8	0.12	-	-	0.0	0.4	0.25	0.06	0.05	0.15	0.9	1.1	82	0.7	-	-	-	-	-	-	0.012	-	2050
	60-90	5.5	-	-	-	0.0	1.2	1.4	0.14	0.05	0.11	2.9	3.8	76	1.5	42.5	30.1	5.3	19.5	1.7	nil	0.013	-	2051
(e) Pale sands, with water-table																								
L9	0-30	5.4	0.69	0.050	14	0.4	1.1	0.7	0.05	0.29	0.16	2.3	3.3	70	0.1	47.2	35.7	6.0	9.1	0.9	nil	0.026	-	N1999
	30-60	4.8	0.37	-	-	0.2	0.4	0.6	0.01	0.22	0.30	1.5	3.5	43	0.1	41.7	29.6	3.3	20.3	1.5	nil	0.020	-	2000
	60-90	5.4	-	-	-	0.1	0.5	1.4	0.01	0.09	0.40	2.4	6.0	40	0.9	-	-	-	-	-	-	0.012	-	2001

TABLE 11 (CONTINUED) - ANALYSES OF SOILS FROM THE KILOMBERO VALLEY

Profile No.	Horizon cm.	pH	Organic C %	Total N %	C/N	Avail. P mg. %	Exchangeable cations m.e./100 g. soil: Ca	Mg	Mn	K	Na	Total	Capacity	Satn. %	Stones and gravel %	Mechanical analysis. % of fine earth fraction: Coarse sand	Fine sand	Silt	Clay	Moisture	$CaCO_3$	Conductivity: 1:5 ext. m-mhos	Satn. ext. m-mhos	Lab. No.
NON-ALLUVIAL SOILS (Continued)																								
(f) Other pale sands																								
P168	0–13	5.6	0.48	0.038	13	5.1	1.5	0.5	0.10	0.14	0.11	2.4	3.4	71	0.1	38.7	50.2	4.3	6.1	0.8	nil	0.020	-	N975
	13–24	6.6	0.15	0.016	9	0.1	0.8	0.3	0.02	0.05	0.33	1.5	2.2	68	0.2	50.0	41.7	3.5	3.6	0.5	nil	0.022	-	976
	24–35	7.6	0.08	0.006	13	0.0	0.4	0.1	0.00	0.04	0.35	0.9	1.0	90	2.3	60.6	34.1	3.3	1.3	0.2	nil	0.024	-	977
	35–75	8.9	0.16	0.022	7	0.1	9.3	2.3	0.00	0.13	3.0	14.7	13.7	100	11.6	27.2	33.0	6.8	28.6	4.2	0.5	0.254	-	978
	75–120	9.0	0.07	0.012	6	3.7	-	-	-	-	-	-	-	-	6.0	21.8	28.2	12.0	34.8	4.8	5.2	0.170	-	979
	120–130	9.2	0.09	0.007	13	1.4	14.6	3.7	0.03	0.11	6.3	24.7	20.8	100	54.2	42.8	15.4	7.0	31.9	4.0	n.d.	0.370	-	980
	130–160	9.2	0.05	0.002	25	0.8	-	-	-	-	-	-	-	-	18.8	17.7	24.6	9.3	42.5	5.8	2.2	0.470	-	981
	160–170	9.3	-	-	-	0.2	-	-	-	-	-	-	-	-	43.3	57.8	9.2	3.5	27.8	3.1	n.d.	0.320	-	982
	170–190	8.5	-	-	-	0.2	-	-	-	-	-	-	-	-	0.1	3.8	14.1	18.8	55.7	8.0	0.3	0.296	-	983
P253	0–15	5.4	1.00	0.060	17	0.7	1.7	0.6	0.10	0.06	0.12	2.6	5.9	44	0.0	42.6	40.7	4.3	9.9	1.1	nil	0.163	-	N2016
	15–55	6.0	0.23	0.015	15	0.1	0.4	0.2	0.01	0.04	0.05	0.7	1.1	64	0.1	55.1	35.7	3.0	4.9	0.3	nil	0.206	-	2017
	55–75	5.2	0.23	-	-	0.1	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-	-	0.071	-	2018
	75–105	5.5	-	-	-	0.0	1.5	1.2	0.05	0.04	0.14	2.9	4.0	73	0.1	34.8	26.2	3.8	35.0	2.1	nil	0.023	-	2019
	105–150	5.4	-	-	-	0.0	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	0.051	-	2020
	150–190	5.5	-	-	-	0.0	2.4	1.9	0.03	0.00	0.38	4.7	9.9	47	0.5	32.0	18.0	3.0	45.6	2.5	nil	0.038	-	2021
(g) Grey sandy clays on sloping ground																								
L6	0–30	5.4	1.77	0.090	20	4.0	8.1	3.4	0.17	0.21	0.75	12.6	15.7	80	0.1	26.1	34.3	13.0	21.3	3.4	nil	0.135	-	N1990
	30–60	5.8	0.98	0.048	20	0.2	-	-	-	-	-	-	-	-	0.9	-	-	-	-	-	-	0.108	-	1991
	60–90	6.5	-	-	-	0.0	5.1	3.7	0.03	0.14	0.68	9.7	10.1	96	0.6	24.8	30.3	9.8	27.3	3.8	nil	0.070	-	1992

TABLE 14 - ANALYSES OF SOILS FROM THE LOWER RUFIJI

Profile No.	Horizon cm.	pH	Organic C %	Total N %	C/N	Avail. P mg. %	Exchangeable cations m.e./100 g. soil: Ca	Mg	Mn	K	Na	Total	Capacity	Satn. %	Stones and gravel %	Mechanical analysis. % of fine earth fraction: Coarse sand	Fine sand	Silt	Clay	Moisture	$CaCO_3$	Conductivity: 1:5 ext. m-mhos	Satn. ext. m-mhos	Lab. No.
SANDY LEVEE																								
R2	0-5	6.1	2.21	0.143	15	32.5	4.8	2.2	0.15	1.80	0.22	9.2	15.6	59	0.6	27.4	50.7	7.3	9.8	2.6	nil	0.170	-	N789
	5-22	5.9	0.30	0.026	12	26.3	2.9	1.5	0.08	0.58	0.16	5.1	5.6	91	0.7	36.6	52.8	2.4	6.3	1.2	nil	0.115	-	790
	22-45	6.8	0.09	0.007	13	16.8	2.1	1.1	0.03	0.38	0.11	3.7	3.9	95	0.1	8.0	85.9	0.8	3.8	0.8	nil	0.110	-	791
	45-80	7.0	0.05	0.006	9	13.8	-	-	-	-	-	-	-	-	0.0	28.3	67.0	0.3	4.0	0.7	nil	0.090	-	792
	80-140	6.1	0.53	0.064	8	4.4	20.8	9.3	0.07	0.83	0.60	31.6	32.9	96	0.1	7.0	10.1	25.4	51.0	8.6	nil	0.065	-	793
	140-158	6.0	0.21	0.025	8	6.9	-	-	-	-	-	-	-	-	0.0	0.3	65.9	8.8	21.3	4.1	nil	0.070	-	794
	158-200	5.8	0.24	-	-	5.3	-	-	-	-	-	-	-	-	0.0	0.9	22.9	17.5	51.2	8.3	nil	0.080	-	795
R7	0-10	7.2	2.13	0.115	19	17.0	11.9	3.4	0.06	0.61	0.48	16.5	16.7	99	0.0	5.4	66.4	10.5	14.4	2.6	nil	0.155	-	N803
	10-18	7.6	1.05	0.060	18	16.4	11.3	4.3	0.05	0.32	0.33	16.3	17.0	96	0.0	0.9	67.6	10.5	18.0	3.6	nil	0.066	-	804
	18-22	7.3	1.01	0.085	12	4.9	-	-	-	-	-	-	-	-	0.0	8.5	33.2	24.0	28.6	6.4	nil	0.075	-	805
	22-30	7.3	0.71	0.045	16	13.3	8.6	2.8	0.12	0.25	0.13	11.9	12.5	95	0.0	37.7	35.2	9.3	15.7	2.8	nil	0.060	-	806
	30-43	7.4	0.19	-	-	10.4	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.043	-	807
	43-58	7.4	0.30	-	-	13.9	7.1	3.0	0.06	0.20	0.13	10.5	10.5	100	0.0	5.0	75.3	4.5	12.2	2.4	nil	0.048	-	808
	58-63	7.4	0.53	0.046	12	2.8	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.070	-	809
	63-85	7.6	0.19	-	-	10.7	6.1	2.4	0.03	0.17	0.15	8.8	8.4	100	0.0	24.7	53.2	6.5	11.3	2.0	nil	0.055	-	810
	85-122	7.8	0.36	0.027	13	10.9	-	-	-	-	-	-	-	-	0.0	2.1	76.3	6.0	12.7	2.7	nil	0.052	-	811
	122-150	7.7	0.83	-	-	10.0	18.0	3.6	0.01	0.55	2.67	24.8	28.5	87	0.0	-	-	-	-	-	-	0.080	-	812
	150-190	7.6	-	-	-	0.4	-	-	-	-	-	-	-	-	0.0	0.3	9.3	26.3	55.9	9.6	nil	0.112	-	813
P160	0-12	7.1	0.91	0.078	12	17.5	7.5	2.4	0.05	0.62	0.11	10.7	11.4	94	0.0	12.0	48.2	14.8	20.4	3.2	nil	0.051	-	N946
	12-25	7.3	0.51	0.039	13	5.5	7.1	2.9	0.01	0.46	0.16	10.6	11.1	96	0.0	18.1	58.1	7.0	12.1	2.0	nil	0.031	-	947
	25-70	7.5	0.06	0.007	9	4.1	2.4	1.0	0.01	0.08	0.06	3.5	3.8	92	0.0	25.0	69.4	1.5	4.0	0.7	nil	0.020	-	948
	70-140	7.3	0.05	0.004	12	5.3	-	-	-	-	-	-	-	-	0.0	14.8	78.5	2.0	2.2	0.8	nil	0.024	-	949
	140-200	7.3	-	-	-	9.7	-	-	-	-	-	-	-	-	0.0	12.6	81.3	1.8	1.9	0.7	nil	0.024	-	950
	200-205	6.9	0.42	0.052	8	1.5	-	-	-	-	-	-	-	-	0.0	0.7	19.7	31.5	43.3	6.6	nil	0.071	-	951
CLAYEY LEVEE																								
B15	0-12	6.7	2.16	0.129	17	8.8	16.2	4.5	0.14	1.51	0.47	22.5	26.9	84	0.0	2.5	46.9	18.3	26.6	5.0	nil	0.100	-	N872
	12-28	6.6	0.69	-	-	6.6	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.035	-	-
	28-50	6.2	0.72	-	-	4.7	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.070	-	-
	50-75	7.3	0.11	0.013	8	8.5	3.6	2.2	0.04	0.11	0.13	6.1	6.7	91	0.0	6.2	80.8	2.3	8.6	1.6	nil	0.030	-	873
	75-85	7.5	0.30	0.033	9	4.1	2.8	2.7	0.06	0.11	1.04	6.8	7.7	88	0.0	0.6	38.6	21.3	33.4	6.9	nil	0.040	-	874
	85-155	7.2	0.57	-	-	4.3	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.080	-	-
	155-165	7.3	0.27	-	-	4.6	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.080	-	875
	165-190	7.5	0.09	0.014	6	4.2	4.0	2.4	0.06	0.07	0.84	7.4	7.3	100	0.0	2.2	84.0	1.3	7.7	1.8	nil	0.050	-	876
ALLUVIAL CLAY																								
B5	0-8	6.1	1.50	0.109	14	7.3	21.8	6.8	0.09	1.25	0.48	30.4	42.1	72	0.0	0.8	4.8	28.0	58.1	9.3	nil	0.128	-	N796
	8-25	6.0	0.77	0.067	11	5.0	19.0	6.6	0.12	0.35	0.44	26.4	39.0	68	0.0	0.3	5.8	25.5	58.8	10.0	nil	0.087	-	797
	25-38	6.1	0.41	0.053	8	3.9	18.7	3.6	0.12	0.18	0.67	23.3	31.5	74	0.0	0.5	23.7	22.0	46.5	8.3	nil	0.092	-	798
	38-75	5.8	0.41	0.060	7	4.5	-	-	-	-	-	-	-	-	0.0	2.3	5.8	27.5	53.8	10.9	nil	0.098	-	799
	75-100	6.1	0.37	-	-	4.1	20.6	4.2	0.10	0.31	0.65	25.9	36.9	70	0.0	7.7	10.1	16.3	58.2	9.9	nil	0.110	-	800
	100-135	7.2	0.07	0.010	7	5.6	2.1	2.0	0.05	0.09	0.30	4.5	6.6	68	0.0	42.6	43.8	2.0	10.2	1.8	nil	0.098	-	801
	135-200	7.7	-	-	-	4.7	-	-	-	-	-	-	-	-	0.0	1.9	8.9	23.5	58.6	10.3	nil	0.125	-	802
B8	0-8	6.4	1.53	0.174	9	2.4	21.1	6.6	0.54	0.58	1.4	30.2	37.5	81	0.0	0.1	19.3	22.3	49.7	8.4	nil	0.112	-	N814
	8-16	5.9	1.50	0.174	9	2.8	20.6	6.0	0.61	0.39	1.6	28.6	37.5	76	0.0	0.2	16.3	21.5	52.2	8.9	nil	0.103	-	815
	16-22	5.9	1.00	-	-	4.3	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	-	-	816
	22-50	7.0	0.53	0.059	9	2.6	18.0	9.2	0.09	0.36	8.0	35.7	38.1	94	0.0	3.0	10.3	21.8	55.8	10.1	nil	0.130	-	817
	50-70	9.0	0.29	-	-	2.8	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	0.32	0.260	-	818
	70-90	9.6	0.10	0.013	8	4.9	3.3	2.1	0.00	0.10	4.4	9.8	7.7	100	0.0	44.1	39.4	2.3	12.5	2.1	0.48	0.200	-	819
	90-130	8.8	-	-	-	4.4	-	-	-	-	-	-	-	-	0.0	25.9	59.4	3.3	9.4	1.9	nil	0.100	-	820
P207	0-15	5.9	1.41	0.066	21	1.7	21.8	5.0	0.16	1.46	0.5	28.9	37.8	76	0.0	1.9	6.7	29.8	51.1	7.4	nil	0.044	-	N1268
	15-40	6.3	0.74	0.063	12	1.0	21.8	4.9	0.06	0.71	0.8	28.3	36.7	77	0.0	1.2	10.7	30.3	50.4	7.5	nil	0.026	-	1269
	40-75	6.5	0.74	0.055	13	0.8	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.027	-	1270
	75-125	5.6	0.55	-	-	0.3	22.0	5.5	0.07	0.43	2.5	30.4	41.2	74	0.0	0.2	4.9	23.0	65.5	7.7	nil	0.032	-	1271
	125-180	7.2	-	-	-	0.0	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.055	-	1272
	180-190	8.4	-	-	-	0.7	13.7	6.0	0.00	0.18	1.6	21.5	18.4	100	0.0	0.5	57.4	10.3	25.7	3.4	nil	0.048	-	1273
B17	0-12	6.3	2.40	0.183	13	5.5	14.5	13.3	0.48	1.92	1.0	31.2	41.3	76	0.0	1.8	5.3	26.0	56.3	10.4	nil	0.085	-	N877
	12-30	6.0	0.60	-	-	4.1	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.150	-	-
	30-60	5.7	0.60	0.045	13	4.4	12.3	16.7	0.63	0.61	5.4	35.6	39.9	89	0.0	1.0	3.8	14.5	70.0	11.6	nil	0.600	-	878
	60-96	4.7	0.64	-	-	4.1	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	2.100	6.3	879
	96-140	4.5	0.30	0.036	8	4.5	2.8	5.6	0.18	1.14	4.6	14.3	32.4	44	0.0	0.3	9.6	19.8	61.2	11.4	nil	1.750	7.4	880
	140-190	4.2	0.41	0.044	9	4.6	1.5	5.7	0.17	1.38	4.0	12.7	30.8	41	0.0	0.8	18.5	18.8	54.4	9.6	nil	2.100	9.4	881

TABLE 14 (CONTINUED) - ANALYSES OF SOILS FROM THE LOWER RUFIJI

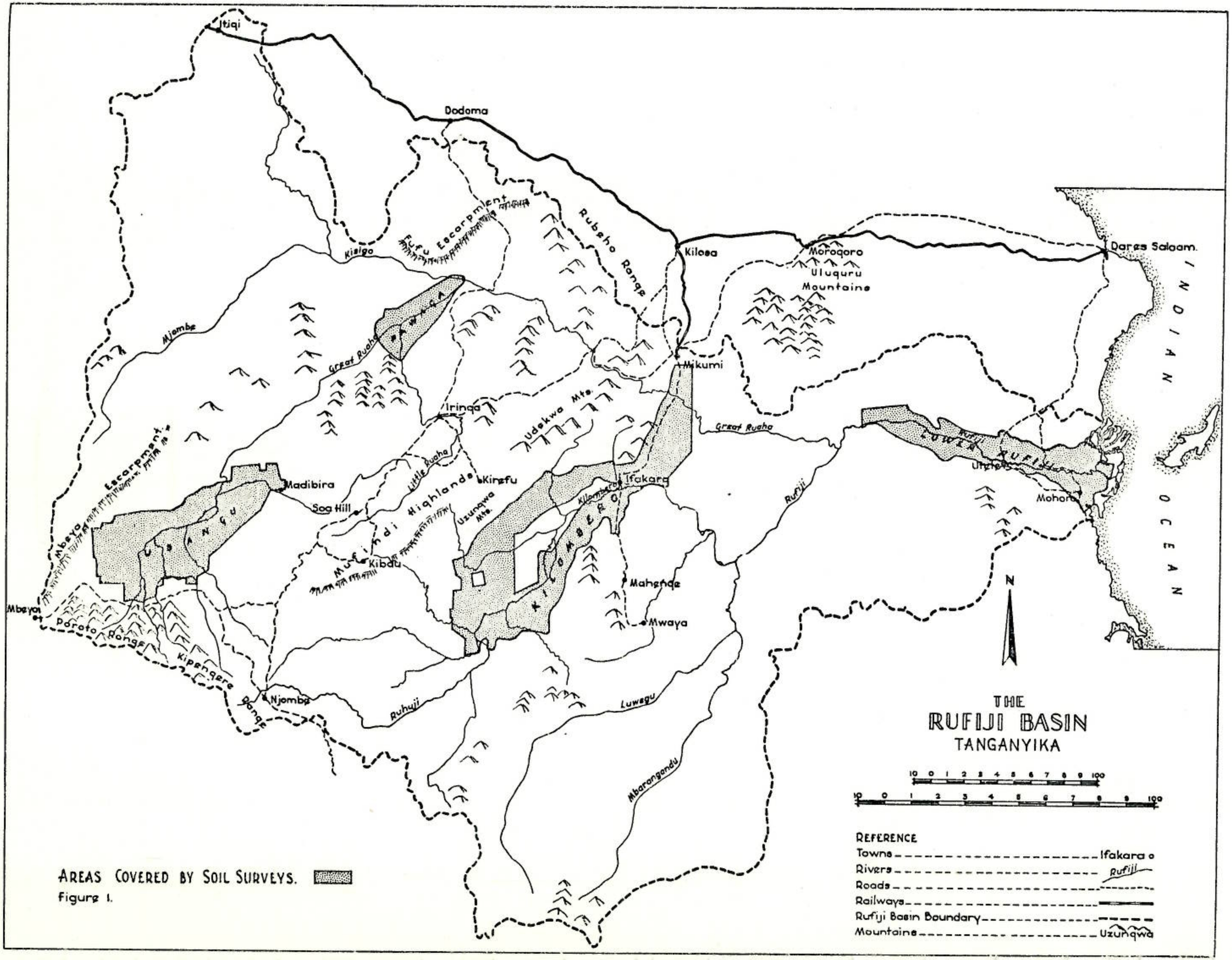
Profile No.	Horizon cm.	pH	Organic C %	Total N %	C/N	Avail. P mg. %	Exchangeable cations m.e./100 g. soil: Ca	Mg	Mn	K	Na	Total	Capacity	Satn. %	Stones and gravel %	Mechanical Analysis. % of fine earth fraction: Coarse sand	Fine sand	Silt	Clay	Moisture	$CaCO_3$	Conductivity 1:5 ext. m-mhos	Satn. ext. m-mhos	Lab No.
ALLUVIAL CLAY (Continued)																								
R20	0-8	6.9	2.44	0.155	16	8.8	10.0	5.0	0.28	1.06	1.2	17.5	23.0	76	0.0	1.3	50.2	18.8	24.4	4.5	nil	0.095	-	N887
	8-22	8.1	0.93	0.088	11	4.4	16.2	4.4	0.02	0.44	3.2	24.4	26.4	92	0.0	1.9	42.0	16.0	33.1	6.4	nil	0.165	0.7	888
	22-50	8.6	0.42	0.043	10	5.0	14.3	3.1	0.00	0.24	3.9	21.6	23.9	90	0.0	2.1	44.0	16.3	32.4	6.2	nil	0.200	0.6	889
	50-55	8.2	0.16	-	-	7.0	-	-	-	-	-	-	-	-	0.0	6.3	74.4	8.0	10.4	2.3	nil	0.120	-	890
	55-70	8.1	0.17	0.023	7	3.8	8.6	4.4	0.00	0.17	3.0	16.2	14.7	100	0.0	1.4	68.9	7.8	19.1	3.7	nil	0.180	-	891
	70-95	8.9	0.35	-	-	2.9	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.240	-	892
	95-120	8.6	0.41	0.043	10	2.9	16.2	4.5	0.00	0.50	9.8	31.0	27.5	100	0.0	2.1	9.2	17.3	62.8	10.9	nil	0.250	-	893
	120-155	8.2	0.26	-	-	2.5	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.235	-	894
	155-175	7.0	-	-	-	3.8	-	-	-	-	-	-	-	-	1.2	84.4	12.4	1.3	2.3	0.4	nil	0.100	-	895
	175-210	6.8	-	-	-	6.4	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.135	-	896
R24	0-20	7.6	1.76	0.132	13	5.4	14.4	10.7	0.29	1.2	1.0	27.6	36.5	76	0.0	0.1	6.2	15.8	66.6	10.5	nil	0.084	-	N900
	20-70	5.8	0.96	0.094	10	6.7	12.8	4.0	0.21	1.2	2.4	20.6	37.3	55	0.0	0.2	6.9	15.3	65.3	10.9	nil	0.250	-	901
	70-100	5.3	0.24	-	-	3.8	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	1.300	1.6	902
	100-180	5.3	0.12	-	-	4.4	7.4	4.3	0.01	5.4	7.1	24.2	32.4	75	0.0	0.3	12.9	20.0	56.5	10.8	nil	0.300	-	903
ALLUVIAL CLAY MIXED WITH SANDY COLLUVIAL MATERIAL																								
R10	0-8	6.0	3.22	0.207	16	3.9	25.3	10.3	0.39	1.39	0.54	37.9	43.9	86	0.0	3.3	8.8	20.5	57.8	8.7	nil	0.124	-	N821
	8-18	5.8	1.79	0.145	12	2.8	20.7	7.5	0.29	0.90	0.43	29.8	33.4	89	0.0	7.2	22.8	12.8	49.2	7.0	nil	0.075	-	822
	18-38	5.9	0.43	0.038	11	2.1	-	-	-	-	-	-	-	-	0.0	34.5	23.7	7.5	30.1	5.1	nil	0.070	-	823
	38-85	6.4	0.20	0.027	7	1.8	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.072	-	824
	85-100	6.8	0.13	0.015	9	1.6	8.6	2.5	0.01	0.17	0.35	11.6	11.6	100	0.0	41.9	19.6	5.3	29.2	5.3	0.64	0.067	-	825
	100-165	8.0	0.11	0.011	10	3.5	-	-	-	-	-	-	-	-	8.7	-	-	-	-	-	-	0.155	-	826
	165-180	8.1	0.09	-	-	4.2	-	-	-	-	-	-	-	-	4.4	24.7	20.5	11.0	37.6	6.8	1.29	0.178	-	827
SANDY CLAYS HARDENING ON DRYING																								
R12	0-3	7.1	1.51	0.116	13	2.9	4.2	2.7	0.22	0.51	3.2	10.8	12.2	89	0.0	38.8	29.7	9.0	17.9	3.0	nil	0.170	4.9	N828
	3-10	7.6	0.35	0.035	10	2.5	-	-	-	-	-	-	-	-	0.0	36.7	30.1	7.3	22.9	3.5	nil	0.150	-	829
	10-17	9.5	0.21	0.022	10	2.1	7.8	4.6	0.01	0.64	11.1	24.1	21.2	100	0.0	23.7	25.8	9.0	35.0	5.9	0.91	0.420	5.7	830
	17-45	9.6	0.17	-	-	2.5	-	-	-	-	-	-	-	-	8.2	-	-	-	-	-	-	0.700	-	831
	45-90	10.1	0.03	0.005	6	1.4	1.2	0.7	0.00	0.41	20.1	22.4	19.3	100	9.8	28.0	27.8	8.6	31.0	5.4	1.50	0.890	5.7	832
	90-140	9.9	-	-	-	1.5	-	-	-	-	-	-	-	-	9.3	-	-	-	-	-	-	0.980	-	833
	140-190	9.7	0.04	0.007	6	1.8	3.8	2.5	0.00	0.25	23.4	30.9	25.1	100	3.0	16.5	31.8	12.5	34.9	6.6	1.28	0.830	9.0	834

N.B. Soluble salts were not removed before determination of exchangeable cations.

Profile No.	Horizon cm.	pH	Organic C %	Total N %	C/N	Avail. P mg. %	Ca	Mg	Mn	K	Na	Total	Capacity	Satn. %	Stones and gravel %	Coarse sand	Fine sand	Silt	Clay	Moisture	$CaCO_3$	1:5 ext. m-mhos	Satn. ext. m-mhos	Lab No.
ALLUVIAL CLAY OVERLYING SANDY LEVEE																								
P158	0-15	6.0	2.04	0.123	17	1.6	17.5	9.5	0.07	0.77	0.27	28.1	34.3	82	0.0	0.6	22.5	26.8	44.9	5.8	nil	0.042	-	N935
	15-30	5.9	1.20	0.068	18	0.3	14.6	9.1	0.07	0.74	0.36	24.9	33.8	74	0.0	1.3	21.8	21.8	47.2	7.3	nil	0.047	-	936
	30-45	6.1	0.51	0.049	10	0.1	10.2	5.9	0.04	0.26	0.38	16.8	20.0	84	0.0	0.7	56.2	8.8	30.1	4.0	nil	0.031	-	937
	45-75	6.3	0.14	0.025	6	0.1	7.2	4.3	0.01	0.15	0.29	12.0	14.0	86	0.0	1.5	70.8	6.3	19.1	2.9	nil	0.031	-	938
	75-115	7.1	0.12	-	-	0.4	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	0.064	-	939

TABLE 15 - ANALYSES OF SOILS FROM PANAGA

Profile No.	Horizon cm.	pH	Organic C %	Total N %	C/N	Avail. P mg. %	Ca	Mg	Mn	K	Na	Total	Capacity	Satn. %	Stones and gravel %	Coarse sand	Fine sand	Silt	Clay	Moisture	$CaCO_3$	1:5 ext. m-mhos	Satn. ext. m-mhos	Lab No.
232	0-15	7.0	0.50	0.050	10	0.8	14.8	4.9	0.02	0.34	0.38	20.4	19.6	100	2.5	30.0	28.5	7.5	30.2	4.3	0.0	0.059	-	N1636
	15-30	8.3	0.16	0.024	7	0.9	-	-	-	-	-	-	-	-	1.5	-	-	-	-	-	1.1	0.086	-	1637
	30-75	8.8	0.07	0.016	4	1.1	16.2	7.8	0.01	0.32	0.41	24.7	18.9	100	1.0	28.5	26.7	8.5	28.7	4.5	4.3	0.082	-	1638
	75-130	8.8	0.09	-	-	1.0	-	-	-	-	-	-	-	-	2.0	-	-	-	-	-	3.9	0.088	-	1639
	130-190	8.6	-	-	-	1.2	14.4	8.5	0.01	0.34	0.33	23.6	22.4	100	3.5	19.5	33.6	15.0	29.0	5.2	1.4	0.079	-	1640
235	0-15	8.7	0.37	0.044	8	1.5	27.1	6.3	0.01	0.66	1.2	35.3	n.d.	-	nil	14.3	19.4	12.3	48.6	6.8	2.3	0.145	-	N1650
	15-35	8.6	0.32	0.039	8	1.3	-	-	-	-	-	-	-	-	nil	-	-	-	-	-	2.6	0.177	-	1651
	35-100	7.8	0.26	0.036	7	1.5	37.2	14.0	0.02	0.64	6.0	57.8	n.d.	-	nil	12.8	19.3	11.5	49.2	7.4	2.6	2.101	6.9	1652
	100-170	7.9	0.12	-	-	1.2	-	-	-	-	-	-	-	-	nil	-	-	-	-	-	3.8	2.801	10.1	1653
	170-190	8.6	0.10	-	-	1.3	19.8	6.4	0.02	0.38	9.0	35.6	n.d.	-	1.0	15.6	25.8	13.5	38.4	6.6	4.7	1.318	9.2	1654
236	0-15	8.1	0.43	-	-	0.9	20.3	6.2	tr.	0.95	1.7	29.2	26.9	100	-	-	-	-	-	-	nil	0.100	-	N1655
	15-30	8.6	0.41	-	-	0.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	nil	0.168	-	1656
	30-80	8.7	0.36	-	-	1.1	10.6	15.7	tr.	0.32	3.8	30.5	n.d.	-	-	-	-	-	-	-	slight	0.589	5.1	1657
	80-130	8.3	-	-	-	1.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	slight	2.213	12.9	1658
	130-180	8.2	-	-	-	1.4	11.1	18.8	0.02	1.06	17.1	48.1	38.0	100	-	-	-	-	-	-	slight	2.839	12.8	1659



AREAS COVERED BY SOIL SURVEYS.

Figure 1.

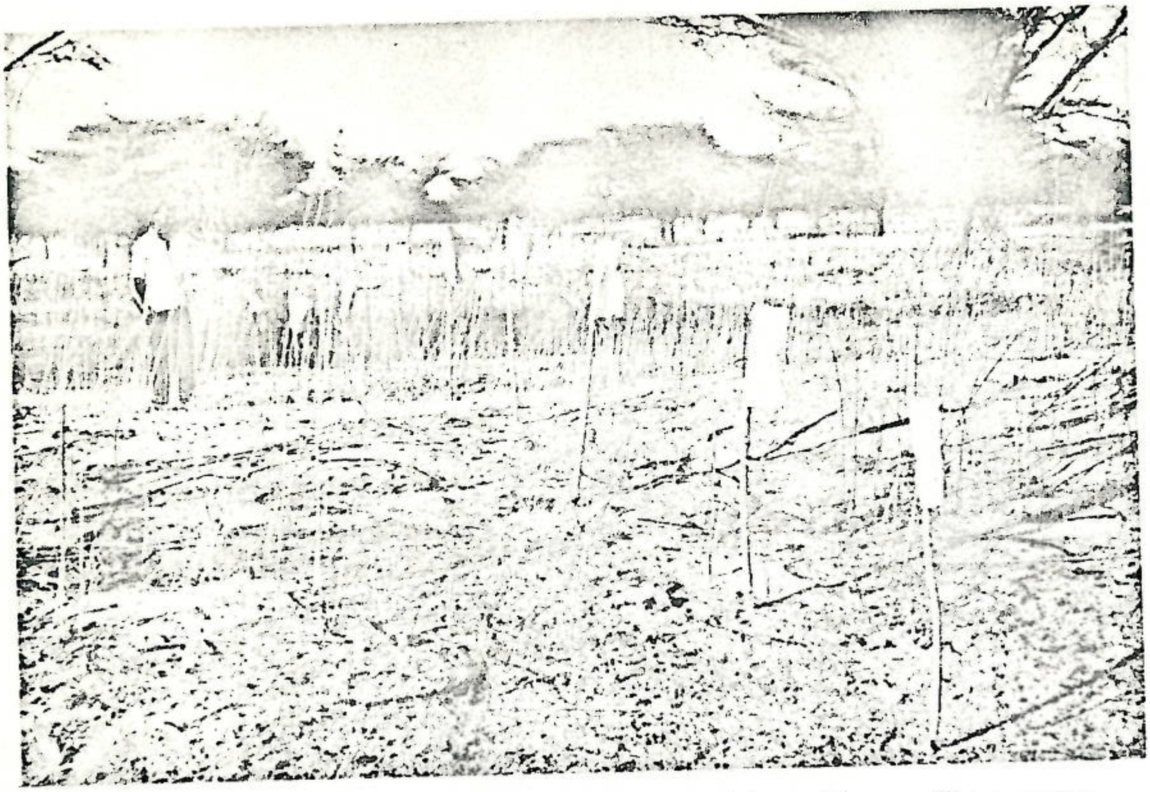


Fig. 3. Sand ridge on the site of the Mbarali Irrigation Scheme, Usangu. The trees are Acacia spirocarpa.

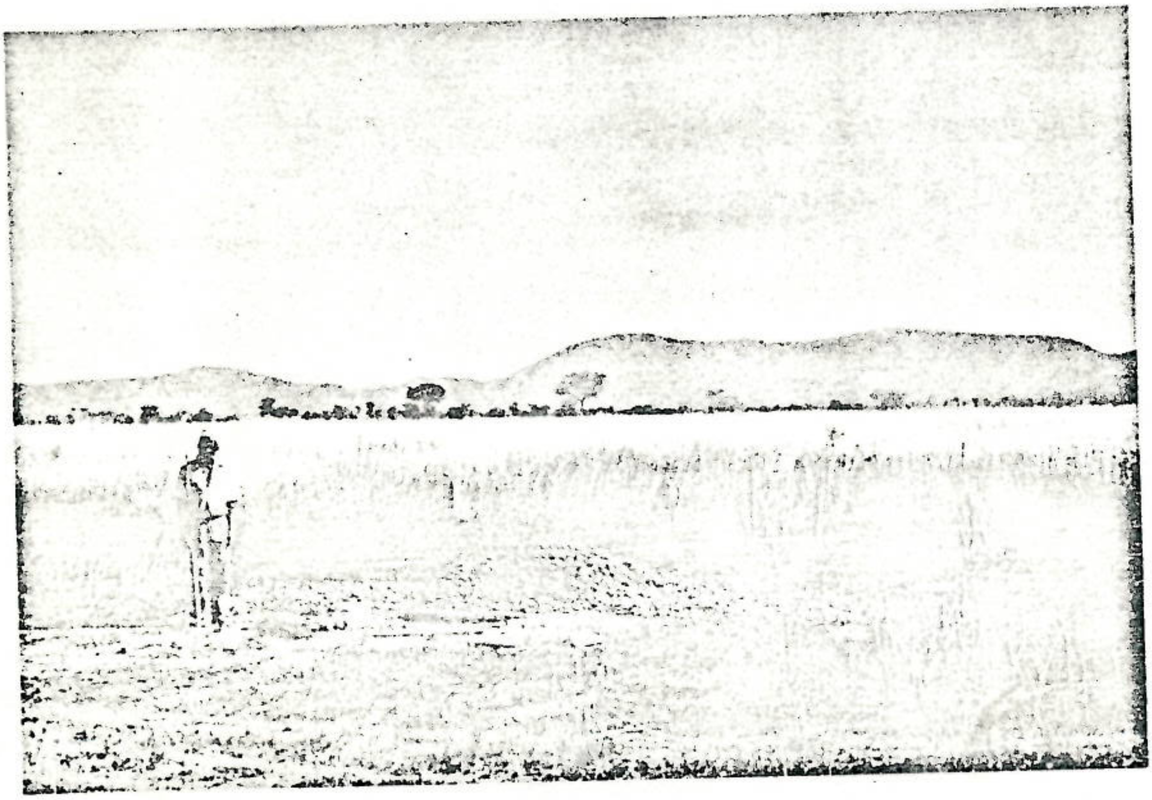
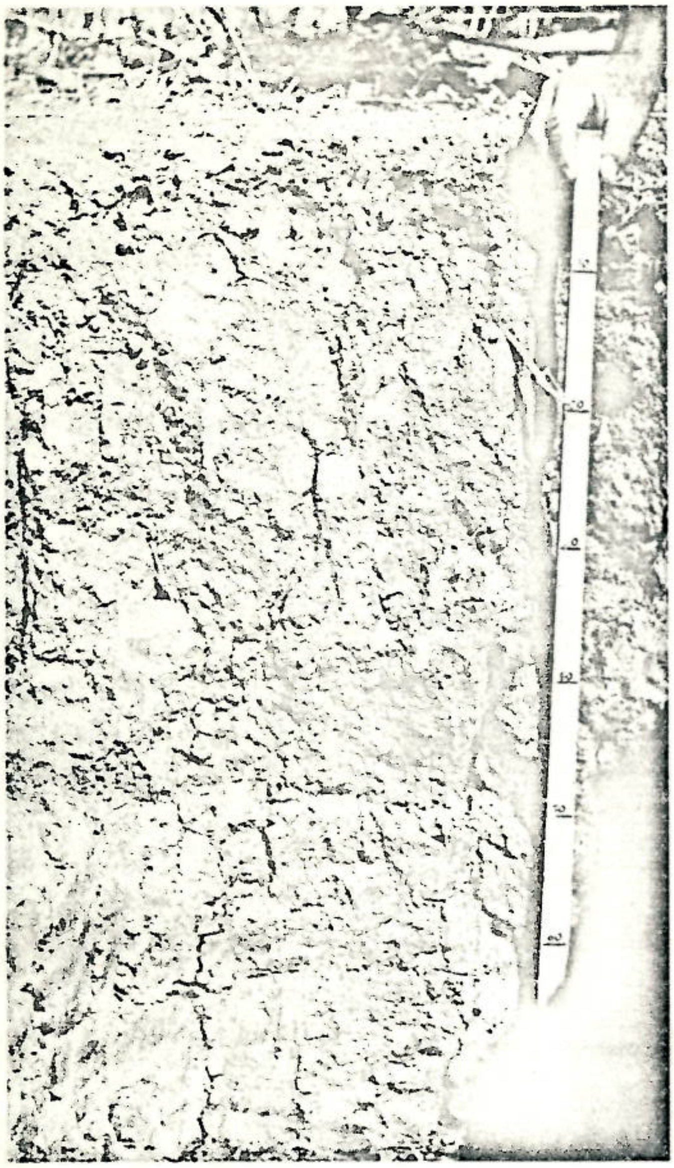


Fig. 4. Recently deposited clay in the Mwima Valley west of Madibira, Usangu. (See also figure 5).



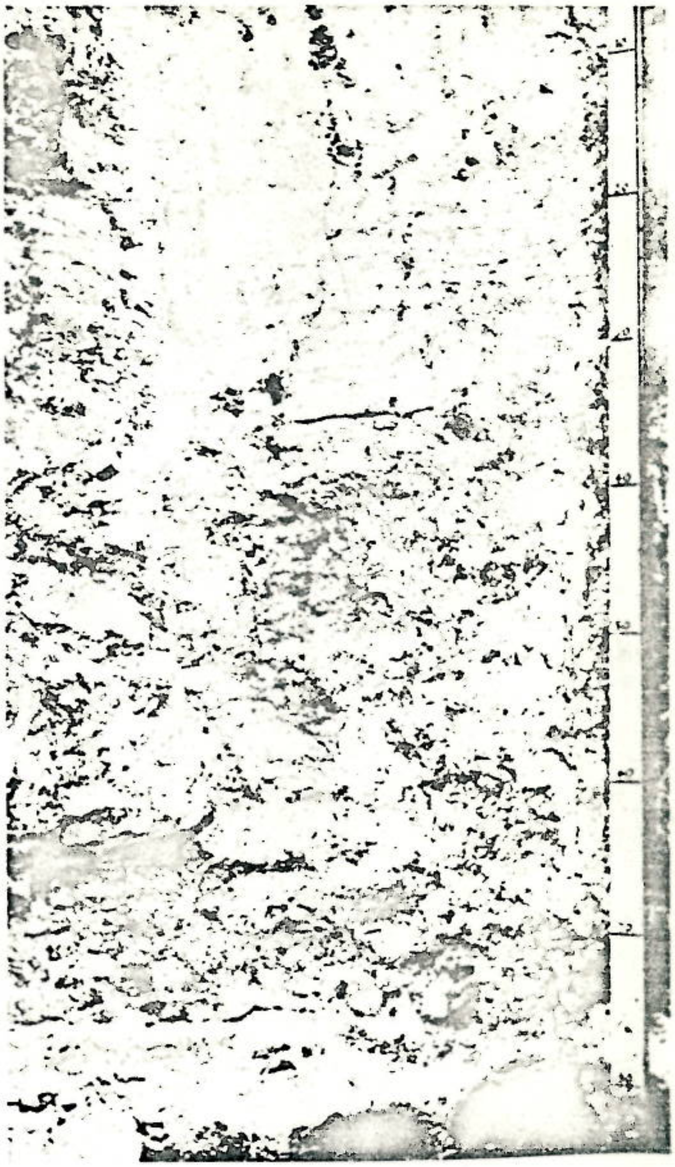
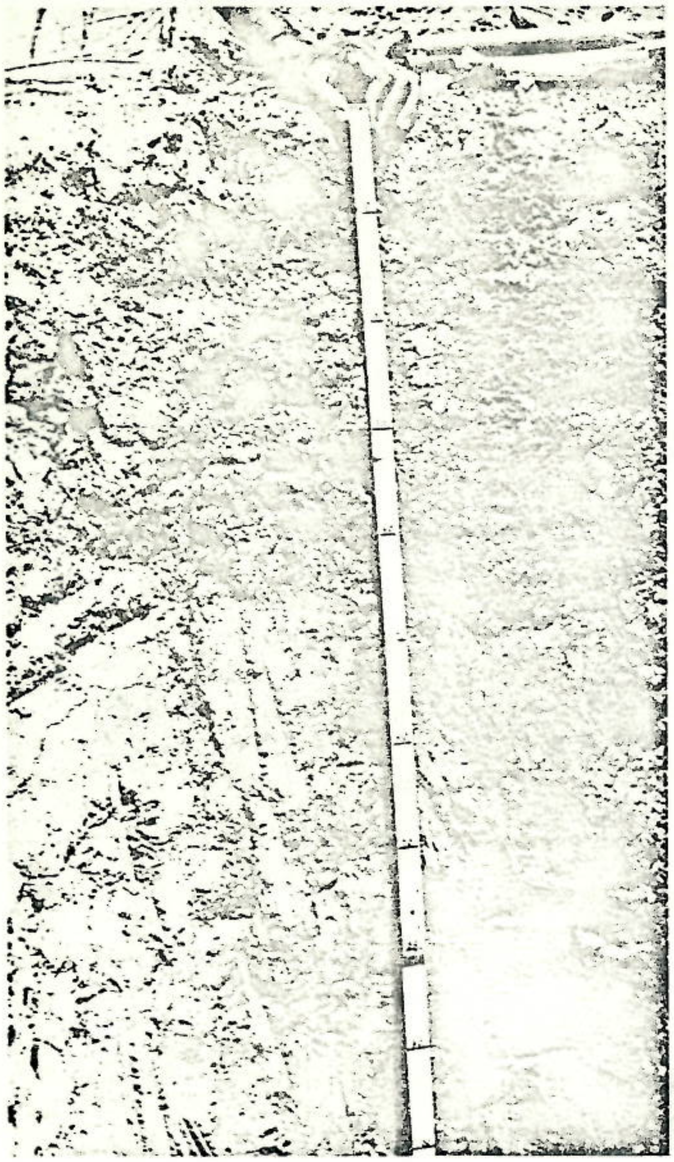


Fig. 5. Recently deposited clay profile from the site shown in figure 4. The scale is marked at 10 cm. intervals.

Fig. 6. Part of Profile 241 in Lake-bed sediments near Songwe cattle market, Usangu. The scale is marked at 10 cm. intervals and its lower end marks the top of the underlying clay at 208 cm. below ground level.



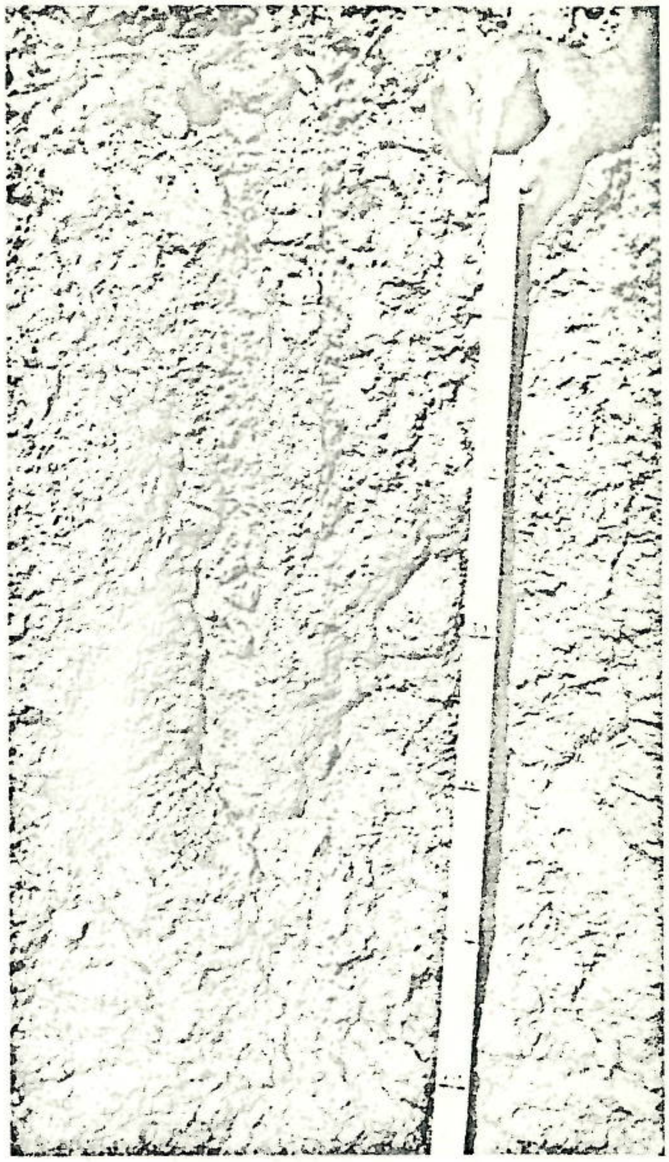


Fig. 7. Older alluvial clay with good surface structure Profile 226 from the site of the Mbarali Irrigation Scheme.

Fig. 8. Older alluvial clay with poor surface structure due to overstocking. Profile 223 from the site of the Mbarali Irrigation Scheme.

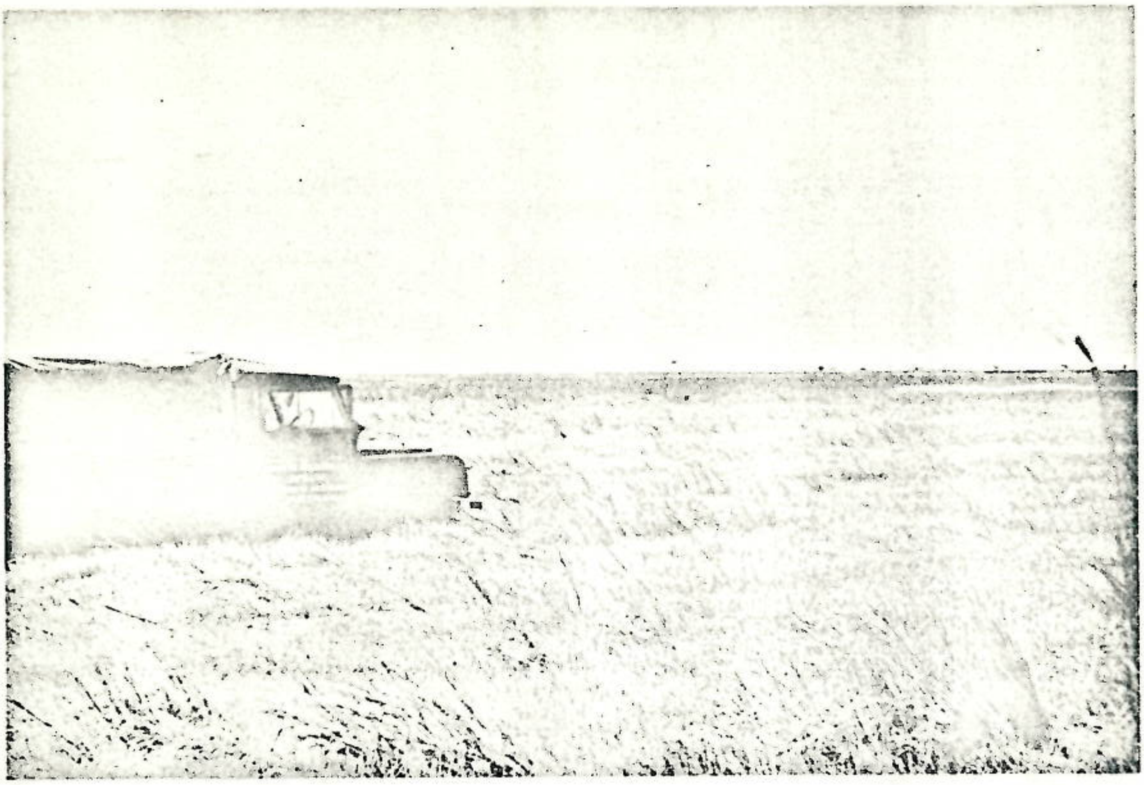


Fig. 11. Alluvial clay subject to prolonged seasonal flooding. Profile B15, near Msaka, Usangu.

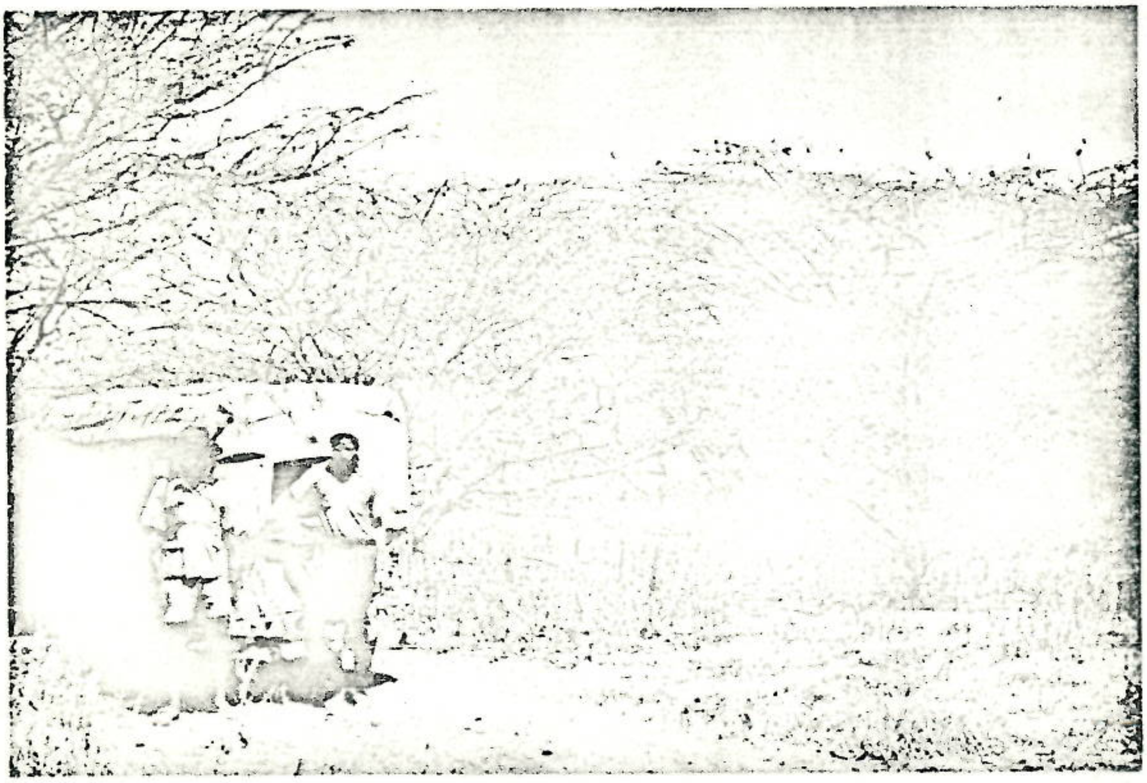


Fig. 12. Dense Acacia kirkii thicket on an alkaline clay. Near Profile B14, Usangu.

Fig. 13. Gilgai relief in alluvial clay near Wanginyi, on eastern edge of the Usangu plain.

Fig. 14. Alluvial clay subject to prolonged flooding. Profile J6 near Wanginyi, Usangu.

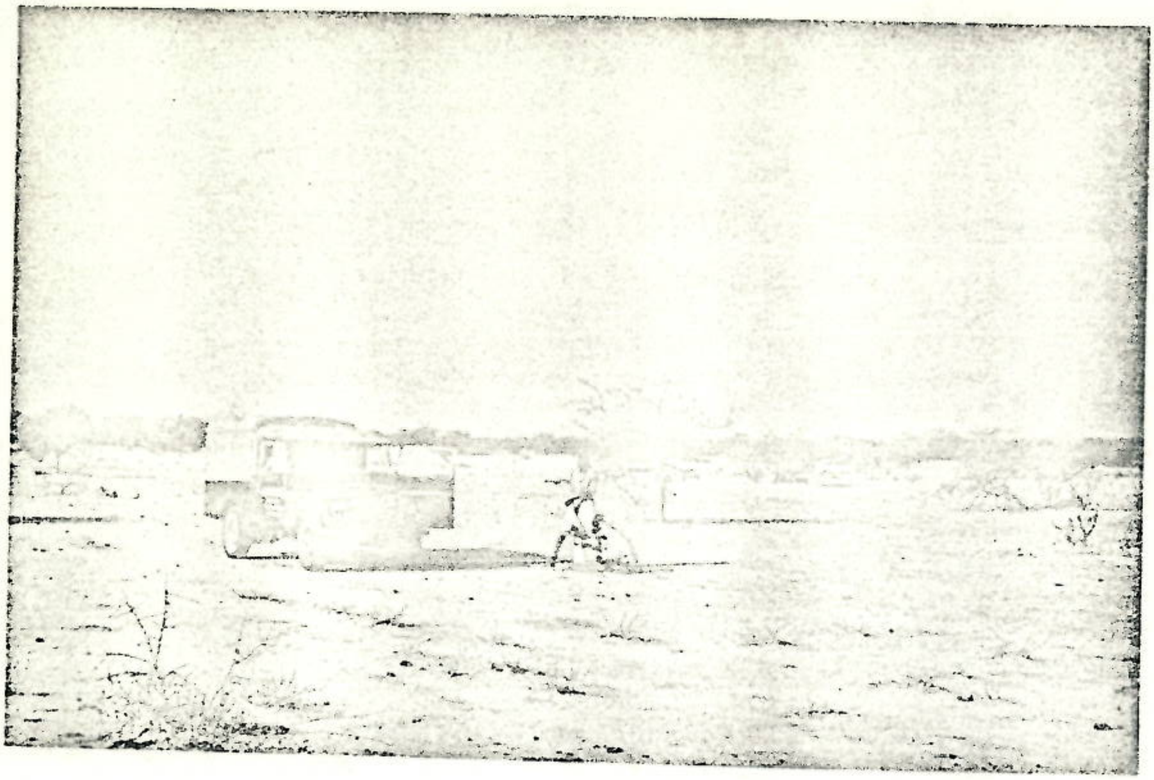


Fig. 15. Alkaline sandy loam on Usangu plain. Profile J4 near Igunda.

Fig. 16. Soils with sodium carbonate, near Kilambo, Usangu, looking south. The ground is mostly bare.

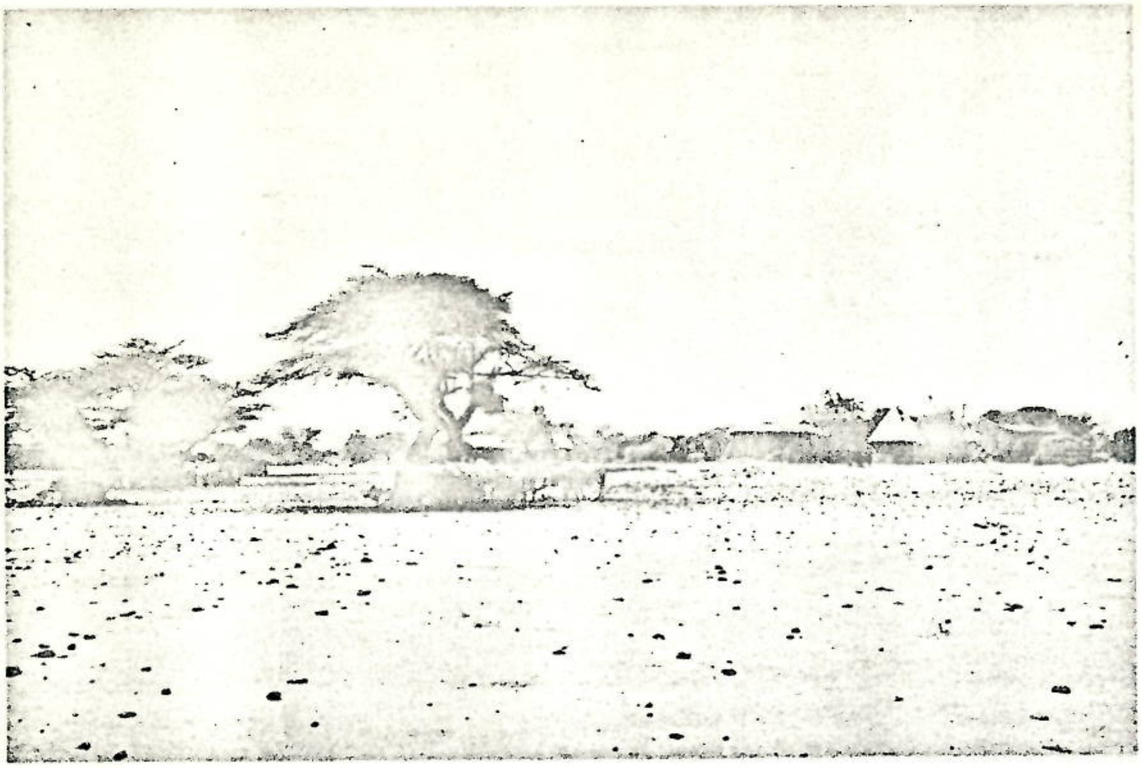


Fig. 17. Overstocked land near a village, Usangu.

Fig. 18. Subsidence near Songwe, Usangu. The "panga" (bush-knife) is about two feet long.

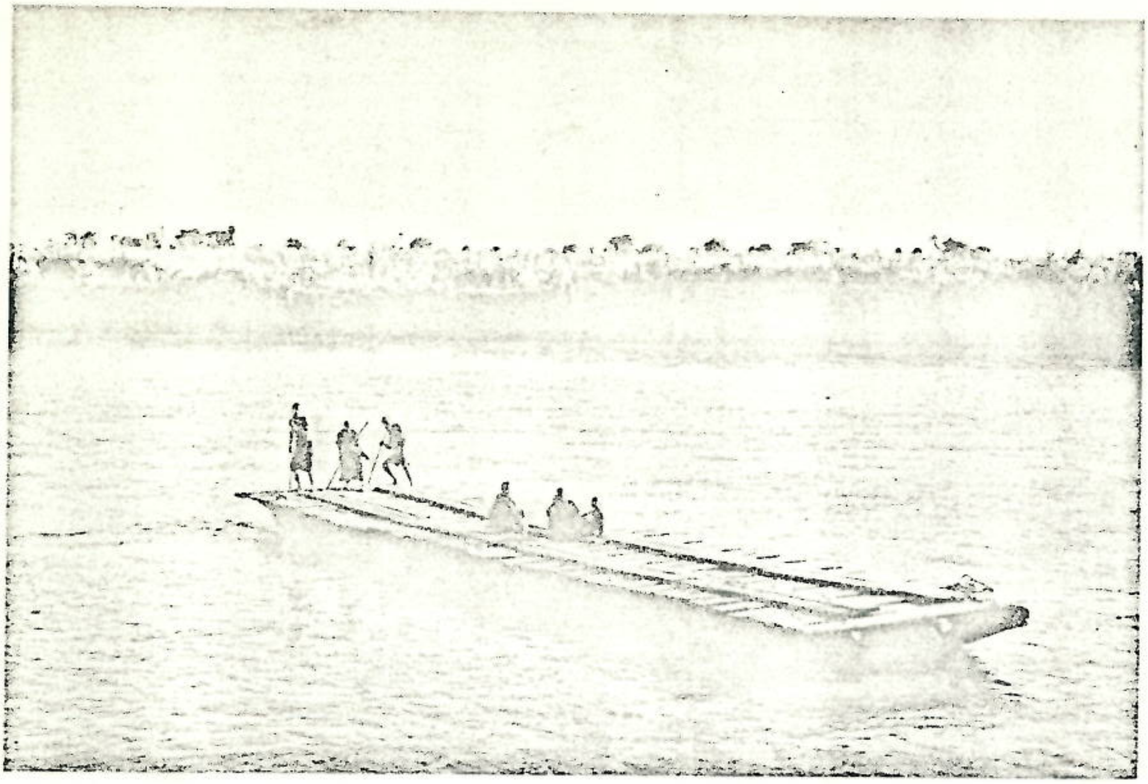


Fig. 19. Ifwema ferry on the upper Kilombero (Mnyera) River.

Fig. 20. Looking up the Kihanzi Valley from near Luavaka, Kilombero Valley.

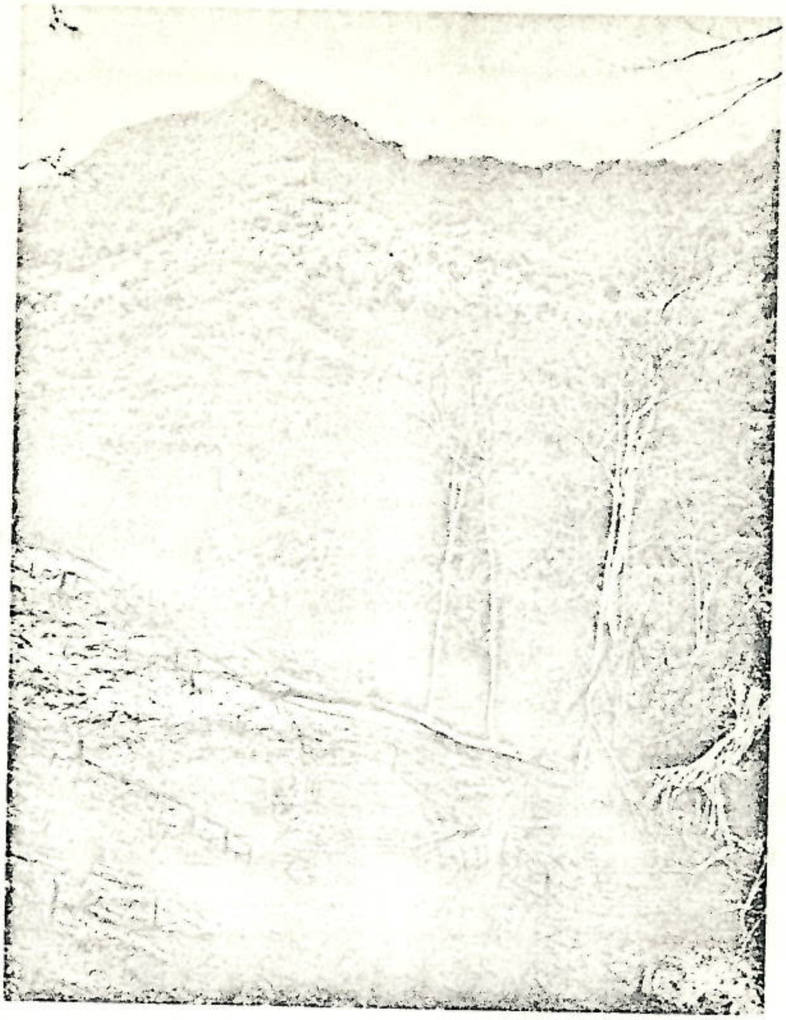


Fig. 21. Felling and burning of forest prior to cultivation on the escarpment near Mangula, Msolwa Valley.

Fig. 22. Taking a soil sample in a swamp in the Kihanzi Valley. Profile M7, a sandy loam, near Itundu.

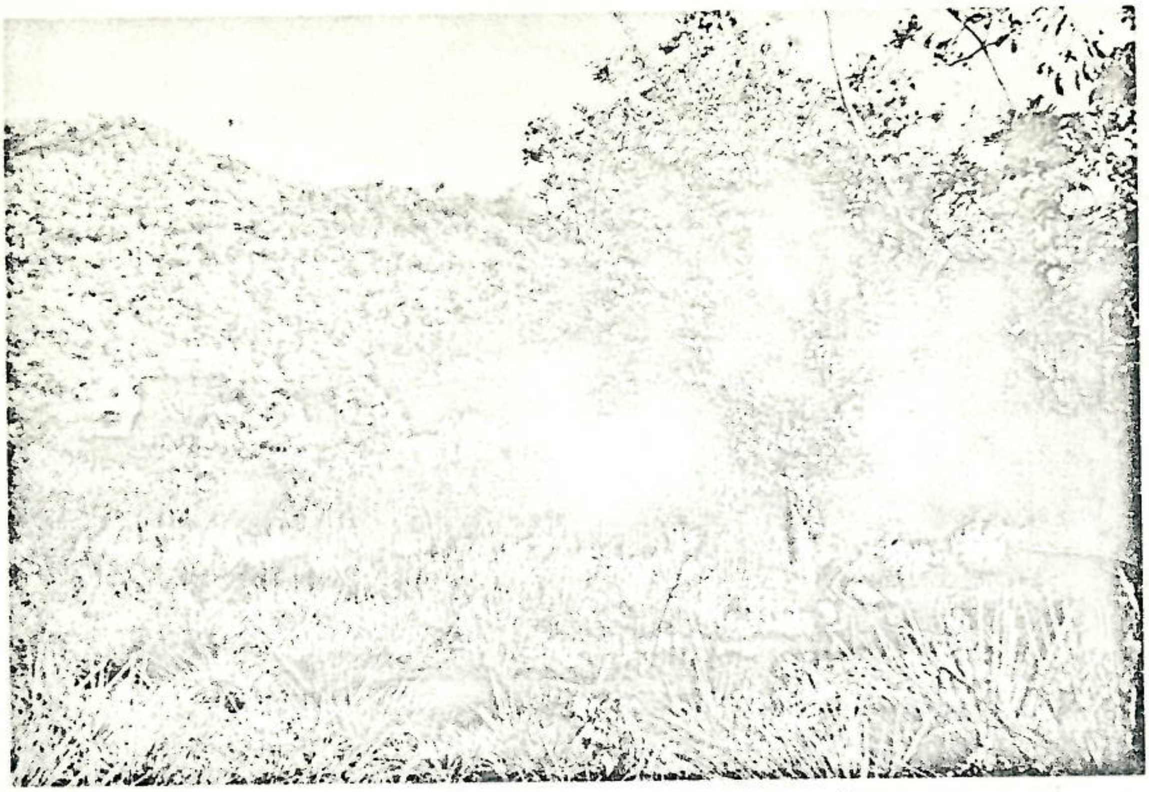
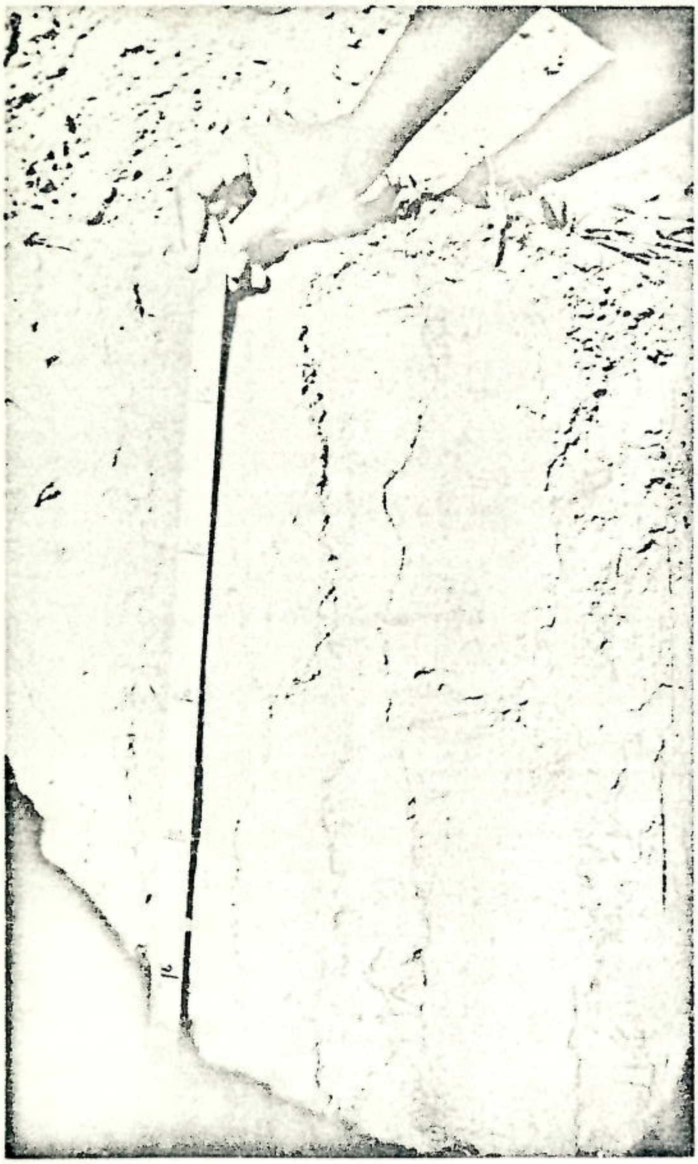


Fig. 23. The site of Profile 257, an alluvial loam, at Mkula, Msolwa Valley. (See also figure 25).

Fig. 24. Older alluvial clay on the left bank of the Msolwa River, south-east of Kidatu. Looking west towards the Southern Highlands escarpment.



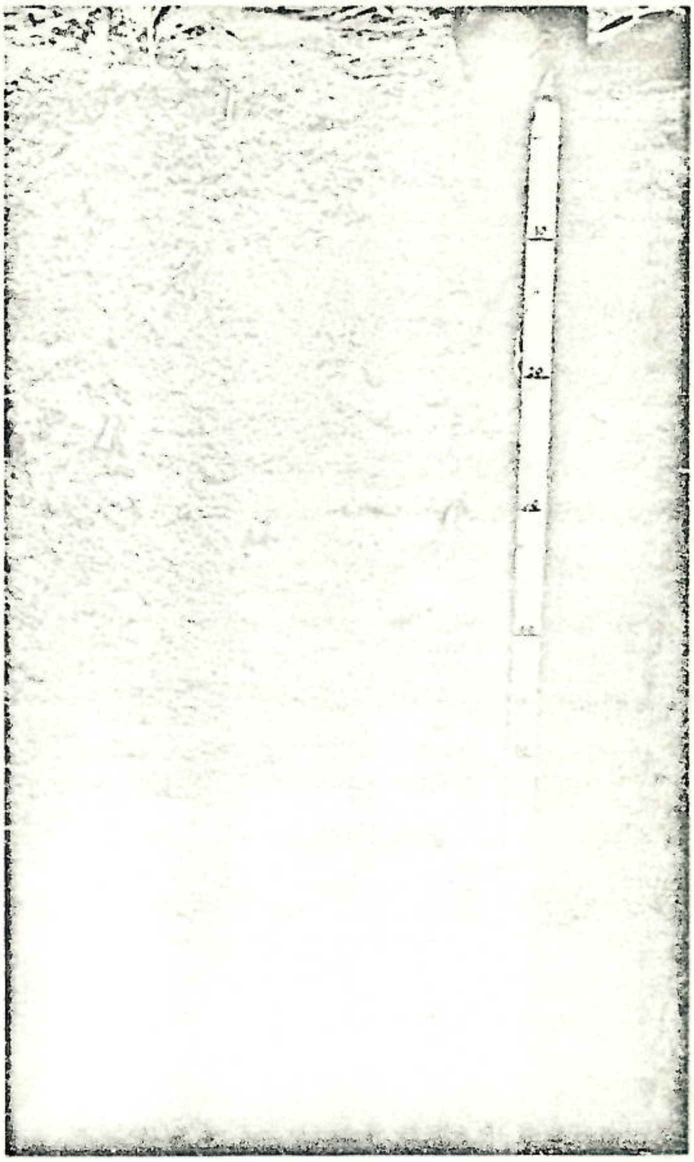


Fig. 25. Alluvial loam, Profile 257, at Mkula. (See also figure 23). The scale is marked at 10 cm. intervals.

Fig. 26. "Pale Sand" profile, Profile 253, near Kiberege, Msolwa Valley.

Fig. 27. "Clay with partial overlay of sand". Looking towards Kiberege and the Southern Highlands escarpment from near the Msolwa River (near Profile L3).

Fig. 28. Rice-fields on "low-lying sandy soil" near Profile 253, Msolwa Valley. The huts are for crop protectors when the grain is ripening; birds are the chief pest.

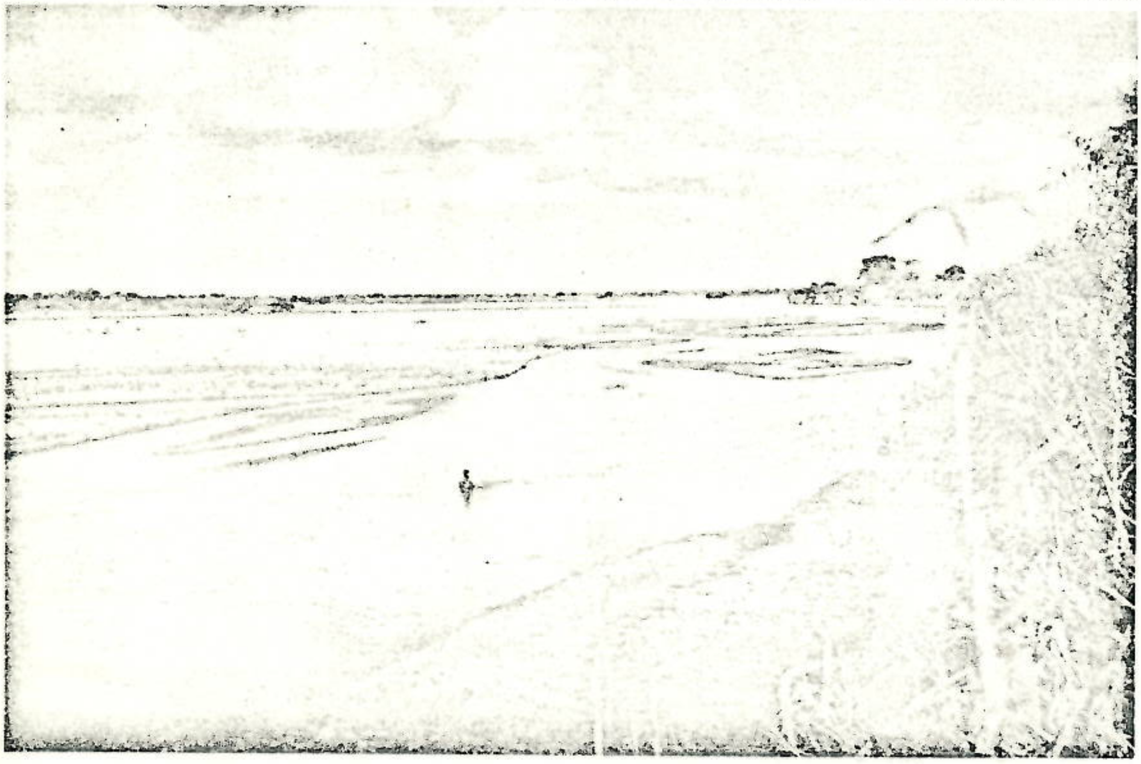


Fig. 29. In the Magombera Forest in the Msolwa Valley.

Fig. 30. The Rufiji at Zombe looking downstream.

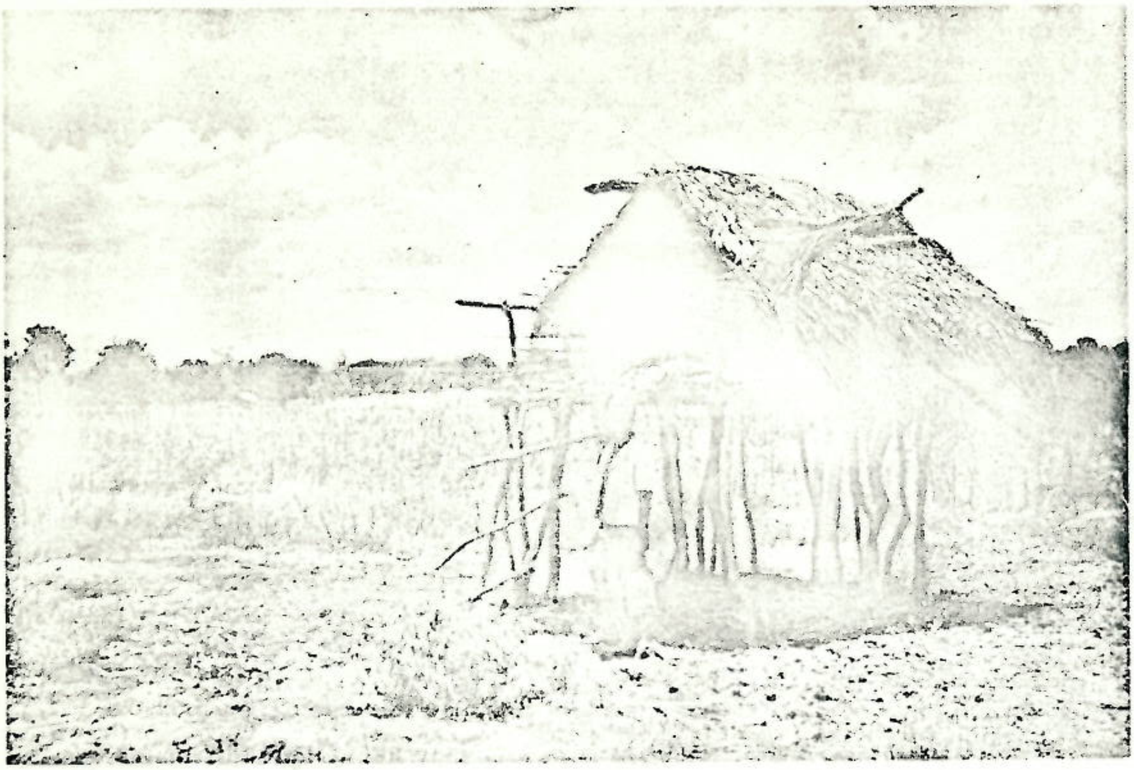


Fig. 31. Rice-fields (in the dry season) on alluvial clay at Zombe, on the Rufiji River.

Fig. 32. Preparing ground for rice on the Rufiji delta.