The Physical Environment of Northern Nyasaland

with special reference to soils and agriculture

by

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PREFACE

It is only in relatively recent years that soil and ecological surveys have become accepted as a necessary preliminary to agricultural development. Even in Britain and the United States, surveys of this nature have still reached only their early stages. In Nyasaland the first attempt at soil survey was made in 1938 by A. J. W. Hornby and others, and this was a preliminary account of the soils which could not pretend to much detailed investigation. No work on this subject was able to be done during the war, but various lines have been followed up since then. The principal work was done by G. Jackson, who was able to carry out investigations in all parts of the country. This work was done principally on an ecological basis supplemented by some work on the soils, using the methods developed in Northern Rhodesia by C. G. Trapnell. In addition to this a number of local surveys were made which had the object of planning for resettlement and development schemes. Many thousands of soil analyses have also been made, either for advisory purposes or in connection with fertilizer experiments which have been laid out all over the country.

In these ways, knowledge of a number of local soils and of their agricultural properties has been acquired without any framework to which this could be related and by means of which it could be extended. The need was therefore felt for a survey which would have as its object the assessment of the total agricultural resources of the country and the mapping of the distribution of these resources. This would provide a basis for cropping programmes, farm planning and other aspects of agricultural development, both on a national and on a local scale. It would also put on a permanent record the local knowledge of the district officers and provide a co-ordinating framework for research and experimental work.

Nyasaland is entirely dependent on agriculture for its resources and if these are to be increased and developed there is no doubt of the need for a broad approach to these problems. A narrowly based investigation which is confined to problems that are purely local in importance frequently tends to beget other problems and so, in the long run, greatly increases the amount of research work required.

The authors, in their introduction to this survey, say they intend it not only as a guide for agricultural development, but also as a scientific account of the area. The proof that these two aims need not be incompatible is shown by a study of the text, and it will be seen that both these objectives have been successfully achieved. Unless an investigation of this nature is undertaken with the consideration of all the environmental features, there can be no sound basis for proper agricultural planning.

This is the first section of a survey which is intended to cover the whole of Nyasaland in three parts. The work involved for the central part of Nyasaland is largely completed and publication will follow in a short time. A certain amount of the investigational work for the Southern Province has already been done and this final part will follow at a later date. The authors are to be congratulated on the amount of work that has been achieved in the time available. It was necessary to study and collate a mass of information that had been accumulated in the past, but the greater part of the information now recorded has been collected as a result of extensive journeys in the field.

There have been many attempts to find mineral wealth in Nyasaland, and though a number of valuable minerals have been found, so far there have been good economic reasons why these could not be developed. So far as can be seen, the future prosperity of Nyasaland depends on developing its agricultural resources to the maximum. Unless this can be done, there is no possibility of a substantial increase in the standard of living. There is reason to believe that the farmers of Nyasaland have never been so interested in development as they are today. It is, therefore, most important that such development should be planned to make the best possible use of the financial resources of the country so that they shall be developed to the full and not be wasted.

I believe that this bulletin makes an important contribution to these objectives.

S. T. HOYLE, O.B.E.
Chief Agricultural Research Officer

29th November, 1961

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This survey could not have been produced without the assistance and co-operation of a large number of people. The authors would like to express their thanks to all of these.

In the Nyasaland Department of Agriculture, particular mention should be made, firstly of the staff of the soil survey section. All the maps and diagrams in this memoir, with the exception of the coloured map of natural regions and areas, have been drawn by Mr. R. B. Mwangala. The many stages involved in the transfer of detail from air photographs to maps have been carried out by Mr. Mwangala with the assistance of Mr. E. B. Gunda. All mechanical soil analyses and pH determinations have been made by Mr. G. M. Mandala. In identifying plants, Mr. E. Banda's detailed knowledge of Nyasaland vegetation species has been of great assistance. All of the above have assisted with the, at times arduous, work of field soil survey. Secondly, thanks are due to Mr. R. A. Wood, Mr. W. D. Chona, and the staff of the soil analysis laboratory of Chitedze Agricultural Research Station, for numerous soil analyses. Thirdly, the assistance of all members of the Nyasaland Department of Agriculture in Northern Province has been invaluable, both in carrying out agronomic experiments and in making arrangements for field soil survey. Fourthly, the authors would like to express particular thanks to Mr. S. T. Hoyle, O.B.E., and Mr. H. B. Ambrose for their continuous support of the survey and for guidance in its course.

Assistance has been received from many other government departments. Petrographic descriptions of rock specimens have been supplied by Mr. K. Bloomfield of the Nyasaland Department of Geological Survey. Members of the Branch of Botany and Plant Pathology, Federal Ministry of Agriculture, kindly identified plant specimens. Climatic statistics were supplied by the Federal Meteorological Department. The Federal Department of Trigonometrical and Topographical Surveys undertook the printing of the map of natural regions and areas. Assistance has also been received from the Nyasaland Departments of Forestry and of Water Development.

Mr. G. Jackson, formerly Ecologist in the Department of Agriculture, actively supported the survey in its early stages. This memoir owes much to his detailed knowledge of Nyasaland and his keen perception of the inter-relationships of environmental factors, both freely passed on to others.

The field soil survey and air-photograph interpretation was carried out by A. Young, who has edited the bulletin and is responsible for chapters I–IV, VI–VIII, and the series descriptions in chapter IX. The agronomic experimental work was carried out under the direction of P. Brown, who is responsible for chapter V and the agronomy sections of chapter IX.

INTRODUCTION

This survey attempts to serve both practical and scientific purposes. Firstly, it is hoped that it will be of assistance in the planning of agricultural development. Secondly, it is intended as a contribution to regional geography.

The first part of the bulletin gives an account of the physical environment of northern Nyasaland, together with an outline of its present-day agriculture. This is intended to provide a factual basis for overall agricultural planning, and to serve as a framework for research. The second part summarizes existing knowledge of the soils, and their potentialities for agricultural utilization, in each part of this area. It is designed to be of assistance in local agricultural development, on the scale of individual farms or village land holdings.

In describing the environment, the geographical approach has been adopted. Emphasis is placed upon the inter-relationships of the various factors and the distributions of each of them are discussed from a causal point of view. It is contended that this approach, which emphasizes the essential unity of the environment, is one that is necessary in all types of planning which involve a modification of pre-existing conditions in the landscape, whether these conditions are natural or whether they result in part from human occupation.

The survey covers that part of Nyasaland lying north of latitude 12° south. This comprises the Karonga, Nyika, and Nkata Bay sheets of the topographic map on a scale of 1:250,000, produced by the Federal Department of Surveys, Salisbury. It does not therefore cover the whole of the Northern Province of Nyasaland, the southern part of Mzimba District being omitted. The latter will be included in a survey of central Nyasaland which is in course of preparation.

Arrangement of the bulletin

Part One contains a systematic account of the physical environment of the whole of the area, and of its agriculture. In order to give cohesion to this account, the soil has been taken as a focal point. Consequently in chapters I–III, emphasis has been placed on those aspects of the factors under discussion which have the greatest effects on soil formation, and each chapter includes a discussion of these influences. Chapter IV is an account of the soils themselves, considered from a genetic point of view. An attempt is made to assess the relative importance of the various environmental factors in producing the observed distribution of soil types. Chapter V describes the agricultural and non-agricultural uses that are made of these soils at the present time.

This part of the survey is summarized in the *Map of Natural Regions and Areas*, on a scale of 1:500,000 (*in pocket at back cover*). The major divisions of the landscape are termed *natural regions*, and their sub-divisions *natural areas*. The key to the map shows in tabular form the principal environmental conditions of the natural areas; chapter VI outlines the characteristics which give unity to each of the natural regions. In the text, the regions and areas shown on this map are referred to by their numbers, e.g. the Misuku Hills (3), the plateau remnants of the North Vipya (13a).

Part Two gives an account of the *soil series* that have been identified, together with the present knowledge of their agronomic characteristics. In a reconnaissance survey of this nature it is not possible to produce a map showing in detail the distribution of soil series, which is ideally what is required for agricultural planning. Consequently the method that has been adopted is as follows. For each natural area, the soil series that are known or believed to occur within it are given in the key to the map of natural regions and areas. Chapter VIII contains a key, somewhat similar to a botanical key for the identification of plant species, by means of which the series to which an observed soil belongs can be determined. Chapter IX includes a definition and description of each series, together with a summary of the results of agronomic work carried out upon it. The sections on agronomy refer not only to the soil itself, but to the environmental conditions under which it occurs. The means by which this Part may be used in connection with local agricultural planning is given on pp 65–66 below.

Method of survey

The field survey consisted of observations of two types. Firstly, soil profile descriptions were made at representative sites, together with accounts of the soil parent materials, landforms, vegetation, and agriculture of the surrounding areas. Secondly, mile-by-mile notes were made along the great majority of roads and motorable tracks, comprising a continuous record of altitude, together with such observations of the environment as could be made from a moving vehicle, e.g. nature of landforms, predominant slope angles, local range of relief; vegetation physiognomy, dominant and characteristic tree species; topsoil colour, sandiness, and stoniness; subsoil colour as observed in cuttings and termite mounds; and the proportion of land under cultivation. The majority of the soil profiles were sampled from all horizons, and mechanical analyses and pH measurements were subsequently made. After the determination of soil series, full chemical analyses of representative profiles were carried out.

The mapping was based on stereoscopic examination of more than 3,000 air photographs, on scales of 1:20,000 and 1:40,000. Boundaries were drawn directly upon these (*see* p. 56 below), and in addition the rivers, roads, and tracks were marked. Strips were constructed from these photographs, and these were pantographically reduced to a scale of approximately 1:120,000. The boundaries were then transferred to the 1:250,000 map by the following means. Control points, e.g. river confluences, bridges, identifiable on both the strip and the map, were selected; where possible these were at intervals of the order of 20 miles apart. The distances between corresponding control points on the strip and map were measured, and their ratio found. The boundaries were then transferred by setting a sketchmaster to this ratio and placing the control points in their correct positions. The boundaries shown on the map of natural regions and areas, on a scale of 1:500,000, therefore represent a reduction of either 12 or 25 times from the scale at which the mapping was initially carried out.

The soil series having been determined, all land on which agronomic experimental work had been carried out was identified as to series. The results of these experiments, including many carried out prior to the survey, were then re-assessed in relation to soil series.

It should be emphasized that this survey provides only a starting point in the investigation of the natural environment and agricultural potentialities of northern Nyasaland. It is desirable that it should be followed by more detailed studies, and in particular by systematic soil mapping on a scale of 1:50,000. Much also remains to be done in the field of agronomic work, and the accounts of this given in Part Two should be taken as an interim statement of progress, the conclusions from which are liable to modification from future work.

The wide variety of conditions found within a small area makes Nyasaland an ideal country for the investigation of geographical relationships and agricultural problems in tropical Africa. Agriculturally, it is potentially a rich country; scientifically, it is a complex but rewarding one.

Part One

THE PHYSICAL ENVIRONMENT

CHAPTER I

GEOLOGY AND GEOMORPHOLOGY

GEOLOGY

Detailed geological mapping has been carried out for only small areas of northern Nyasaland. These comprise two coal-fields [1, 2], a belt along the Karonga lake shore [3, 4], and the Mafingi Mountains [5, 6]; in addition, a less detailed survey of the Upper South Rukuru Valley has been made [7]. For the greater part of the area, however, it is necessary to rely on reconnaissance accounts. The first description was given in 1910 [8], and from 1923 onwards a number of records have been published in the Annual Reports of the Geological Survey Department of Nyasaland. A summary, together with a complete bibliography, has been given by Cooper [9]. The following account is based partly on these sources, and partly on unpublished information supplied by the Geological Survey Department.

Geological succession (map I)

1. *The Basement Complex.* A large proportion of the area is occupied by ancient metamorphic and igneous rocks forming part of the Precambrian shield which underlies much of southern Africa. Four sub-divisions may be distinguished:

a. Undifferentiated Basement Complex. This group, formerly referred to as the Mozambique Series, is characterized by strike directions within 30° of north–south, and by a high grade of metamorphism. Gneisses form the majority of the rocks, with hornblende-biotite-gneiss the commonest type.

b. The Mafingi System. This is distinguishable from the previous group on the basis of lithology, and is also probably of younger age. The rocks are lightly metamorphosed, schists predominate over gneisses, and quartzites and quartz reefs are common. Apart from the type area in the Mafingi Hills, the extent of the system has not been fully determined. It occurs at Livingstonia, and forms the scarp which bounds the Nyika Plateau to the north-west (9b); on map I a section of the Karonga Scarp Zone has been tentatively assigned to this system on the basis of photo-interpretation, without field examination.

c. The Misuku Series. This comprises rocks with strike directions between north-west and west-north-west, and occupies the northern section of the Province. Gneisses, schists and quartzites are present.

d. Igneous intrusions. A large granite mass forms the majority of the Nyika Plateau and the hills to the south of it; in its typical form it is a medium-grained biotite-granite, with large quartz phenocrysts. A second large granitic intrusion lies north-west of the Nyika, and a number of smaller granitic and syenitic bodies also occur.

2. *The Karroo System.* The most extensive outcrops of sedimentary rocks are those of Karroo (Permian-Rhaetic) age. They comprise sandstones, siltstones, and mudstones, in which a number of coal seams occur. At Livingstonia they form a capping overlying the Mafingi System. North of this they outcrop north-west of Florence Bay (6k), in a north–south belt crossing the North Rukuru 11 miles west of Karonga (5e), and adjacent to the Songwe (3i). A further belt occurs along the middle course of the North Rukuru (5c); the extent of this belt indicated on map I is determined from photo-interpretation.

3. *Cretaceous*. To the west of the Karonga Lake Shore Plain, sandstones of Cretaceous age, the Dinosaur Beds, outcrop in a series of narrow, discontinuous belts running parallel to the present shoreline.

4. *Tertiary and Pleistocene*. Sandstones and other sedimentary rocks of these ages occur as raised beach deposits at a number of places on the Karonga Lake Shore Plain. They comprise the Sungwa, Chiwondo and Chitimwe Beds[3]. Sandstones are also found on parts of the Nkata Bay Lake Shore Lowlands, but their age and extent are not known.

5. *Recent*. Alluvium forms the flood-plains and terraces along many parts of the larger rivers. The most extensive belt of these is along the South Rukuru, extending up the Luwewe, Kasitu, and a number of smaller tributaries. Broad areas of heavy-textured alluvium occur in the Vwaza Marsh (11d) and the Limpasa Dambo (21f). The Karonga Lake Shore Plain is formed principally of river-borne alluvium in which the fine sand fraction is usually dominant. Areas formed of sands deposited by lacustrine processes also occur along the lake shore.

Soil parent materials

Within any limited range of topographic and climatic conditions, parent material may exercise a dominant effect on soil formation. It is a factor which tends to be of greatest importance in detailed soil surveys of small extent. In Nyasaland the largest area in which other environmental conditions are relatively uniform consists of the plains at 3,400–4,400 ft., with a rainfall of 30–45 ins. per annum; many of the considerable variations in soil type which occur within this area are caused by parent material differences. The principal soil-forming properties of the rock types met with in northern Nyasaland are as follows:

1. *Igneous and metamorphic rocks*. In respect of soil formation, metamorphic rocks in which recrystallization has occurred may be considered jointly with igneous rocks. The most important soil-forming property of both groups is their relative proportions of quartz, feldspars, and ferromagnesian minerals.

Quartz is not subject to chemical weathering, therefore quartzites, which consist largely of this mineral, can give rise only to thin, stony soils. Quartz veins remain in the soil profile as stone lines; these are common on steep slopes, where downhill soil movement concentrates the quartz fragments at a depth varying from 1–3 ft., by a process which is not fully explained.

Acid igneous and metamorphic rocks contain free quartz, but few or no ferromagnesian minerals. They are pale in colour, and include granites and granitic gneisses. They have a relatively low content of weatherable minerals, and are normally associated with strongly leached, poorly structured soils, often sandy and of low fertility. Very low values of base saturation are commonly found in these soils.

Intermediate rocks have a small proportion of free quartz, and a low to moderate content of ferromagnesian minerals. Many hornblende- and biotite-gneisses fall in this group. In appearance the black ferromagnesian minerals typically stand out against a matrix of grey, white, or pinkish feldspars. These rocks permit " normal " climatically-determined soils to develop.

Basic igneous and metamorphic rocks consist predominantly of ferromagnesian minerals, and are dark or black in colour. They are of restricted distribution in the area surveyed. Having a high content of weatherable minerals they are normally associated with weakly leached, strongly structured soils, of moderate or high fertility.

A second, less important, soil-forming property of crystalline rocks is the grain-size of the quartz minerals that they contain. This directly determines whether fine or coarse sand predominates in the sand fraction of the soil.

2. *Sedimentary rocks.* These have already undergone one cycle of weathering, prior to deposition. They therefore have a low content of weatherable minerals, and tend to influence soils in a similar way to acid igneous rocks, producing strongly leached soils. The degree of compaction and cementation, which usually varies with age, is an important property. The older sedimentary beds, those of Karroo and Cretaceous age, are hard and strongly cemented, and tend to give rise to thin, stony soils. The Tertiary and Pleistocene beds break down more readily into their component grains, and normally form very sandy soils.

3. *Superficial deposits.* The alluvium of the Karonga Lake Shore Plain, and of the terraces of the South Rukuru, Kasitu, and Upper Lufira, is in many respects similar. Depositional bedding occurs, giving sharp changes of texture in the soil; beds of clay are common, resulting in impeded profile drainage, whilst beds of almost pure coarse sand are also found. Two characteristic features of the Karonga lake shore alluvium are the predominance of fine sand, and the presence of abundant muscovite (white mica).

Alluvial clays become deposited in still water on level ground. The resulting combination of poor drainage both of the site and within the profile causes black colours or mottling to occur in all horizons of the soil.

Lacustrine sands are composed very largely of quartz grains, and are therefore almost unaffected by pedogenic processes. After they have been deposited for a period of time, however, they acquire a vegetation cover and an admixture of wind-blown finer material. The resulting soils have very rapid permeability, causing excessive profile drainage and high acidity.

GEOMORPHOLOGY

A complete account of the geomorphology of an area includes both a description of the landforms present, and an explanation of how these forms orginated, in so far as there is evidence of this. Descriptive geomorphology is fundamental to any regional study, having both direct and indirect effects on climate, vegetation, soils, and agriculture. It has additional importance in a reconnaissance survey, since landforms are the only environmental factor which can be directly observed from air photographs. In the present survey more than 90 per cent. of the boundaries of the map of natural regions and areas were initially drawn on the basis of landform differences. Explanatory geomorphology, however, is not essential to the understanding of soils and agriculture. Consequently the following account will be largely confined to a description of the relief, consideration of its origin being mentioned only where this assists in understanding the nature and distribution of the landforms.

Landforms

Table I gives a classification of the landforms encountered in northern Nyasaland, and map III shows their distribution. The primary basis of classification is according to the predominant slope angles. On this criterion four principal groups are distinguished: depositional plains with almost level constructional surfaces, erosional plains with predominantly gentle slopes, dissected areas of moderate slopes, and steep hill areas. The first group is subdivided into forms due to deposition by rivers and by Lake Nyasa. The remaining groups are divided according to slope, range of relief (*see* notes below table I), drainage density, altitude, and the presence of specialized landform types.

Five distinctive landform types have been included. *Pediments* are the gentle slopes which lead up to the foot of hills. They are almost invariably present below hills of all sizes. They typically slope at 2°–4°, becoming slightly steeper on their

TABLE I—LANDFORM CLASSIFICATION

		Landform		*Predominant slopes*	*Range of relief*	*Drainage density*
I. Depositional plains	Alluvial	1. Lake-shore plains		Level	Low	Very wide
		2. Valley-floor flood-plains and terraces		Level	Low	—
		3. Marshes		Level	Low	—
	Lacustrine	4. Sand beaches, bars, spits, and dunes		Level to gentle	Low	—
		5. Raised beaches		Level	Low	Wide
II. Erosional plains and plateaux		6. Almost level plains (old age)		Level to gentle	Low	Very wide
		7. Gently sloping plains (old age)	7a. High-altitude 7b. Medium-altitude	Gentle	Low to moderate	Wide to very wide
		8. Moderately sloping plains (late maturity, or old age with new-cycle dissection)	8a. High-altitude 8b. Medium-altitude	Moderate	Moderate	Medium to wi
III. Dissected areas with moderate slopes		9. Dissected areas with moderate slopes (maturity)	9a. Moderate relief	Moderate	Moderate	Medium
			9b. High relief	Moderate	High	Medium
		10. Very closely-spaced dissection		Moderate	Low to moderate	Very close
		11. Pediments and dissected pediments		Gentle	Low	Medium
		12. Cuestas	12a. Normal	Moderate to steep	Moderate	Medium
			12b. Micro-cuestas	Moderate to steep	Moderate	Close
IV. Hills and hill areas with steep slopes		13. Hills and hill areas with strong structural influence, ridges dominant (youth)		Steep	High	Close to mediu
		14. Hills and hill areas without strong structural influence (youth)	14a. Moderate relief	Steep	Moderate	Close to medium
			14b. High relief	Steep	High	Close to medium
		15. Scarps		Steep	High	Close to medium
		16. Gorges		Steep	High	—

Slopes	*Slope angles*	
Level:	0°– 1°	(0– 2%)
Very gentle:	1°– 2°	(2– 4%)
Gentle:	2°– 5°	(4–10%)
Moderate:	5°–15°	(10–25%)
Steep:	15°–35°	(25–70%)

Range of relief	*Altitude difference between valley floors and adjacent interfluve crests*
Low:	Less than 100 ft.
Moderate:	100–400 ft.
High:	More than 400 ft.

Drainage density	*Distance between drainage courses*
Very close:	Less than 250 ft.
Close:	250 ft.–¼ mile
Medium:	¼–1 mile
Wide:	1–2 miles
Very wide:	More than 2 miles

The terms in parentheses indicate the stage reached in Davisian cycle of erosion.

upper parts; below large massifs, such as Mafingi Mountain (4a, c), they are steeper. At points where streams emerge from the hills, pediments are frequently covered by alluvial fans. *Cuestas*, consisting of alternating scarp and dip slopes, occur where sedimentary beds of varying lithology dip in one direction and have been partially bevelled by erosion. This is found on the outcrops of Karroo beds. Broad cuestas, with long, gentle dip slopes, occur east of Livingstonia, and at the southern end of the Karroo outcrop along the upper North Rukuru (7c). Elsewhere the beds dip steeply and a micro-cuesta topography results, with many closely-spaced, low, steep scarps and short, moderately steep dip slopes. Areas of *very closely spaced dissection* consist of large numbers of narrow, shallow, but moderately steep-sided gullies, giving a landscape sometimes referred to as " badland " topography. *Scarps* are long and continuous steep slopes separating areas of different altitudes. The class of *gorges* is used to distinguish the deep and very steep inner valleys which occur on the lower courses of many of the rivers draining to Lake Nyasa.

The term " marsh " is used throughout this memoir to describe the type of area known in Nyasaland as a *dambo*, a word common to both the Nyanja and Tumbuka languages. These occur along most valley floors, ranging from narrow belts along small streams to broad flood-plains of major rivers, and also as extensive areas on level ground. A *dambo* becomes waterlogged, with periodic flooding, during the rains, but dries out in the latter part of the dry season; it carries a vegation of tall grass, without trees. Permanently waterlogged marshes, with a vegetation of reeds, are considerably less extensive.

In relation to arable use, landform classes 1, 2, 7b, 8b, and 11 mainly have a relatively high agricultural potential, classes 5, 6, and 9a are of moderate or low potential, and the remaining classes are unsuitable for cultivation. Classes 7b and 8b are particularly suitable for forestry

Major relief units

The five major relief units which may be distinguished are shown in map IV. These are distinctive from each other on the basis both of altitude, and of the predominance within them of particular landforms. They will be discussed in descending order of altitude

I. *The High Plateaux*. A series of high-altitude plateaux occur, which have many environmental characteristics in common. They lie mainly above 6,000 ft. (invariably above 5,000 ft.) and in every case have an area of gentle or moderate slopes on their crests, bounded by steep slopes, either scarps or deeply dissected zones, on all sides. The two most extensive are the Nyika Plateau (8) and the High Vipya Plateau between Mzuzu and Mzimba (19 a, b). Both of these include firstly, areas of gently undulating relief, with very broad, smoothly convex interfluves and wide marshy areas in the valley floors (8a, 19a); and secondly, areas of moderate slopes and a greater range of relief, but in which broad convexities are again characteristic (8b, 19b) (*see* fig. 1a). The smaller plateaux resemble these latter areas, having moderate slopes. They include an area north-east of Pirewombe Hill (4b); the Mafingi Plateau (4a); in the Misuku Hills, Windindi and Mugesse Ridges, together with a smaller area north-east of Mugesse (3c); two outliers of the Nyika, to the north a small plateau which includes Kawozya and Mpanda Hills, and to the south Nkonjera Hill (8b, d); and the plateau remnants of the North Vipya (13a). A number of other hills and ridges, for example Msissi Hill, reach up to the altitude of these plateaux but have only narrow crests.

It is probable that these plateaux are remnants of a former erosion surface of considerable age. Similar features occur in central and southern Nyasaland, for example the Dedza, Mlanje, and Zomba massifs. By analogy with these, the most probable date at which this surface was initially formed is end-Jurassic or early Cretaceous[10].

II. *High-Altitude Hill Zones.* This unit comprises all steeply sloping land which rises above the Mid-Tertiary Surface (*see* below); it falls principally within the altitude range 4,000–6,000 ft. It includes the scarps and scarp zones of the high plateaux, together with seven extensive hill areas.

The Misuku Hills (3a, b, d) consist mainly of high ridges aligned south-east and east-south-east, following the strike of the Misuku Series rocks. These are separated by deep, steep, V-shaped valleys; the range of relief exceeds 1,000 ft. in many places, particularly in the south-western sector (3d). A long high scarp (3f) bounds them to the south-west. In the Ruwenya Hills (1), and also in the hills immediately west of the Misuku (3e), structural control is less strong, and massive forms as well as ridges occur. The hills of the Upper Lufira (4d, e) are situated partly on granitic intrusive rocks; high, massive hills of irregular shape are characteristic

The Nyika Plateau is bounded partly by scarps and partly by hill zones. North-west and south-east of it are two parallel scarps (9b) orientated north-north-east; to the north-east a third linear scarp follows the north-north-westerly orientation of the landforms of the Karonga Scarp Zone. These three features follow structural trends, either faults or strike directions. A fourth scarp, north of the plateau, is irregular in plan. Immediately south of the plateau is an area in which the range of relief is highish but slopes are moderate (9a). The main area of the South Nyika Hills (9d) however, has steep slopes; their most southerly part consists of high, massive ridges, broken by the gorge of the South Rukuru at Rumpi, and by wind-gaps at two points further south. In the East Nyika Hills (9c) extremely deep valleys separated by narrow-crested ridges are characteristic.

The Livingstonia Hills (10) and the North Vipya Hills (13) have the form of a dissected plateau, with a moderate uniformity of crest heights in many parts; they include valleys descending below 3,000 ft., cut by rivers draining direct to Lake Nyasa. Uzumara, Ngunikira, Chimaliro, and several smaller hills (13b) rise above the plateau level. The southern extension of this area is a massive ridge adjacent to the lake shore, the Kandoli Hills (13e). The Central Mzimba Hills (17) contrast with with the preceding areas in having only a moderate range of relief; they consist of a dissected area extending north–south along the South Rukuru-Kasitu watershed. The Vipya Plateau is bounded to the west by a high scarp (18d) overlooking the Kasitu Valley. The high western part of the Vipya is separated from the lower eastern part by the Mid-Vipya Scarp (19e); this is of moderate height and steepness, with a north–south linear form, offset by two miles in the centre in a manner which suggests a fault origin.

III. *The Mid-Tertiary Surface.* The majority of agriculturally valuable land in Northern Province occurs on a group of plains and dissected plains in its western half. These lies in the altitude range 3,400–4,400 ft. They form part of the most extensive erosion surface found in Southern Africa, which is considered to have been initially formed in the Mid-Tertiary.

The Fort Hill Plain (2) lies mainly at 4,100–4,600 ft., falling to 3,600 ft. close to the Songwe. Its main area (2a) is very gently undulating, consisting of broad valleys with 1°–2° sides and with wide marshy areas in their floors (fig. 1b). The Luwewe Plain (11), part of which is known as the Nkamanga Plain, is almost level, and river courses on it are changeable; it lies at 3,400–4,000 ft., and includes the Vwaza Marsh (11d). Between these two plains a number of smaller nearly level areas occur, west of the Nyika (7a); these are parts of an extensive plain, at an altitude of 4,100–4,400 ft., which is mainly developed in Northern Rhodesia.

The largest part of the Mid-Tertiary Surface is associated with the South Rukuru and its tributaries. In the southern part of the Upper South Rukuru Valley (16c, d, e) the interfluves consist of two sectors: level crest areas, often of considerable width, separated by a distinct change of slope-angle from valley sides of 2°–4° (*see* fig. 1c). In the northern part of this basin, slopes are predominantly 1°–2°, and the landforms resemble those of the Fort Hill Plain. The Lower South Rukuru Valley includes a number of level surface-remnants (12c), including the Chazgama Plain. Along this part of the South Rukuru, between Rumpi and the Pwezi Rapids, there occurs a characteristic landform assemblage, which is found also along the Lower Kasitu, Luviri and Mwazisi Rivers (fig. 1d). The valley floors have level, marshy flood-plains, together with low, level terraces (12a); at the margins of these, forming the lower valley sides, are pediments, sloping evenly towards the valley centres at 2°–4° (12b). Above the pediments, steep hills or scarps bound the valleys on both sides.

The Middle Kasitu Valley (15) and Upper Kasitu Valley (18) are less gently sloping than the preceding areas. Tributary streams dissect them to the depths of 100–300 ft., and slopes at all angles up to 10° are common.

The lower, eastern part of the Vipya Plateau (19c), which includes the site of Mzuzu, lies mainly at 4,100–4,500 ft., and on the basis of altitude it is included with the Mid-Tertiary Surface on map IV. Its position with respect to the Mid-Vipya Scarp (19e, *see* above) and to the Rift Valley suggests, however, that genetically it may be a downfaulted sector of the High Plateaux. An inaccessible plateau remnant of moderate size (20d) occurs south-east of the Vipya.

IV. *The Rift Valley Scarp Zone*. This consists of hilly country lying east of the preceding relief units, and associated with the rift faulting which gave rise to the Lake Nyasa trough. It descends to the level of the lake surface, 1,550 ft., and rises in parts above 4,000 ft. Three sectors may be distinguished, the divisions between them occurring at Florence Bay and Nkata Bay.

The northern sector, the Karonga Scarp Zone (5), is a belt of rugged country 20 miles in width; much of it is very inaccessible. Adjacent to the Lake Shore Plain is a plateau (5a), the surface of which is broken by numerous, sub-parallel, structurally-controlled ridges. Much of this plateau lies at slightly above 2,200 ft., but in its northern part it appears to rise gradually in height inland, until it exceeds 3,500 ft. at its most westerly point. The main part of the zone consists of a deeply dissected hill area (5d), without well-defined scarps

Between Florence Bay and Nkata Bay the main Rift Valley scarp coincides with the lake shore, resulting in a markedly linear shoreline (14a). The land falls from 4,000 ft. to the lake surface (1,550 ft.) over a distance of 1–2 miles; close to this shore are the deepest parts of the lake, over 300 fathoms, indicating that the scarp continues below lake level. In the northern part, the Livingstonia Scarp (14b), a capping of Karroo Beds gives a stepped form to the upper part of the scarp, clearly seen below Mount Waller. The line of this scarp is continued inland to the north-north-west for 22 miles (9b). The southern part of the scarp includes narrow raised-beach remnants (14c), considerably dissected but contrasting strongly with the very much steeper slopes of the scarp. These occur at two altitudes, an upper group at 2,300–2,700 ft., and a lower group, separated from the present shore by only a narrow cliff, at 1,800–1,950 ft. (350–400 ft. above lake level). Small deltaic alluvial fans occur at the mouths of all rivers (14d). A feature of interest is Range Point, where a sand bar has extended from the shoreline to a small hill which was originally an island, and a large triangular area of alluvium has been deposited behind this bar; the latter is entirely cultivated, apart from a small marsh.

East of the Vipya Plateau the scarp zone again consists of a broad area of deeply-dissected country (20). The principal features are the gorges of the Luweya and its tributaries (20b). These are of considerable dimensions, which may be due in part to the very high discharge of this river system (*see* below).

V. *The Lake Shore Plain.* This is developed in two separate areas, from the Songwe to Florence Bay, and from Nkata Bay southwards.

The Karonga Lake Shore Plain (6) is 4–5 miles wide in its northern and central parts, widening to 12 miles west of Deep Bay. It includes an inner part, underlain by Cretaceous, Tertiary and Pleistocene sediments, and an outer part formed of Recent superficial deposits. Within the former are remnants of a level raised beach (6i), lying at 1,800–1,900 ft. It has been dissected into a series of separate low plateaux, but within each of these there are no drainage courses, and the ground is level. Human artifacts have been found in this area [11]. Of greater extent is a belt in which Cretaceous and Tertiary beds have undergone exceedingly fine-textured dissection (6j), with numerous closely-spaced gullies.

The main part of the plain consists of an almost level depositional surface, at a height close to that of Lake Nyasa (6a, b, c, d). It is crossed by rivers flowing from the Scarp Zone to the lake. The banks and beds of these rivers are clearly defined but valleys are absent, the tops of the banks being at the level of the plain. In times of flood the capacity of these beds is exceeded; parts of the plain become inundated, and the load of the rivers is deposited. For example, soil profiles one mile north of Karonga show 3 ft. of sand overlying the original surface, deposited during recent flooding.

Lacustrine deposition is a second process by which the area of the plain is extended. On Lake Nyasa the prevalent winds are from the south-east (*see* fig. 2), and this is also the direction of greatest fetch; consequently sand-movement along the shore is towards the north and north-west. On the main, north-north-westerly orientated, part of the shore, sandspits have been built; this has enclosed a series of marshes, together with Mlali and Chiwondo Lagoons. At Florence Bay, Young's Bay, and adjacent to the Songwe, parts of the shore face south-east. Here the shore is being built forward by the deposition of sand-bars; adjacent to the Songwe 11 bars, with intervening parallel linear depressions, are crossed on a traverse from the shore inland.

The Nkata Bay Lake Shore Lowlands (21) are a belt of dissected country, with a general elevation of 1,700–2,000 ft., broken into two parts by the broad marshy area of the Limpasa Dambo. The eastern sector (21b) has both moderate and gentle slopes. For eight miles southwards from Nkata Bay it is separated from the shore by a cliff sloping at 35°–45°. South of Chinteche this sector is separated from the Limpasa Dambo by a low but steep west-facing scarp, to the east of which the ground slopes down gently to the lake. Between Mankhambira and Chinteche, and again south of Bandawe, the shore faces south-east, and zones of sand bars and enclosed marshes occur.

Inland of the Limpasa Dambo slopes are steeper, but relief in most parts is less than 200 ft. (21a). Remnants of the surface from which this area has been dissected are preserved in a number of places (21c, d, e). A fuller account of the relief of this zone has been given elsewhere[12].

The Limpasa Dambo (21g) is a north–south depression, the line of which is continued to the north by the valley of the Chikwina River. Its southern end is blocked by a line of sand bars, and it is now entirely infilled with alluvium, resulting in a broad marsh. Alluviation extends up the valleys leading into it in a manner which suggests that these valleys were cut at a time when the level of Lake Nyasa was lower. Following the rise in lake level which terminated this stage it is possible that the Limpasa Dambo temporarily became an arm of the lake.

Drainage

River flow shows the same marked seasonal variation as rainfall. Following the commencement of the rains in December, discharge on the larger rivers increases progressively to a maximum in February or March; the delay with respect to the rainfall maximum is due to the recharging of depleted groundwater reserves. Flow remains relatively high in April but falls sharply in May, subsequently declining progressively or ceasing. On the South Rukuru approximately 75 per cent. of the mean annual discharge occurs in the four months January to April. On the smaller rivers flow is erratic, sudden flash-floods resulting from storms coincident with their catchment areas. The majority of these streams are dry for five to six months of the year, although in many cases the water-table remains only a small depth below their beds. Perennial flow is maintained on the Luweya system, draining an area which has substantial winter rainfall; on the Songwe; and on rivers which have major tributaries rising on the Nyika Plateau.

Only a brief description of the valley forms and hydrology will be given. The hydrology is described in detail in an unpublished report by Pike[18], and full records of flow measurements are contained in the Annual Reports of the Nyasaland Water Development Department. The river systems will be discussed under eight groups; the catchment areas and principal tributaries of these are shown on map V, and their mean annual discharges are given in table II.

TABLE II—RIVER FLOW

With the exception of the figures for Chimsewezo, which lies on the upper South Rukuru, all the gauges shown are sited relatively close to the mouths of rivers: that on the Kasitu is close to its confluence with the South Rukuru.

River	*Gauging Station*	*Catchment area sq. miles*	*Mean annual flow acre-feet*	*Mean annual no. of days with no flow*	*Estimated maximum recorded flow cusecs*
South Rukuru ..	Chimsewezo	362	49,281	22	1,200
Kasitu .	Njakwa	804	90,344	37	2,600
South Rukuru ..	Pwezi	4,557	465,400	Nil	2,900
North Rukuru ..	Mwakenja	753	270,005	Nil	14,000
Lufira . ..	Ngerenge	602	124,670	2	5,000
Songwe ..	Mwangulukuru	1,567	875,553	Nil	6,900
Nyungwe ..	Nyungwe	155	109,012	118	14,000
North Rumpi	Livingstonia road	117	143,034	Nil	3,000
Luweya	Luweya ferry	900	720,733	Nil	13,000

Source: *Ann. Rep. Wat. Dev. Dept. Nyas.*, 1959

1. *The South Rukuru-Kasitu System.* The South Rukuru rises in the South Vipya, and initially flows south-west (south of the area shown on map V). It then flows northwards for 70 miles in an asymmetric position close to the western margin of its basin, receiving a series of right-bank tributaries from the Central Mzimba Hills. The line of this valley is continued north by the course of the Luwewe as far as the Vwaza Marsh; the Luwewe, however, flows southwards, and at their confluence the South Rukuru turns north-eastwards. For 100 miles the gradient of the South Rukuru averages 6 ft. per mile; it flows in a marsh belt with a fairly regular width of ½ mile, Lake Kazuni being a slightly depressed part of this belt. At Rumpi the river breaks through a high massive ridge in a spectacular gorge, immediately below which it joins the Kasitu. The latter river, rising on the Vipya Scarp, follows a northerly course, along most of which it flows in a marsh belt 300–500 yards in width. The combined South Rukuru-Kasitu, augmented by three major left-bank tributaries from the Nyika Plateau, continues to flow with a gentle gradient as far as the Pwezi Rapids. Below these it descends into a deep valley, within which an extremely steep-sided gorge occurs near its mouth. The mean gradient over this section of 20 miles is 90 ft. per mile.

The volume of flow is relatively small above the confluence of the Runyina, and ceases entirely in the late dry season. The main access of water comes from the tributaries draining the Nyika; this produces a large total discharge, and maintains perennial flow over the lower part of its course (*see* table II).

2. *The North Rukuru.* This rises on the Nyika Plateau and initially flows south-west with a gentle gradient. It then turns north and enters a gorge section, at the commencement of which are a series of waterfalls. It flows northwards for 40 miles through hilly country, partly along the trough in which a belt of Karroo sediments is preserved, before turning east to descend the Karonga Scarp Zone. At 12 miles from the lake a flood-plain commences, becoming progressively broader down-stream until it merges with the Lake Shore Plain. The large volume of sediment carried down by the North Rukuru has resulted in a deltaic projection of the shoreline at its mouth, immediately north of Karonga; a number of changes in the position of its channel have occurred in this area. The discharge is high and perennial, due to its origin on the Nyika Plateau.

3. *The Lufira.* The course of the Lufira is strikingly parallel to that of the North Rukuru, lying approximately 12 miles to the west and north of the latter. A group of its left-bank tributaries are cutting below the Fort Hill Plain, and the water-shed of this system is coincident with the eastward limit of the undissected plain (2a). The annual discharge is less than half that of the North Rukuru, and flow ceases entirely for a short period in some years.

4. *The Songwe.* This river forms the northern border of Nyasaland, and receives the majority of its discharge from its left-bank tributaries in Tanganyika. Its largest tributary in Nyasaland is the Kaseye; the sluggish streams draining the Fort Hill Plain join this river, which then cuts a deep gorge through the north-western extension of the Misuku Hills. The Songwe-Lufira watershed runs through these hills.

5. *Rivers of the Karonga lake shore.* Between Karonga and Florence Bay 7 rivers of moderate size and approximately 12 smaller streams drain north-eastwards to Lake Nyasa. All of these possess two contrasted sections: a deeply incised valley in the Karonga Scarp Zone, from which nearly all their flow is derived, and an alluvial section, subject to flooding, on the Lake Shore Plain. In table II the Nyungwe is given as an example of this group; this river ceases flow for a third of the year, whilst the smaller streams remain dry for at least six months.

6. *The North Rumpi.* This is the third river system orginating on the Nyika Plateau; and like the Runyina-South Rukuru and the North Rukuru its flow is maintained throughout the year. Its course is incised from the point where it leaves the Nyika to its mouth, terminating in a deep gorge similar to that of the South Rukuru. The Manchewe Falls, near Livingstonia, result from the recent capture, by the Manchewe, of the former south-eastward flowing headwaters of the Luwatizi, a tributary of the North Rumpi.

7. *The North Vipya lake shore rivers.* The watershed between the South Rukuru and drainage direct to Lake Nyasa lies approximately 12 miles from the shore in this region. Six rivers and many smaller streams flow eastwards in moderately direct courses. Gorge sections occur, that of the Ruvuo being markedly straight. No flow measurements have been made on these rivers.

8. *The Luweya system.* The whole of the catchment area of this system receives more than 50 ins. rainfall, and much of it 60–90 ins. Consequently the discharge of the Luweya considerably exceeds that of all other Nyasaland rivers (*see* table II). The main river flows north-eastwards in an almost straight gorge 25 miles in length, before cutting irregularly eastwards. The Vipya Plateau streams drain into

this system, the watershed with the Kasitu following the crest of the scarp which bounds the plateau on its north-west side (18d). The Chikwina-Limpasa river enters the Limpasa Dambo at its northern end, and is joined by the Luweya shortly before it enters the lake.

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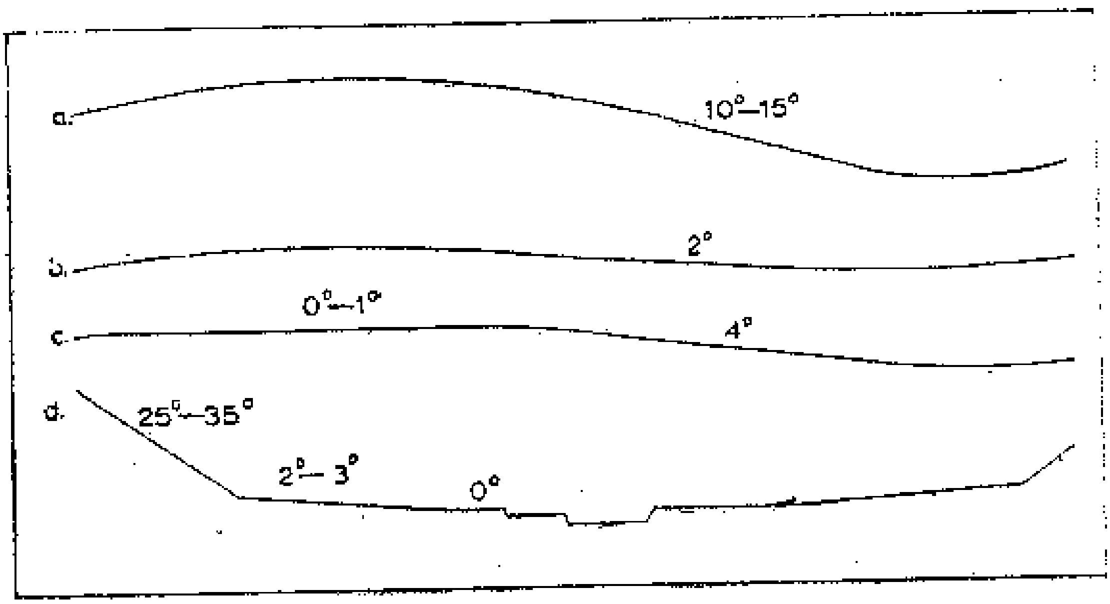

FIG. 1. *Typical cross-profiles of landforms.* a. The Nyika Plateau (area 8a). b. The Fort Hill Plain (area 2a). c. The southern part of the Upper South Rukuru Valley (area 16c). d. The Lower South Rukuru, Lower Kasitu, Luviri, and Mwazisi Valleys (areas 12a and 12b).

CHAPTER II

CLIMATE

Many climatic features, and in particular the seasonal changes, are common to all parts of northern Nyasaland. It lies between latitudes 9° and 12° south, and approximately 450 miles from the coast of the Indian Ocean. Consequently, the climate is continental in character, with a large seasonal variation in temperature; and, in contrast to Tanganyika and other East African territories situated closer to the Equator, only a single rainy season is experienced.

During the winter months of the Southern Hemisphere the sub-tropical high pressure belt covers Southern Africa, with pressure higher over the land than over the adjacent oceans. Nyasaland is normally covered by a south-easterly air stream, formed of dry air, of continental origin, with a stable lapse-rate due to its association with an anticyclonic circulation system. Records of wind speed and direction in July are shown in fig 2a. Gentle to moderate speeds, of 4–13 knots, predominate, with south-easterly and easterly winds greatly exceeding all others in frequency (the anomalous directional distribution for Nkata Bay is probably influenced by local topographic conditions). This anticyclonic system becomes established over Nyasaland by about May, and persists until November. In the early part of the period, temperatures are relatively low. Subsequently the sun moves southwards, passing directly overhead at mid-day during the beginning of November From July to November temperatures rise steadily, but conditions remain dry

The southward movement of pressure systems lags behind that of the sun, and it is normally not until December that the inter-tropical convergence zone becomes established over Nyasaland. This zone is associated with the meeting of air-streams originating in the sub-tropical high pressure belts of the Northern and Southern Hemispheres. The air-masses within it normally possess unstable lapse rates and a high relative humidity, resulting in the formation of heavy convectional storms. The mean wind speed becomes less than in July, and the direction more variable (fig. 2b).

As a result of these circulation conditions, three seasons are experienced:

(i) The cool season, May to August; dry, with relatively low temperatures.

(ii) The hot season, September to November; dry, with temperatures progressively increasing to a maximum in November.

(iii) The wet season, December to March or April; hot and wet.

Temperature

Using records from 30 stations, situated in all three Provinces of Nyasaland, the following relationship between altitude, latitude and temperature has been obtained:

$$T = 86.5 - \frac{3A}{1000} - \frac{L}{2}$$

where T=mean annual temperature in degrees fahrenheit, A=altitude in feet, and L=latitude in degrees. The standard deviation between temperatures obtained from this formula and observed temperatures is 1.02. This indicates that in two thirds of all cases the computed values will be correct to within plus or minus 1°, and in 95 per cent. of cases to within plus or minus 2°. Map VI has been constructed by this means; its accuracy is limited primarily by that of the contours.

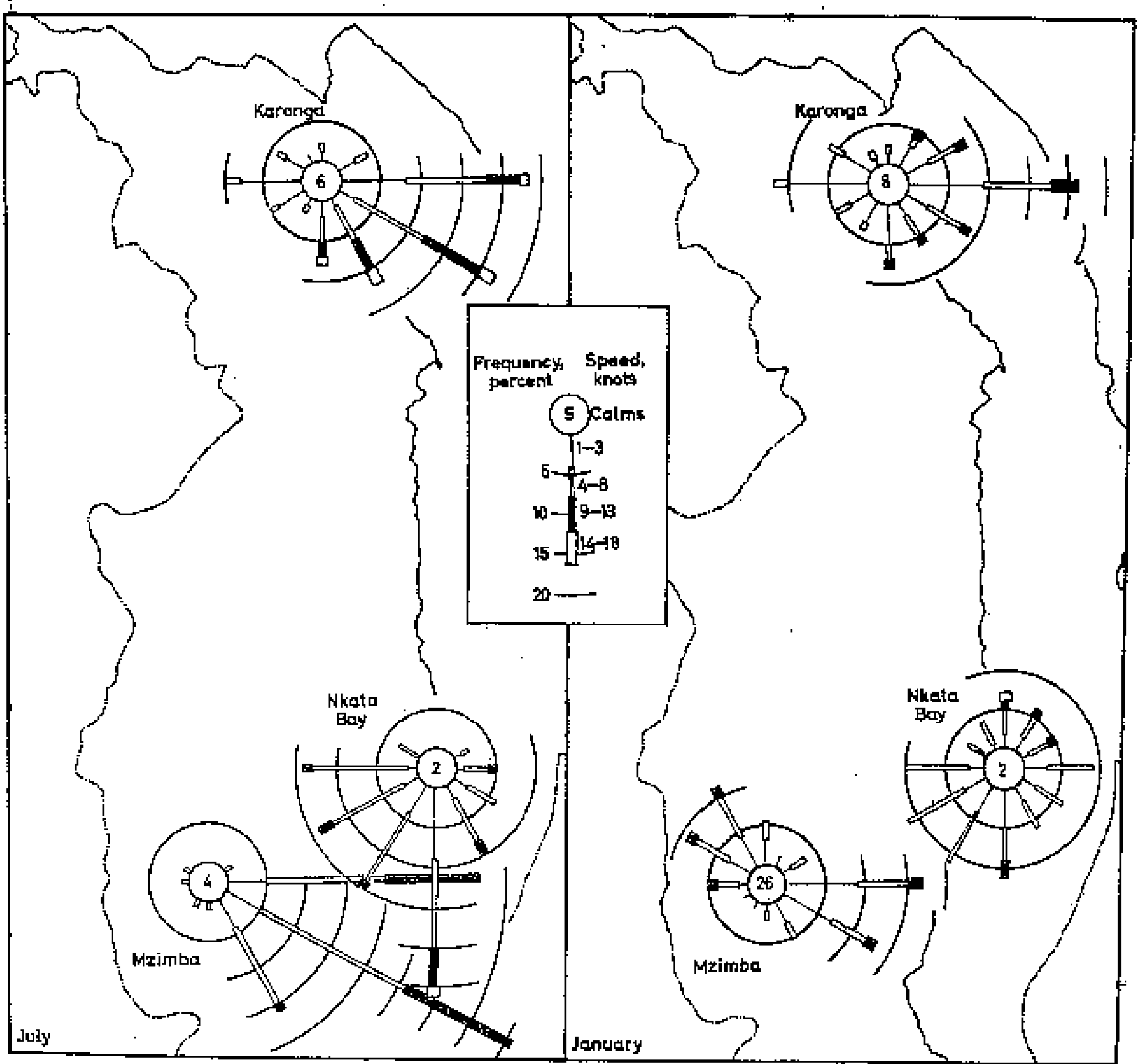

Fig. 2. *Winds.* The percentage frequency of winds of each direction and speed range is shown. The circles and arcs represent 5 per cent. intervals. The percentage of calms and variables is shown by the figure in the inner circle. The observations are for daylight hours. Source: *Surface wind frequencies,* Climate Information Sheet No. 15, 1960, Fed. Met. Dept., Salisbury

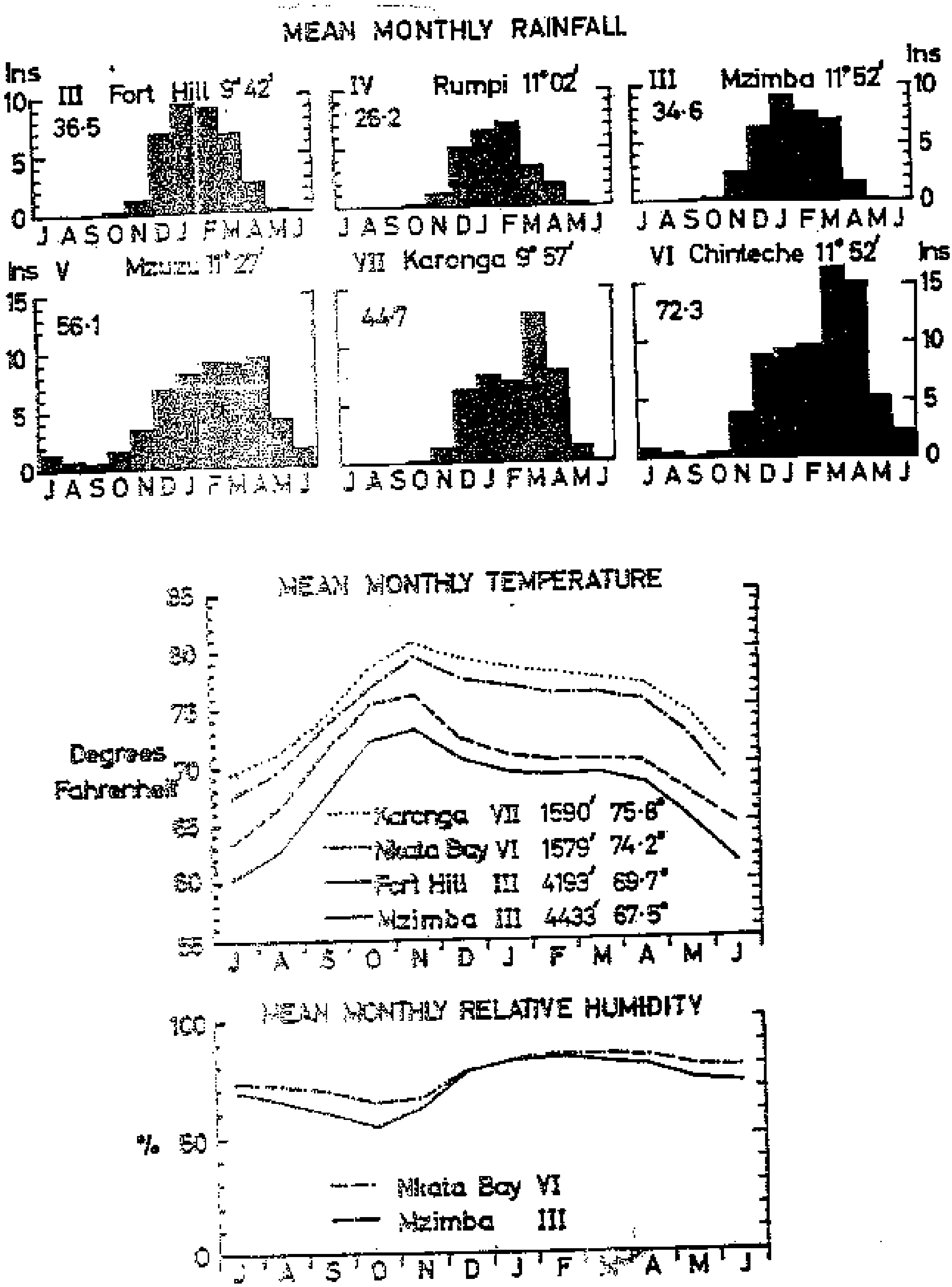

FIG. 3. *Rainfall, temperature, and relative humidity for selected stations.* The roman numbers refer to the climatic region in which the station is situated (*see* map VIII).

Within northern Nyasaland the maximum effect of difference in latitude on temperature amounts to only slightly over 1°; consequently mean annual temperature varies mainly with altitude, at a rate of 3° per 1,000 ft. Each of the major relief units (*see* pp. 17–20) forms a temperature zone. The High Plateaux mainly come within the range 60°–65°, but those parts of the Nyika lying above 7,000 ft. fall below 60°; on the summit of Nganda Hill, the highest point in northern and central Nyasaland, the computed mean annual temperature is 55.2°. The Mid-Tertiary Surface, together with hill areas between 3,500 and 5,300 ft., form a zone at 65°–70°, and the Rift Valley Scarp Zone one of 70°–75°. The variations in mean annual temperature between different parts of the Lake Shore Plain amount to only 2°, giving a temperature zone of 75°–77°.

The mean annual range of temperature, which is the difference between the monthly means of the hottest and coldest months, is close to 13° for all stations. The hottest month, November, has a mean temperature 5.8° above the annual mean. The fall in temperature in the cool season is influenced slightly by proximity to Lake Nyasa. Lake shore stations, and sites exposed to lake influence such as Livingstonia, have July temperatures averaging 6.9° below the annual mean; stations sheltered from this influence by intervening high ground have a higher degree of continentality, the corresponding difference being 7.5°.

Fig. 3b shows mean monthly temperatures for four stations. It illustrates firstly the general uniformity in seasonal variations, and secondly the lake influence. From July onwards the temperature rises to a maximum in November. The onset of the rains in December brings a sharp fall, but this is considerably less marked in lake shore stations, 1.0°–1.5°, compared to 2.5°–3.0° for "continental" sites. Temperatures then remain fairly high throughout the wet season, before falling more steeply in May and June. Thus the Lake Shore Plain remains above 75° for seven months of the year, whilst stations on the Mid-Tertiary Surface experience these conditions for only one or two months.

The mean diurnal range exceeds the annual range. There is again a small lake influence, stations exposed to the lake having a range of between 17° and 19.5° and sheltered stations between 19° and 22°. Livingstonia, however, records an exceptional range of 12.6°, the lowest in Nyasaland apart from Likoma Island.

Frosts occur regularly each year on the Nyika and less frequently on the other High Plateaux. In 1937 and again in 1955 frost was experienced at lower altitudes, causing severe damage to trees[1].

Relative Humidity

This climatic factor is significant with respect to evaporation and in relation to human comfort. Fig 3c shows the annual variation for one lake shore station and one station on the Mid-Tertiary Surface. During the dry season there is a substantial difference between the two sites; in October Mzimba and Nkata Bay differ by 11 per cent., and Fort Hill (47 per cent.) and Karonga (59 per cent.) by a similar amount. At the onset of the rains, humidities rise sharply and become similar for all areas, remaining at 75–87 per cent. from December to April. On the Lake Shore Plain high relative humidities therefore occur in association with high temperatures (75°–80°) for five months.

Rainfall

Rainfall is the most significant climatic factor with respect to agriculture. It is particularly critical in Nyasaland owing to the contrast between a single wet season and a long dry period. It will therefore be considered in detail.

The map of mean annual rainfall (map VII) has been drawn from records of 42 stations, including those maintained by the Nyasaland Departments of Agriculture, Forestry, and Water Development, in addition to those of the Federal Meteorological Department. These figures show a close relationship with aspect, stations sited in ground which rises to the north-west having relatively high totals, whilst those with higher land to the south-east are relatively dry. Consequently in areas where records are sparse, the isohyets on map VII have been drawn with regard to this relationship.

The two areas of highest rainfall occur where the shore of Lake Nyasa trends in a south-westerly direction. South-west of Nkata Bay a broad belt with 70–90 ins. extends 80 miles along the shore and 20–30 miles inland. At the northern end of the Karonga Lake Shore Plain there is a steep rainfall gradient, Karonga (lat. 9°57′ S.) recording 45 ins., Mwen tete (9°48′ S.) 68 ins., and Mwafigulukulu (9°42′ S.) 115 ins. The North Vipya (13) and Livingstonia Hills (10) probably receive over 60 ins., although this is uncertain due to the sparsity of records. A network of gauges on the Nyika Plateau indicates that the majority of it receives 40–50 ins., but that a high-rainfall belt exists along the south-eastern margin. The Misiku Hills (3), Deep Bay (6g, 1), the Vipya Plateau (19), and an area north-east of Mzuzu record 50–60 ins

On the Mid-Tertiary Surface the Fort Hill Plain (2) receives 35–40 ins. whilst the South Rukuru section is drier. Two stations in the Lower Kasitu Valley (12) both record 29 ins. Rainfall measurements for the Upper South Rukuru Valley (16) are inadequate. Rumpi receives 26 ins. and Mbawa and Loudon, a short distance south of latitude 12°S., both record 32 ins. By analogy with topographic conditions in the Lower Kasitu Valley it is therefore probable that the northern part of the Upper South Rukuru Valley receives less than 30 ins., but the extent of this dry area is very uncertain. A raingauge recently established at Mpherembe, 23 miles south-west of Rumpi, has recorded the very low totals of 14.5 and 19.4 ins. in successive years.

Variability from year to year is considerable. Table III shows rainfall confidence limits for nine out of ten years in relation to mean annual totals. The feature of particular agricultural significance is that only areas with a mean annual total above 40 ins. are reasonably free from the danger of drought. All parts of the Mid-Tertiary Surface will experience a year with less than 26 ins. at least once in a decade, whilst a large area in the Upper South Rukuru and Lower Kasitu Valleys will receive less than 16 ins. with this frequency.

TABLE III—RAINFALL CONFIDENCE LIMITS FOR 9 OUT OF 10 YEARS

Mean Annual Rainfall ins.	*Lower confidence limit ins.*	*Upper confidence limit ins.*
88–96	57	128
80–88	52	117
72–80	46	106
64–72	41	95
56–64	36	84
48–56	31	73
40–48	26	62
32–40	21	51
24–32	16	40

Source: Jack, D. T., *et al.*, 1960. *Report on an economic survey of Nyasaland* 1958–1959, map no. 2.

The dominant characteristic of the rainfall is its high degree of concentration in a single season. Fig 3a shows the monthly distribution for six stations. Light falls may occur during November, but the main rains do not normally commence until the following month; the date of their onset varies from year to year between the beginning and end of December. At stations having annual totals below 35 ins., falls become small in April and largely cease in May, the succeeding six months being dry. In wetter areas rainfall remains high in April and continues into May. In the extreme north of the country a double maximum, with a short dry spell in February is commonly experienced. For example in 1939/40 Karonga recorded 17.0 ins. in January, 4.2 ins. in February, rising again to 10.3 ins. in March. In a 30-year period from 1925, monthly distributions of this pattern occurred in 12 years at Karonga but only 4 years at Mzimba.

The proportion of the total rain falling in the four months December–March is shown in fig. 4a. Over the majority of the area it exceeds 80 per cent., and near the western border approaches 90 per cent. A zone which includes Nkata Bay and Mzuzu has a lower degree of seasonal concentration. Fig. 4b shows a factor of importance in the cultivation of perennial crops, the total rain received in the six driest months. Areas with annual means of under 40 ins. experience almost complete drought during this period. In contrast a lake-shore belt extending as far north as Livingstonia receives 5–10 ins.

Evaporation

Measurements of evaporation have been made for only a short period, insufficient for the establishment of reliable means. The available records of mean annual evaporation from standard raised screened pans are as follows:

Karonga	86 ins.	Mzuzu	66 ins
Deep Bay	93 ins.	Mzimba	90 ins
Nkata Bay	83 ins		

The three lake-shore stations have reasonably consistent totals, but evidence from the Mid-Tertiary Surface is inadequate. Two stations on this surface in Central Province, Lilongwe and Chitedze, record 72 and 78 ins. respectively. Evidence from all stations in Nyasaland shows an approximate relationship with temperature, a fall of one degree in mean annual temperature corresponding to a decrease of 3 ins. in mean annual evaporation. Consequently the true values on the Mid-Tertiary Surface are probably between 60 and 80 ins., the record for Mzimba being anomalously high.

Mean monthly evaporation remains at approximately 5–6 ins. during both the wet season and the cool season. From July onwards it rises to a maximum of over 10 ins. in November, before falling sharply in December with the arrival of more humid air accompanying the onset of the rains.

Climatic Regions

The above features may be summarized by means of climatic regions. Seven regions are shown on map VIII. In describing these, the terms cool, wet, etc. will be used in a relative sense, as applied to the range of conditions experienced in Northern Nyasaland.

I. *Cool, wettish.* Mean annual temperature predominantly 60°–65°, falling below 60° on the Nyika; light frosts occasionally occur. Mean annual rainfall 40–60 ins. Nyika Plateau (8), High Vipya Plateau (19a, b), Misuku Hills (3a–d), Mafingi Plateau (4a), Pirewombe Plateau (4b).

II. *Cool to warm, wet.* This region comprises all wet areas apart from the Lake Shore Plain. Rainfall 60–90 ins., temperature varying with altitude, 60°–70°. A belt extending through the East Vipya Scarp Zone (20), North Vipya Hills (13), Livingstonia Hills (10), and the south-east margin of the Nyika (part of 8b); east Misuku Hills (3g, h).

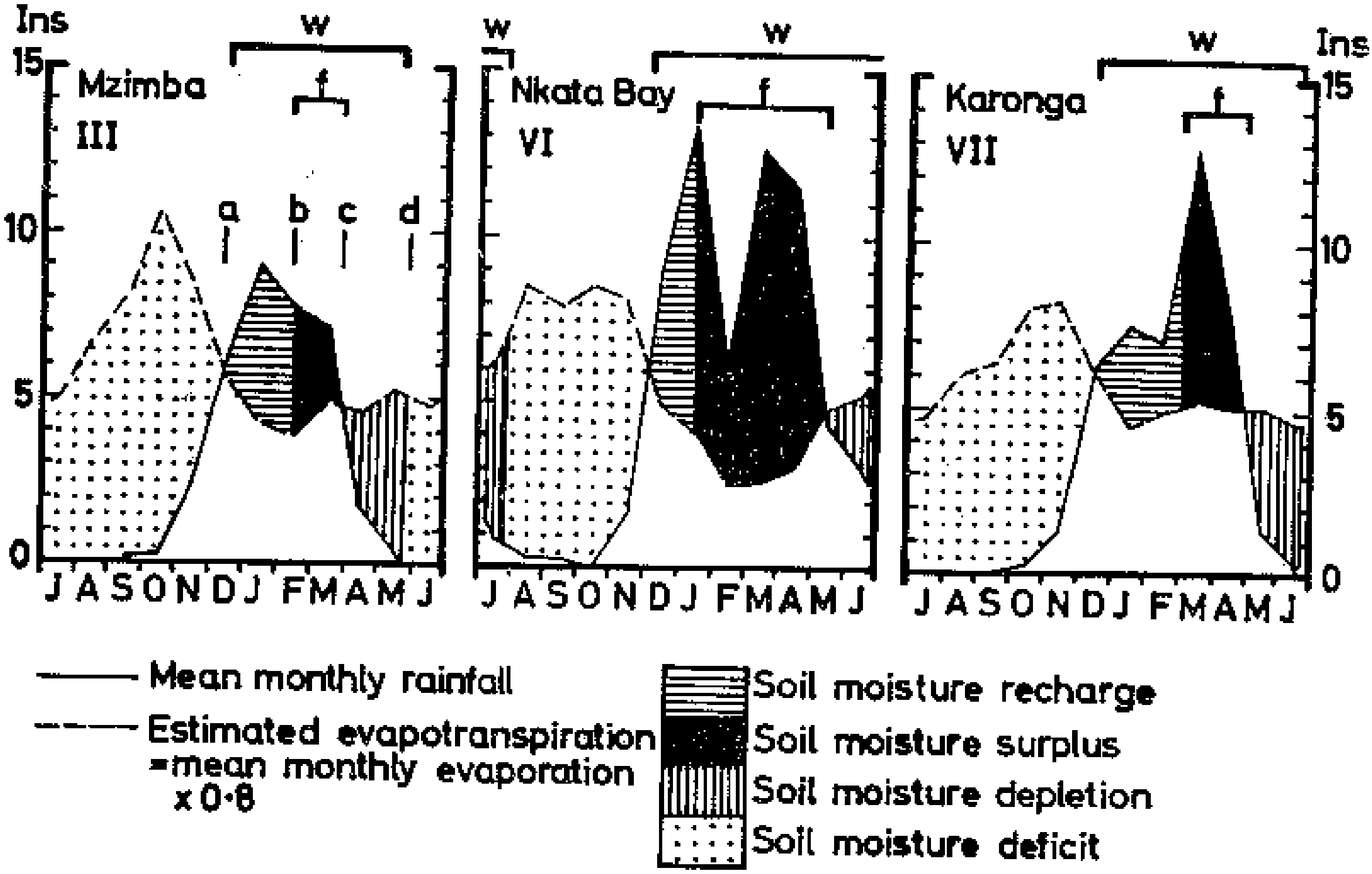

FIG. 5. *Annual soil moisture changes for selected stations* For explanation see text.

III. *Warm, dryish.* Temperature 65°–70°, rainfall 30–40 ins. Mean monthly temperatures range from 58°–62° in July to 71°–76° in November. The wet season lasts four months, December–March, with only light falls in April. Rainfall during the six driest months averages less than 1 in. Annual rainfall totals below 20 ins. occur approximately once in ten years. Fort Hill Plain (2); Hills of the Upper Lufira (4d–g); Plains and Hills West of the Nyika (7); parts of the South Rukuru drainage basin, including the Central Mzimba Hills (17).

IV. *Warm, dry.* Temperature 65°–70°, rainfall 25–30 ins. Characteristics are similar to Region III except for the lower rainfall and correspondingly greater possibility of drought. Lower Kasitu Valley and northern section of the Upper South Rukuru Valley (12a, b, 16a–c).

V. *Warm to hot, wettish.* Temperature 65°–75°, rainfall 40–60 ins. A region free from drought danger, occurring principally on the hilly country of the Karonga Scarp Zone (5) and the East Vipya Scarp Zone (20) but also including important agricultural areas near Mzuzu (15, 20c) and Nchenachena (10a–c).

VI. *Hot, wet.* Temperature 75°–77°, rainfall mainly 60–90 ins., rising above 90 ins. near the mouth of the Songwe. From December to April, temperatures above 75° and relative humidities above 75 per cent. The wet season lasts longer than in regions III and IV, continuing into April; over 5 ins. of rain falls in the dry season. Northern section of the Karonga Lake Shore Plain (6a), Nkata Bay Coastal Lowlands (21).

VII. *Hot, dryish to wettish.* Temperature 75°–77°, rainfall mainly 30–45 ins., rising to 45–60 ins. near the boundary with region VI and near Deep Bay. Rainfall in the 6 driest months averages 1–2 ins. Central and South Karonga Lake Shore Plain (6b–j)

Comparison with Northern and Southern Rhodesia

The economy of Nyasaland is linked with that of the two Rhodesias, and it is of relevance to agricultural development to compare the range of climatic conditions experienced

Mean annual temperatures of over 75° occur in the Zambezi and Luangwa Valleys of both Northern and Southern Rhodesia, parts being hotter than any areas of northern Nyasaland. Means of below 60° are found in the Inyanga Highlands of Southern Rhodesia, but in Northern Rhodesia are confined to a small area of the Nyika Plateau adjacent to Nyasaland. The most extensive temperature zone in northern Nyasaland, 65°–70° is also the largest in Southern Rhodesia, and occupies considerable areas of Northern Rhodesia. Temperature conditions are thus comparable in all three territories. In Southern Rhodesia, however, frosts may occur at moderate altitudes from June to August.

In respect of rainfall, Nyasaland is wetter than the Rhodesias. Northern Rhodesia has no regions with over 70 ins., although it resembles Nyasaland in that the greater proportion of its area receives 30–60 ins. Southern Rhodesia is considerably drier; totals exceeding 50 ins. are confined to a narrow strip along the eastern border whilst over one third of its area receives less than 25 ins.

This difference is reflected in the correspondence between the Nyasaland climatic regions and the natural regions, defined on a climatic and vegetational basis, employed in the Agro-Ecological Survey of Southern Rhodesia[2] (the former will be referred to as N. I, N. II . . . . etc. and the latter as SR. I, SR. II . . . . etc). N. I, N. II and N. V are included in SR. I; the Rhodesian survey groups together all country with a rainfall exceeding 42 ins., owing to the smallness of the total area covered. N. III corresponds closely to SR. IIa, in respect of rainfall, temperature and vegetation. N. IV approximately corresponds to SR. IIb, its driest parts tending towards SR. III. N. VI and

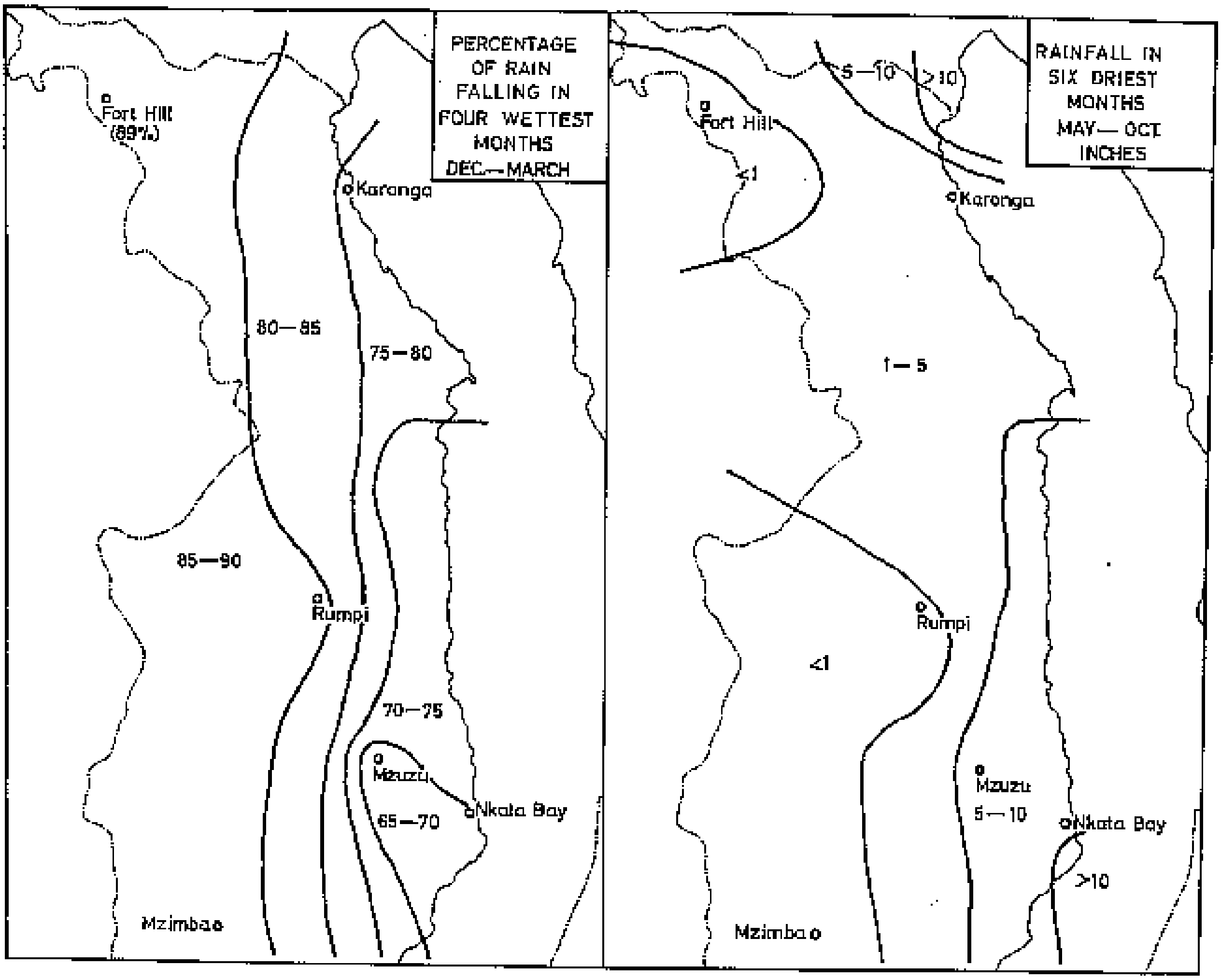

FIG. 4. *Seasonal concentration of rainfall.*

N. VII are not represented in Southern Rhodesia, although N. VII has affinities with SR. III, the higher temperatures of N. VII compensating for its higher rainfall, to produce similar effective rainfall and a moderate degree of vegetational correspondence. SR. IV and SR. V have drier conditions than any experienced in Nyasaland.

Soil Moisture

During the months of January to March, rainfall considerably exceeds evaporation in all parts of northern Nyasaland, and the soil moisture content is raised to field capacity at all depths. During the dry season this moisture is depleted, partly by evaporation but principally by plant transpiration. Losses from transpiration continue until the soil moisture content reaches wilting point; this occurs first at the soil surface, and with continued absence of rain extends progressively downwards. Studies by Wood [3, 4] in the Central and Southern Provinces of Nyasaland have shown that the depth to which wilting point extends varies with land use. The results obtained on a sandy clay latosol at Chitedze (3,770 ft.), near Lilongwe, may be summarized as follows:

Bare fallow:	Wilting point reached at 1 ft., in some seasons at 2 ft.; soil at 3 ft. remains at field capacity
Groundnuts:	No definite difference from bare fallow
Tobacco:	Wilting point normally extends to 2 ft. depth
Maize:	Wilting point is reached at 2 ft. and sometimes 3 ft.; some moisture is drawn from 4 ft., lowering the moisture content below field capacity
Indigenous grasses:	Wilting point is reached at 4 ft., and moisture is drawn from at least 6 ft.

The last finding is explained by Wood [4, 5] from studies of rooting systems. Many indigenous grasses root deeply, to 10–12 ft.; the dominants change seasonally, deeper-rooting species flourishing in the drier months[6].

Fig. 5 shows a diagrammatic comparison of soil moisture regimes. Its method of construction is based on the assumptions: (i) that evapotranspiration from crops or vegetation = 0.8 × evaporation from a standard pan[7]; (ii) that during the dry season, 7 ins. of moisture is removed from the soil, an average figure based on measurements by Wood[5]. The continuous line shows mean monthly rainfall, and the broken line estimated monthly evapotranspiration. At the date when rainfall first exceeds evapotranspiration, marked as " a " on the graph for Mzimba, the soil moisture content is raised above wilting point. Moisture recharge continues, until at " b " field capacity is reached throughout the profile; the horizontally-shaded area is equivalent to 7 ins. of moisture. During the ensuing period, excess moisture is rapidly lost by run-off or drainage through the soil. At " c ", depletion of soil moisture commences. The vertically shaded area is also equivalent to 7 ins. of moisture, and at " d " the upper horizons of the soil will be reduced to wilting point, and only deep-rooting plants will be able to continue growth. The upper soil horizons remain close to or above field capacity during the period marked " F ", and above wilting point during that marked " W ". The latter period is 22 weeks for Mzimba, 27 weeks for Karonga, and 33 weeks for Nkata Bay. The majority of climatic regions II and VI have higher rainfalls than Nkata Bay, whilst region IV and parts of region III are drier than Mzimba. It is therefore probable that the period during which the soil remains above wilting point is nearly twice as long in regions II and VI as in regions III and IV. The significant factor in causing this difference is shown by fig. 5 to be the continuation of the rains into April and May in the former regions, rather than their greater total rainfall.

Climate and Soil Formation

These features of the soil moisture regime, a consequence primarily of the high degree of concentration of the rainfall in a short period, have the following effects upon soil formation:

(i) During the period in which the soil is at field capacity (" F " on fig. 5), a large quantity of moisture drains downward through freely drained soils. These soils are therefore subject to strong leaching for part of the year.

(ii) In soils where any degree of drainage impedance occurs, either due to site drainage or to impermeable horizons within the profile, there is a strong tendency for waterlogging to occur during this same period.

(iii) In soils with both free and impeded drainage, the upper horizons are dried out annually. This results in a tendency for the precipitation of dissolved substances, particularly iron compounds, forming a mottle or concretions.

The combination of these three processes is particularly favourable for the formation of ground-water laterites in soils with site drainage impedance, due to the irreversible precipitation of dissolved iron compounds in the form of ferric oxides and hydroxides.

The essential climatic characteristics which give rise to these conditions of soil formation are:

(*a*) Mean annual temperature above 65°, causing relatively rapid chemical reactions in the soil, and consequently rapid weathering.

(*b*) Mean annual rainfall above 25 ins., causing the dominant direction of water movement in freely drained soils to be downwards.

(*c*) More than 75 per cent. of the annual rainfall occurring in four months, causing strong leaching.

(*d*) Less than 5 ins. of rain in the six driest months, causing the soil to dry out annually.

A similar range of soil types should be expected in other parts of the world in which these conditions occur. The three major regions in which this is the case are: (i) countries adjacent to Nyasaland, principally the Rhodesias and Moçambique (e.g. Salisbury, Southern Rhodesia, 65.3°, 31.9 ins. 79 per cent., 1.9 ins., with respect to (*a*)–(*d*) above); (ii) a belt in West Africa approximately along latitude 12°–13° N., passing through Gambia and northern Nigeria (e.g. Bathurst, Gambia, 77.7°, 47.6 ins., 92 per cent., 0.3 ins.); (iii) parts of the monsoon climatic region of central and south-west India (e.g. Bombay, 80.6°, 72.4 ins., 95 per cent., 0.6 ins.).

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CHAPTER III

VEGETATION

Complete or partial accounts of the vegetation of Nyasaland have been given by Jackson[1], Topham[2], Jackson and Wiehe[3], and Hursh[4], whilst vegetation maps have been published by Jackson[5], and in the Federal Atlas of Rhodesia and Nyasaland[6]. A summary of the principal grassland types is contained in the memoir accompanying Rattray's map of the grasslands of Africa[7], and a detailed description of the use of plants in the native economy is given by Williamson[8]. Regional descriptions of limited areas have appeared in the Annual Reports of the Nyasaland Department of Agriculture, from 1950 to 1958/59 by G. Jackson and from 1958/59 to 1959/60 by A. Young. Detailed information on forest management and plantations is given in the Annual Reports of the Nyasaland Department of Forestry. Of considerable value are a number of unpublished reports and maps by G. Jackson, held by the Department of Agriculture.

The following account is based primarily on field observations made during the course of soil survey, and, with respect to distributions, on air photograph interpretation. These observations have been extensively compared with, and supplemented from, the above publications. In particular, all information on grasses is taken from published and unpublished accounts by G. Jackson.

Vernacular names of plants will be given in only a few instances For comprehensive lists of these, reference should be made to the check lists[2, 3].

Vegetational communities

A classification of the vegetational communities is given in table IV, and their distribution is shown in map IX. The classification is descriptive; it is based primarily on physiognomy, and secondarily upon dominant species.

1. *Montane grassland.* Pure grasslands are uncommon, and are mainly confined to the Nyika Plateau. The normal type is grassland with scattered shrubs of *Protea madiensis*, and in some areas short trees of *Cussonia kirkii*. In the lower part of the altitude range, medium trees of *Erythrina tomentosa* and *Dombeya rotundifolia* occur, principally in valleys. It is probable that in all areas, with the possible exception of parts of the Nyika, this community represents a fire climax, and has replaced a former cover of montane evergreen forest[1] (*q.v.*). It occupies the High Plateaux, and some high-altitude hill areas: the Nyika Plateau (8), the Vipya Plateau (19a–c, e), the North Vipya plateau remnants (13a) and parts of the North Vipya Hills (13b, c) and Livingstonia Hills (10b, e), the Mafingi Plateau (4a), the Pirewombe Plateau (4b) and part of the hill area north-east of it (4d), and the high-altitude ridges of the Misuku Hills (3c). The Vipya area includes coniferous plantations of the Nyasaland Department of Forestry.

2. *Marsh grassland.* This is known within Nyasaland as *dambo* grassland (*see* p. 17). It is normally tall and dense, although it may be kept short by heavy grazing. Trees are absent from the majority of the areas, but at valley-floor margins scattered *Acacia* trees appear amid the grassland. The type shown on map IX as marsh grassland with trees is characterized by numerous large termite mounds; it has been mapped from air photographs, but has not been examined in the field.

A belt of marsh grassland occurs along all valley floors except those of rapidly incising streams. On the Mid-Tertiary Surface such belts may be ¼–1 mile in width, often with a lobate expansion at the valley heads. Extensive grass-covered marshes also occur, particularly in the Lake Shore Plain.

Permanently waterlogged areas with a reed vegetation, principally the *bango* reed (*Phragmites mauritianus*) are found in parts of the larger marshes, and at the margins of lagoons. They are considerably less extensive than the grasslands, and have been included with the latter on map IX.

3. *Montane evergreen forest.* On all of the High Plateaux this occurs as patches in valley floors and heads. The outer margins of these patches are formed by fire-resistant shrubs. A few relics occupying sites other than in valleys are evidence that this community formerly covered all or most of the areas now occupied by montane grasslands. These relics comprise forest reserves in the Misuku Hills (3c), on Uzumara Hill (13b), and on Msissi Hill (4d); a further patch of 1½ × 1 mile, which is not at present a forest reserve, occurs east of Pirewombe Hill (4b).

4. *Semi-evergreen forest.* This consists of a canopy of deciduous *Brachystegia spiciformis*, beneath which is an evergreen understory of trees, shrubs, and creepers. It differs from the moist *Brachystegia* woodland (*q.v.*) in that the understory is dense, and the grass layer is completely suppressed. It occupies the deeper soil areas of the Nkata Bay Lake Shore Lowlands (21c, d), with a rainfall of 60–90 ins.

5. *Riparian forest.* *Syzigium* species trees occur along the banks of actively incising streams, and are sometimes present at the margins of the marsh grassland belts. True forest belts are only found in a few places, for example below the North Rukuru Falls. This unit is not of sufficient extent to be shown on map IX.

Brachystegia woodlands. A general account of these woodlands has been given by Griffith[9]. They form a vegetation unit confined to an approximately circular area of 3 million square miles, lying in East Africa between latitudes 5° and 17° south. Whilst varying considerably in physiognomy and composition, they are characterized by the predominance of *Brachystegia, Isoberlinia,* and *Julbernardia* species. In many areas this unit is known by the Swahili word *miombo.*

6. *Moist Brachystegia woodland.* This is formed of tall trees, 40–60 ft., with a closed canopy, an open understory, and a sparse or very sparse grass cover. *Brachystegia spiciformis* is frequently dominant, but *B. longifolia* and other species also appear in the canopy. Stands in which tall, well-formed *Uapaca kirkiana* is dominant are found, and elsewhere this species occurs in the understory. The tree cover is taller and denser than in the " dry " *Brachystegia* woodland of classes 7 and 8 below. It occurs in areas with over 50 ins. rainfall, principally on the East Vipya Scarp Zone (20), part of the North Vipya Hills (13d, f), and on thin stony soil areas in the Nkata Bay Lake Shore Lowlands (21a, b).

7. *Brachystegia plateau woodland.* This is most commonly found as a savanna woodland of short trees, with the crowns widely separated, and a moderate grass cover. In this form it is a degenerate vegetation, caused by clearance for cultivation, annual burning, and removal of saplings and bark for use in the native economy. An account of these processes, together with a classification of the forms encountered, is given by Hursh[4]; he instances the Central Mzimba Hills (17) as an example of the poorest woodlands in Nyasaland. Taller stands, with touching crowns, are found in the Perekezi (17d, e) and Vinthukutu (6i) Forest Reserves.

This class has been subdivided into a southern sector in which *Julbernardia paniculata* is very common and *Isoberlinia* species of less importance, and a northern sector in which *Isoberlinia tomentosa* and *I. angolensis* are frequent with *Julbernardia* species also present. A type in which *Cryptosepalum pseudotaxus* becomes dominant

TABLE IV—VEGETATIONAL COMMUNITIES

	Community		Dominant and characteristic species: Trees and shrubs		Dominant and characteristic species: Grasses
Grassland	1. Montane grassland		*Protea madiensis, Cussonia kirkii, Erythrina tomentosa, Dombeya rotundifolia*		*Themeda triandra, Loudetia simplex, Exotheca abyssinica, Monocymbium ceresiiforme, Hyparrhenia cymbaria, Andropogon schirensis*
	2. Marsh grassland		*Acacia campylacantha*		*Hyparrhenia* species, *Themeda triandra* var. *hispida, Pennisetum purpureum, Phragmites mauritianus*
Forest	3. Montane evergreen forest		*Aphloia myrtiflora, Maesa lanceolata, Podocarpus milanjianus*		
	4. Semi-evergreen forest		*Brachystegia spiciformis, Erythrophloeum maraviense.* Creepers: *Smilax kraussiana, Landolphia kirkii*		
	5. Riparian forest		*Syzigium guineense, S. cordatum*		
Brachystegia woodland and savanna woodland	6. Moist *Brachystegia* woodland		*Brachystegia spiciformis, B. longifolia, Parinari mobola, Uapaca kirkiana*		
	7. *Brachystegia* plateau woodland	7a. *Brachystegia-Julbernardia* woodland	*Brachystegia* species, *Julbernardia paniculata, J. globiflora*	*Brachystegia boehmii, B. floribunda, B. longifolia, B. manga, B. microphylla, B. spiciformis, B. tamarindoides, B. taxifolia, B utilis, Julbernardia paniculata, J. globiflora; Dichrostachys glomerata, Diplorrhynchus condylocarpon, Pseudolachnostylis maprouneifolia, Parinari mobola, Flacourtia indica, Ochna schweinfurthiana, Xeromphis obovata, Acacia macrothyrsa, A. sieberiana, Fagara speciosa, Monotes africanus, Pavetta crassipes, Protea* species, *Eriosema affine, Asschenonomene* species	*Hyparrhenia filipendula, Hyparrhenia* species, *Themeda triandra* var. *hispida Andropogon schirensis, A. amplectens, Digitaria* species, *Setaria* species, *Panicum maximum, Bewsia biflora, Brachiaria brizantha, B serrata, Pogonarthria squarrosa*
		7b. *Brachystegia-Isoberlinia* woodland	*Brachystegia* species, *Isoberlinia tomentosa, I. angolensis*		
		7c. *Brachystegia-Cryptosepalum* woodland	*Brachystegia* species *Cryptosepalum pseudotaxus*		
		7d. *Brachystegia* lake shore woodland	*Brachystegia* species, *Bauhinia petersiana, Oxytenanthera abyssinica*		
	8. *Brachystegia* hill woodland	8a. High-altitude *Brachystegia* hill woodland	*Uapaca kirkiana, Brachystegia* species, *Protea* species		
		8b. Medium-altitude *Brachystegia* hill woodland	*Brachystegia boehmii, Uapaca kirkiana*		
		8c. Low-altitude *Brachystegia* hill woodland	*Brachystegia boehmii, Bauhinia petersiana, Oxytenanthera abyssinica*		
Acacia savanna and thicket	9. *Acacia-Adansonia-Hyphaene-Sterculia* cultivation savanna of the lake shore		*Acacia spirocarpa, A. campylacantha, Adansonia digitata, Hyphaene ventricosa, Sterculia africana, Kigelia pinnata, Trichilia emetica, Zizyphus mauritiana*		*Panicum maximum, Hyparrhenia* species
	10. *Acacia* cultivation savanna of valley floors.		*Acacia albida, Borassus aethiopicum*		
	11. *Acacia-Combretum* thicket and savanna	11a. Lake shore thorn scrub	*Acacia spirocarpa, A. nigrescens, Hyphaene ventricosa, Dichrostachys glomerata, Combretum ghasalense, Sclerocarya birrea*		*Urochloa pullulans, Panicum maximum*
		11b. *Acacia-Combretum* thicket of plateaux	*Acacia* species, *Combretum* species, *Securidaca*?—*Reissantia indica, Grewia flavescens*		
		11c. *Combretum ghasalense-Acacia* savanna of lower valley sides	*Combretum ghasalense, Acacia* species, *Piliostigma thonningii*		
Specialized vegetation	12. Vegetation of sands		*Magnistipula bangweolensis, Parinari mobola*		*Phragmites mauritianus*

in patches is of restricted distribution. These three subdivisions cover the greater part of the Mid-Tertiary Surface. A low-altitude type, in which *Bauhinia petersiana* and bamboo (*Oxytenanthera abyssinica*) occur, is found on raised beach areas of the Karonga Lake Shore Plain (6i).

Detailed study would be necessary to determine the presence and relative importance of the various species of *Brachystegia*, and of other trees and grasses, in each of these types; in table IV they have been combined, together with the *Brachystegia* hill woodland. The commonest and most widely distributed auxiliary species are known by the vernacular names of *tombozi* (*Diplorrhyncus condylocarpon*) and *msolo* (*Pseudolachnostylis maprouneifolia*).

8. *Brachystegia hill woodland.* This is similar to the preceding class in that an open savanna woodland of short trees is the commonest form. It is distinguished by the greater frequency of species favouring shallow and stony soils, chief among which are *Brachystegia boehmii* and *Uapaca kirkiana* (vernacular: *msuku*).

At altitudes above 5,000 ft., particularly among the Nyika Hills (9), a type with *Uapaca kirkiana* very frequent and *Protea* species common is found. The normal, medium-altitude, type includes a number of *Brachystegia* species, of which *B. boehmii* is the most common; *Protea madiensis* may also be present. Below 3,000 ft. *Protea* is absent, *Bauhinia petersiana* becomes common, and patches of bamboo (*Oxytenanthera abyssinica*) occur. These woodlands occupy the High Altitude Hill Zones, numerous isolated hills rising above the Mid-Tertiary Surface, and the Karonga Scarp Zone (5).

9. *Acacia-Adansonia-Hyphaene-Sterculia cultivation savanna of the lake shore.* "Cultivation savanna" will be used to describe the vegetation of areas which are largely under cultivation, but in which isolated trees, or small woodland patches, remain. The term does not carry any implications as to the type of vegetation which preceded clearance. Parts of the Karonga Lake Shore Plain (6b) are characterized by tall baobab (*Adansonia digitata*) and *Sterculia africana*, together with many palms (*Hyphaene ventricosa*), and shorter *Acacia* species.

10. *Acacia cultivation savanna of valley floors.* The low terraces of certain major rivers, including the Lower South Rukuru, Lower Kasitu (12a), and part of the Upper Lufira (4g), are almost entirely under cultivation. A large majority of the remaining trees are tall *Acacia albida*, together with Borassus palms (*Borassus aethiopium*). The valley floors of the Songwe and some of its tributaries also have a cultivation savanna; Borassus palms are common in the Kanga Valley (2f), but in other parts the vegetational composition has not been recorded.

11. *Acacia-Combretum thicket and savanna.* The main area of this vegetation is the thorn scrub of the South Karonga Lake Shore Plain (6c). It consists of short trees and bushes, varying from thicket to more open forms, in which the majority of species are thorny. In many parts *Acacia spirocarpa* greatly exceeds all other species in frequency. Standing above this vegetation are palms, and occasional tall trees of the same species as found in the lake shore cultivation savanna. A study of this area has been made by Jackson[10]. He concludes that the present vegetation results from abandonment after cultivation, and subsequent heavy grazing by cattle.

Two other communities are included as subdivisions of the *Acacia-Combretum* class. On the area north-west of Rumpi known as the Nkamanga Plain (part of 11a) a low thicket vegetation occurs, in which *Acacia* and *Combretum* species are dominant, and *Reissantia indica* is characteristic. On the lower valley sides of parts of the South Rukuru and its tributaries (11a, b, 12d, 16a, b) the savanna woodland of the freely drained areas gives place to a more open savanna, consisting of *Combretum ghazalense* bushes with short trees of *Acacia* and *Piliostigma thonningii*. The majority of these valley-side belts are too narrow for representation on map IX.

12. *Vegetation of sands.* Constructional landforms of lacustrine sand are initially bare of vegetation. After deposition of coarse sand has ceased, a vegetational succession takes place, associated with the early stages of soil development. Close to the Songwe mouth, *Magnistipula bangweolensis* is dominant at an early stage. On less recently deposited sands south of Nkata Bay, *Combretum* species and *Piliostigma thonningii* were recorded. Wetter areas are colonized by the *bango* reed (*Phragmites mauritianus*).

Vegetation and soils

The principal direct influence of vegetation upon soils is in respect of the organic matter content. This is of agricultural importance firstly because a high organic matter content ensures a well-structured soil, and secondly because there is a close correspondence between topsoil organic matter and nitrogen status (for topsoils analyzed during the present survey, N per cent. = O.M. per cent./20, with a standard deviation (for the ratio) of 3.1). Topsoils with organic matter exceeding 4 per cent. are largely confined to the montane grassland areas. A moderate content, 2–4 per cent., is found in soils beneath semi-evergreen forest and moist *Brachystegia* woodland. The *Brachystegia* plateau and hill woodland is associated with low organic matter contents, in some cases less than 1 per cent; this is partly due to the annual burning to which these areas are subjected.

Vegetation can be of considerable value as an indicator of soil types, and has long been used in this way by the native population in choosing sites for cultivation. It is of particular importance in field soil surveys covering areas of a size which makes it impracticable to examine the soil by a close network of pits or auger-holes. In Nyasaland, however, experience and local knowledge are required to distinguish vegetational changes caused by soil from those due to different histories of clearance and cultivation.

On a local scale, the most important use of vegetation indicators is to distinguish two departures from the " normal " soil type of the area; these are firstly, areas with impeded drainage, and secondly, areas with abnormally thin or stony soils.

The principal change in zones of impeded drainage is that the vegetation opens out, trees and bushes becoming more widely spaced than in adjacent freely-drained sites. At the same time the grass cover becomes taller and denser. This criterion is of general validity, whereas indicator species vary from region to region. Usually the commencement of impeded drainage on lower valley sides is marked by the appearance, or increase in frequency, of *Acacia* species. *Combretum ghazalense* and *Piliostigma thonningii* are also common in such areas, although they may also be found on freely-drained sites.

A reliable indicator of thin, stony soils is the co-dominance of *Brachystegia boehmii* and *Uapaca kirkiana*. *B. boehmii* alone is normally but not invariably found on such soils. *Uapaca kirkiana* occupies more variable sites; as tall trees it may overlie deep, red, strongly acid soils; when present as short trees and bushes, however, thin sandy or stony soils can usually be expected.

A difference of vegetation type that is of local importance occurs on the Nkata Bay Lake Shore Lowlands (21). Here the climatic climax is semi-evergreen forest, with a dense undergrowth. The presence of moist *Brachystegia* woodland, with an open understory, indicates shallow soils.

No attempt to compile a comprehensive list of vegetation indicator species has been made during the present survey. *Cryptosepalum pseudotaxus* tends to be dominant on coarse sandy soil patches. The very thorny shrub *chipembere* (*Xeromphis obovata*) usually appears in woodlands occupying strongly leached, sandy soils of low fertility. The thorny creeper *Smilax kraussiana* is possibly an indicator of a former forest cover, and is found on soils of moderate or highish organic matter content, Jackson[11] gives a list of grass indicator species for eroded lands, light sandy soils, overgrazed areas, and heavy soils.

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CHAPTER IV

SOILS

The method of soil survey normally adopted in English-speaking countries follows the practice, developed by the United States Soil Survey, of using the soil series as the basic unit of classification and mapping. This method has great advantages from the practical point of view. A unit is provided with precisely defined morphological characteristics; by reference to these, a soil encountered in the field can be identified as belonging to a particular series; its agricultural properties can be expected to be similar, within limits, to those of other soils of the same series. This enables the results of agronomic investigations, carried out on soil of a particular series, to be applied to the whole area covered by that series. This is equally the case whether detailed mapping has been carried out, showing to which series every part of the land belongs; or whether, as in reconnaissance surveys, only the areas within which each series is likely to be found are known

The principal disadvantage of the use of soil series is that maps of them are largely incomprehensible when viewed as a whole. The number of series identified in any survey of a substantial area quickly becomes large, and it is hard to obtain a general picture of the distribution of any particular class of soil from the map; this difficulty is frequently increased on small-scale maps by the use of striped shading to represent soil associations or catenas. The fundamental reason for this complexity is that soil genesis is affected by many different environmental conditions. The consequence is that maps of soil series contrast with maps of most other environmental factors, for example altitude or rainfall, from which the general features of the distribution are quickly apparent.

For these reasons the soils will be described in two ways. In this chapter a classification will be given, and the principal features of each class of soil described and compared; the distribution of these classes will be discussed in relation to environmental conditions. This provides a framework to which the descriptions of soil series, given in chapter IX, may be referred.

Classification

The soils of Nyasaland, both of the country as a whole and of the northern part here considered, are divisible into four main groups, strongly distinct from each other in properties. The first comprises all stony and shallow soils, or *lithosols*; these occupy large areas of dissected, steeply sloping country, particularly the Rift Valley Scarp Zone, as well as numerous isolated mountains and hills. All soils which remain waterlogged for a substantial part of the year are included in the second group. These are the *hydromorphic* soils, known locally as " dambo " soils; they are mottled or black in colour, and occupy valley-floor sites at all altitudes. The third group consists of the greyish brown soils; the colour of these is dominated by shades of dark brown and grey, and the lower horizons are usually mottled. This is the *calcimorphic* group and is principally developed on the Lake Shore Plain. The fourth group is formed of all red, reddish brown, and yellowish red soils with free drainage. These are the *latosols*[1]; they occupy the more gently sloping areas with free drainage.

The distinctiveness of these groups, in environmental conditions, profile morphology, analytical characteristics, and agricultural properties, is such that any satisfactory classification of Nyasaland soils, whatever the basis of classification adopted, should begin by distinguishing them.

There are certain groups of soils the classification of which is generally agreed. These are soils developed under some specialized environmental condition, and distinguished by one particular characteristic, which frequently dominates the morphology of the profile; examples are the lithosols, rendzinas, hydromorphic soils, organic soils, and the various classes of saline and alkaline soils. Difficulties of classification arise principally with respect to what have been termed mesomorphic soils[2]; these are soils in which the profile features are associated with normal parent materials and well-drained conditions. In temperate latitudes they are the podzolic and brown earth groups; in the tropics they comprise the latosols.

The two principal systems of classification in use are the morphological and the genetic. The morphological system consists of grouping together soil series having a degree of similarity in their profile characteristics. This system has been developed particularly by the Soil Surveys of the United States, Australia, and New Zealand; in Africa it has been applied to Nigeria by Vine[3]. Its disadvantage is that the selection of which characteristics should be employed at each stage of the classification is to a certain extent arbitrary. In the genetic system, the criteria for classification are based upon the process through which the soil has originated, and the stage of evolution attained. It necessarily corresponds to a particular morphological system, since only the characteristics of the soil are available to observation; but the selection of features for use in each stage of the classification is guided by considerations of the origin of the soil. This system was developed by Russian workers[4], and has been applied to tropical soils particularly in French African territories[5]. It has been adopted by the Inter-African Pedological Service for the Soils Map of Africa at a scale of 1:5M.[6]. In the compilation of the soil map for the Federal Atlas of Rhodesia and Nyasaland it was found to be the most satisfactory means of co-ordinating the different methods of classification previously in use in the three territories of the Federation; in this case, however, the terminology applied by the Inter-African Pedological Service to the subdivisions of the latosols was not used on the finished map, owing to its unfamiliarity.

In the present survey the morphological system will be used at the lowest level of classification, that of the soil series (*see* chapter IX). The genetic system is used in the description of the general features of soil distribution given in this chapter. The genetic soil groups will first be described; these will then be compared in respect of characteristics, agricultural properties, and environmental conditions. The distribution of the groups will then be considered

The genetic soil groups

Table V shows the classification employed, together with the soil series which have been placed in each class. In order to simplify the classification, two classes are shown as sub-groups which do not have equal status with the other sub-groups: "ferrisols with some ferruginous features" is applied to two series intermediate in characteristics between ferruginous soils and ferrisols, and "weakly ferallitic soils" are intermediate between ferrisols and sandy ferallitic soils.

At the highest level of classification, two criteria have been employed for subdivision. Lithosols are separated, on the basis that their profile remains continuously at an early stage of development. Site drainage has been used to classify the remaining soils, since this affects almost all other processes of pedogenesis. These two criteria serve to distinguish the four major groups of Nyasaland soils described above, namely the latosols, the greyish brown soils, the hydromorphic group, and the lithosols.

I. LATOSOLS

The dominant process in the development of all freely-drained soils of humid regions are the weathering of rock minerals and the downward leaching of components.

In all cases these components include clay particles and exchangeable bases; in the latosols the silicates are also leached, resulting in a relative enrichment in iron and aluminium compounds. The subdivision of the latosols used by the Inter-African Pedological Service[6] is based on the degree to which these processes of weathering and leaching are developed. *Ferruginous soils* contain substantial quantities of weatherable rock minerals within the profile, and are relatively weakly leached. *Ferrisols* have a lowish mineral reserve, and are moderately or strongly leached. In *ferallitic* soils the mineral reserve is very low or absent.

1. *Ferruginous soils.* These are latosols in which the processes of weathering and leaching are relatively weakly developed. The subsoil* retains many weatherable minerals, that is, rock minerals other than quartz and muscovite; the base saturation of the lower horizons is above 40 per cent.

Weathering of the minerals contained in the profile results in the formation of clay and of iron compounds, and the release of bases; the processes leading to translocation, the movement of clay particles from one part of the profile to another, are strongly active. The morphological characteristics of the soil result from these features. The subsoil is extremely red in colour, in the 10 R hue. There is a strongly developed textural B horizon in the subsoil; this is a clay, with strong, fine or medium blocky structure. The surfaces of the peds forming this structure carry well-developed illuvial ped cutans[7]. These are coatings of clay particles; when strongly developed they are shiny, and in addition are usually a slightly darker colour than the rest of the soil. In ferruginous soils a frequent combination is that the inner parts of the peds are 10 R 3/6 dark red, with ped cutans 10 R 3/4 dusky red. The group has moderate acidity and moderate base saturation. The base exchange capacity values and the soil consistency indicate that, whilst kaolinite and illite are the predominant clay minerals, some montmorillinite is probably present.

Ferruginous soils are most frequently developed from basic rocks, but have also been observed overlying rocks of intermediate composition.

2 (*a*). *Ferrisols.* These are latosols in which the processes of weathering of rock minerals and of leaching are developed to a moderate degree. Weatherable minerals remain in the subsoil or lower subsoil, but in smaller quantities than in ferruginous soils. The profile is strongly leached, with a base saturation of less than 40 per cent. in the lower horizons. They have also been termed *kraznozems*[8], and are sometimes referred to as "red loams", owing to the fact that their permeability and consistence is that normally associated with loams, although the textures are heavier.

The processes of weathering have reached a more advanced stage than in ferruginous soils, and kaolinitic clay minerals are predominant. There is a high content of hydrated ferric oxides, giving a uniformly red or dark red colour to the profile. The flocculating effect of the ferric oxides hinders the process of translocation, as a result of which the illuvial (textural B) horizon is weakly developed, and often occurs deep in the profile. The predominant textures at all depths are clay and sandy clay. In the subsoil there is a weak fine blocky structure, which characteristically breaks down into a weak fine crumb; ped cutans are usually weakly developed in the subsoil. In depth, however, both structure and ped cutans may reach the moderate or strong grades. Even the clay horizons are freely permeable, soft, and friable, often with a "floury" feel. Ferrisols are strongly acid, pH 4.0–5.0, and have a low base saturation.

2 (*b*). *Ferrisols with some ferruginous features.* This sub-group has been included for convenience, to classify two soil series, the Livingstonia and Misuku series. These both possess a strong fine to medium blocky structure in the subsoil, features normally diagnostic of ferruginous soils. Their other morphological characteristics, however, together with their analytical properties, resemble those of ferrisols.

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* *See* note on horizon nomenclature, p. 49.

TABLE V—GENETIC CLASSIFICATION OF SOILS

Drainage class	*Group*	*Sub-group*	*Series*
I. Free site drainage; leaching the dominant process; red, reddish brown, and yellowish red colours; latosols	1. Ferruginous soils		Chinunka, Ekwendeni
	2. Ferrisols	(*a*) Ferrisols with some ferruginous features	Livingstonia, Misuku
		(*b*) Ferrisols	Chinyakula, NkataBay, Chombe, Nchenachena, Mazamba, Uzumara
	3. Ferallitic soils	(*a*) Humic ferallitic soils	Vipya, Nyika
		(*b*) Weakly ferallitic soils	Loudon, Mpherombe, Jandalala, Chisenga
		(*c*) Sandy ferallitic soils	Rumpi, Nkamanga, Fort Hill, Wenya, Kafukule, Bulala
		(*d*) Sandy ferallitic soils with laterite	Jalira
		(*e*) Ferallitic soils developed from sandy parent materials	Mankhambira, Kashata
		(*f*) Ferallitic soils with impeded profile drainage	Bwabwa
II. Impeded site drainage; greyish brown, black, or mottled colours; calcimorphic soils	1. Lower members of latosol catenas		Kapemba
	2. Alluvial soils		Rukuru, Karonga, Lughali
	3. Alkaline soils		Alkaline soils
III. Poor site drainage	Hydromorphic soils		Mwenitete, Dambo Clays, Sandy Dambo Soils
IV.	Lithosols		Lithosols

3. *Ferallitic soils.* These are latosols in which the content of weatherable minerals in the subsoil is low or non-existent. This is due either to the fact that weathering has reached a very advanced stage, or that leaching is very strongly active. Two sub-groups with greatly differing properties occur, according to which of the above processes named is the dominant cause of the low mineral reserve. These sub-groups are humic ferallitic soils and sandy ferallitic soils[6].

3 (*a*). *Humic ferallitic soils.* These are latosols in which very few weatherable minerals remain in the subsoil, and in which the process of leaching is very strongly active at the present time. The low mineral reserve is due partly to rapid weathering, but may also be partly due to a low content of weatherable minerals in the parent material, which is normally rocks of acid (siliceous) composition.

The colour may be red, in the 2.5 YR hue, or the iron oxides may exist in more hydrated forms, resulting in a yellowish red (5 YR) colour in the lower horizons[9]. There is an illuvial horizon of clay or sandy clay, which commonly occurs immediately above the commencement of weathered rock. The proportion of silt is very low. The subsoil is massive or very weakly structured, with ped cutans absent; the latter may, however, be weakly developed in the illuvial horizon. In Nyasaland, soils of this group occur at high altitudes, above 5,000 ft.; due to the lower temperatures there is a relatively slower rate of decomposition of organic matter, and the topsoils have a characteristically high organic matter content. The sub-group is strongly acid, and has a very low base saturation in the lower horizons. Kaolinitic clay minerals predominate, although probably less markedly so than in the ferrisols.

3 (*b*). *Sandy ferallitic soils.* These are latosols in which the processes of weathering have reached an advanced stage. The content of weatherable minerals is very low, due principally to long-continued weathering in the past. These are " old " soils, in which pedogenic processes are now relatively inactive.

Quartz and kaolinitic clay minerals are the principal constituents, and iron oxides are no longer being released in substantial quantities; consequently the sub-group is less red than most other latosols, with subsoils in the 7.5 YR or 5 YR hues (brown, strong brown, yellowish red, or reddish brown). The topsoil is sandy. There is a strongly developed textural B horizon, usually in the immediate subsoil, consisting of sandy clay loam or sandy clay, with a very low silt content. This horizon is massive, with ped cutans completely absent; it characteristically becomes extremely hard when dry. In contrast to the clay ferallitic soils the base saturation is moderate, 30–80 per cent., due to relatively weak leaching at the present day. The profile is moderately to strongly acid, pH 4.5–5.5.

3 (*c*). *Weakly ferallitic soils.* This sub-group has been included in order to classify four soil series having characteristics intermediate between ferrisols and sandy ferallitic soils. The Loudon and Jandalala series tend towards the ferrisol class, but are less strongly leached and less acid. The Mpherembe series is closer to a sandy ferallitic soil, but retains a weak blocky structure in the subsoil, indicating that weathering and translocation are still active. The Chisenga series has anomalous characteristics; the topsoil and the subsoil have the properties of sandy ferallitic soils, but in the lower subsoil there is an abrupt change to ferruginous characteristics.

3 (*d*). *Sandy ferallitic soils with laterite.* Profiles of this sub-group have the properties of sandy ferallitic soils, but a horizon of laterite occurs, consisting of at least 40 per cent. iron concretions, and in many cases of massive ferricrete. It occurs principally on the lower parts of gently sloping valley-sides; it is therefore considered that these are ground-water laterites. Iron deposition took place when the water-table stood at a higher level in the past, a process observed in present-day hydromorphic soils. The present location of the profile is due to the lowering of valley floors by river erosion.

3 (*e*). *Ferallitic soils developed from sands.* These are sandy ferallitic soils, but the low content of weatherable minerals in the profile is due to the parent material consisting mainly of quartz sand. In the great majority of cases in Nyasaland these are sands of lacustrine origin.

3 (*f*). *Ferallitic soils with impeded profile drainage.* In one series, the Bwabwa series, mottling occurs in the subsoil due to drainage impedance within the profile. It has been classified with the latosols since it is developed on slopes of up to 10°, with free site drainage. The topsoil resembles that of sandy ferallitic soils; the subsoil is heavy textured with low permeability.

II. SOILS WITH IMPEDED SITE DRAINAGE (CALCIMORPHIC, OR GREYISH BROWN, SOILS)

1. *Lower members of latosol catenas.* Soils of this group are extensively developed along the lower parts of valley sides. In a reconnaissance survey, however, it is normally only possible to describe the freely-drained members of each catena. In one case a series on the lower part of the catena has been defined, the Kapembe series. In addition, observations on the modifications to freely drained profiles that take place lower in the catena are given in the series descriptions of the Chombe, Nyika, and Fort Hill series.

This group possesses to some extent the characteristics of the latosols, since leaching occurs in the upper horizons for substantial periods of the year. It is therefore moderately acid in these horizons, but the colour is greyish brown. Mottling occurs, rising in the profile towards the surface as the drainage becomes progressively more impeded.

2. *Alluvial soils.* This group is formed from alluvium, and is characterized by the presence of depositional bedding, which has been only slightly modified by translocation within the profile. The soil is therefore at a " young " stage of development. The high fertility of most alluvial soils results partly from the periodic addition of material, either by deposition of sediment on the surface or by advection from the adjoining higher land in drainage waters.

Since they are an azonal group, other characteristics of alluvial soils vary widely. The following description refers only to the group as developed in Nyasaland. Greys, greyish browns, and dark browns occur throughout the profile, reddish colours being absent. Mottling is present but does not usually reach the topsoil. A wide range of textures occur, but a distinctive feature is that fine sand is frequently predominant over coarse; the proportion of silt is greater than that found in latosols, often exceeding 10 per cent. Structure varies according to texture; clay horizons have a strong coarse blocky structure with strong ped-cutans, whilst sandy horizons are massive. Muscovite (white mica), being practically unaffected by weathering, is frequently present.

The analytical characteristics are entirely distinctive from those of the latosols. Base saturation is high, 80–95 per cent., and the profile is weakly to moderately acid, pH 5.5–6.5. The high base exchange capacity indicates that montmorillonitic clay minerals are predominant. The clays are plastic when wet, and of low permeability, in strong contrast to the friable, kaolinitic clays occurring in the latosols.

3. *Alkaline Soils.* This group includes all soils having an alkaline reaction. They do not occur extensively in northern Nyasaland, but have been recorded in profiles having morphological characteristics resembling both the alluvial and hydromorphic groups.

III. HYRDOMORPHIC SOILS

These include all soils that remain waterlogged for a substantial part of the year. In Nyasaland permanent waterlogging is not normal in valley-floor sites, owing to the considerable fall in the water-table which occurs during the long dry season. Consequently, mottled profiles are more commonly encountered than black; when the soil dries, ferric iron compounds are irreversibly precipitated, resulting in prominent mottles of strong brown, yellowish red, red, and dark red. The clays are montmorillonitic, and when wet are plastic but extremely stiff. These have a strong coarse angular blocky structure, sometimes with a prismatic tendency. The ped surfaces have very strongly developed shiny cutans, which sometimes exhibit fine grooves resulting from the differential movement of adjacent peds during expansion and contraction. The analytical properties are generally similar to those of the alluvial soils.

IV. LITHOSOLS

All thin or stony soils are placed in this class. They normally occur on steep slopes, subject to rapid denudation, as a result of which profile evolution remains continuously at an early stage. Included are bare rock outcrops, found particularly on hill summits, and slopes with many large boulders such as are commonly found on steep hillsides. In many cases quartzite forms the majority of the stones present.

V. OTHER SOIL GROUPS

Organic hydromorphic soils (peats) may be developed to a limited extent in some marsh areas on the Nyika Plateau. No calcareous parent materials occur, therefore rendzinas and red-brown earths are absent. Neither saline soils nor soils with a horizon of calcium carbonate concretions have been recorded, although it is possible that at least the former occurs on certain poorly drained sites near the lake shore. A profile showing some resemblance to a podzol is referred to in the description of the Bulala series.

Comparison of morphological and analytical characteristics

Table VI shows the morphological characteristics of the main groups of latosols, including the humic ferallitic and sandy ferallitic sub-groups, and the alluvial soils.

Ferruginous soils and ferrisols are the reddest, the former invariably, and the latter sometimes, having the extremely red appearance of the Munsell 10 R hue. The ferallitic soils are typically yellowish red, although the humic ferallitic group may also be red. Alluvial soils are never as red as the 5 YR hue.

The ferallitic soils have lighter topsoil textures, a sandy topsoil being one of the main distinguishing features of the sandy ferallitic group. There is less contrast in the texture of the illuvial (textural B) horizon, but in the sandy ferallitic soils this is not normally clay, and may be as light as sandy clay loam. Ferrisols are distinguished from the other groups of latosols in the absence of any marked degree of textural differentiation within the profile. In alluvial soils depositional bedding is present, therefore textures of both the topsoil and lower horizons may vary widely.

The structure normally developed in the lower horizons of latosols is fine or medium blocky, either sub-angular or angular, with a ped size of ¼–1 in. The ped surfaces commonly have illuvial ped cutans, the degree of development of these varying with the grade of structure present. Ferruginous soils have a strong blocky structure, usually angular, with strong ped cutans. In ferrisols the structure in the immediate subsoil is often weak; it becomes stronger with depth, and in the deeper horizons ped cutans are invariably present. When gently crushed the peds in ferrisols break down into a weak fine crumb structure. Both of the ferallitic groups are massive in the subsoil, but humic ferallitic soils may possess a weak structure on the lower subsoil. Alluvial soils are massive if sandy, but usually contain one or more clay horizons having a strong, coarse, angular, blocky structure.

By definition the reserve of weatherable minerals within the profile is high in ferruginous soils. In the humic ferallitic group, however, shallow profiles occur, in which minerals are present in the horizon overlying weathered rock.

TABLE VI—MORPHOLOGICAL CHARACTERISTICS OF GENETIC SOIL GROUPS

	Characteristics		*Ferruginous soils*	*Ferrisols*	*Humic ferallitic soils*	*Sandy ferallitic soils*	*Alluvial soils*
COLOUR	1. Mottle present						X
	2. Reddest Munsell hue above 60 ins.:	7.5 YR				X	X
		5 YR			X	X	
		2.5 YR		X	X	X	
		10 R	X	X			
TEXTURE	1. Topsoil:	Loamy sand				X	X
		Sandy loam			X	X	X
		Sandy clay loam	X	X	X		X
		Sandy clay	X	X			X
	2. Heaviest horizon above 60 ins.:	Sandy loam				X	X
		Sandy clay loam			X	X	X
		Sandy clay		X	X	X	X
		Clay	X	X	X		X
	3. Textural B horizon:	Weakly developed, shallow				X	
		Weakly developed, deep		X	X	X	
		Strongly developed, shallow	X		X	X	
		Strongly developed, deep	X		X	X	
		Depositional bedding present					X
STRUCTURE	Strongest grade above 36 ins., fine, medium, or coarse blocky:	Massive			X	X	X
		Very weak			X	X	X
		Weak		X	X		X
		Moderate		X			X
		Strong or very strong	X				X
PED CUTANS	Strongest developed above 36 ins.:	Absent			X	X	X
		Weak		X	X		X
		Moderate		X			X
		Strong	X				X
MINERAL RESERVE	Content of weatherable minerals above 36 ins.:	Very low			X	X	X
		Low		X	X		X
		Moderate		X			
		High	X				

The values shown are those characteristic of the genetic groups as developed in northern Nyasaland; the same groups developed elsewhere exceed these ranges in some cases, particularly in respect of texture.

In fig. 6 the analytical characteristics of the groups are compared. All the latosols are moderately to strongly acid, contrasting with the alluvial group. The ferrisols and humic ferallitic soils are the most acid, with pH 4.0–5.0. In the degree of base saturation in the lower horizons there is a continuous gradation from highly saturated alluvial soils, through the ferruginous and ferrisol groups, to the very strongly leached humic ferallitic soils. Sandy ferallitic soils, however, are normally less strongly leached than ferrisols

The values for base exchange in the lower horizons indicate a clear contrast between the alluvial soils, in which montmorillonitic clay minerals are present in considerable proportions, and the latosols, in which kaolinitic clay minerals are dominant, probably with some illite.

In respect of topsoil organic matter content, the humic ferallitic soils differ from the other groups in containing 5–10 per cent. There is also in the majority of cases a contrast between the ferrisols, with 2–4 per cent., and the sandy ferallitic soils with less than 2 per cent.

Agricultural properties

The classification outlined above has a genetic basis; the combinations of morphological and analytical characteristics that are used to define the classes are selected according to considerations of the processes of pedogenesis. It is desirable, however, that any system of soil classification should have validity in respect of its agricultural properties; for any particular order of the classification, it should be possible to make generalizations about these properties in respect of each class.

Many of the morphological characteristics are of direct importance in arable use. The abrupt transition between a sandy topsoil and a heavy-textured subsoil in the sandy ferallitic soils is unfavourable to the growth of many crops. The massiveness of the subsoil in this group hinders root development; in contrast, the clay illuvial horizon of the ferruginous group can be easily and extensively penetrated by roots, owing to the structural planes present. The deepness of the profile in the ferrisols, and the softness and friability of all horizons, favours the cultivation of perennial crops, which require deep root penetration. The presence of many weatherable minerals within the profile in ferruginous soils results in a continuous release of those nutrients which originate partly from rock weathering, particularly potassium, calcium, and magnesium.

The strong acidity of the ferrisols and humic ferallitic soils renders plant nutrients relatively less available than in the other latosols and in alluvial soils. These groups are also subject to strong leaching, which will tend to remove added nutrients from the profile relatively quickly. In contrast the sandy ferallitic soils should normally give good fertilizer response since they are initially low in nutrients (*see* below), but leaching is currently of only moderate intensity, and the acidity is moderate

The values of the three major plant nutrients recorded for the groups is also shown in the lower part of fig. 6. Nitrogen varies with the organic matter content (*see* p. 36); it is high (above 0.2 per cent.) in the humic ferallitic soils, and moderate in the remaining three groups. Phosphorous and potassium values show more variation within each group. With respect to phosphorous the only generalization that can be made is that it tends to be low (below 20 p.p.m.) in all the latosol groups, but is usually adequate in alluvial soils. Exchangeable potassium is normally adequate in all groups with the exception of sandy ferallitic soils, in which it frequently falls below 0.4 m.e. per cent. The sandy ferallitic group is thus usually deficient in all major nutrients, whereas the alluvial soils have a high nutrient status.

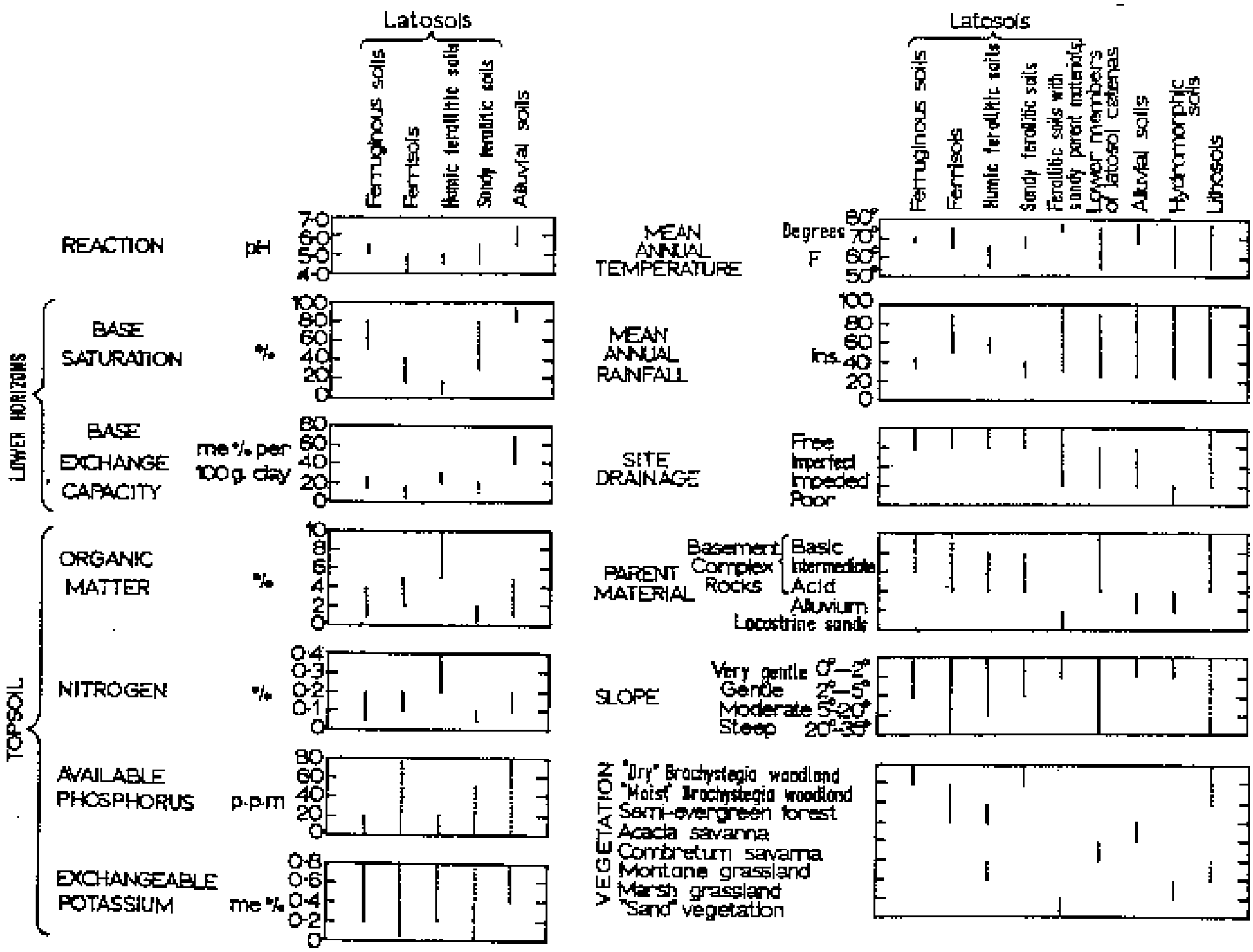

FIG. 6. *Analytical characteristics, nutrient status, and environmental conditions of genetic soil groups.* The values shown are those characteristic of the groups as developed in Northern Nyasaland. The same groups developed elsewhere exceed these ranges in many cases. Dotted lines indicate values less frequently observed

The base exchange capacity per 100 grams of clay, for the lower horizons, indicates the nature of the clay minerals present. The exchange capacities of the principal clay minerals, in m.e. per 100g of clay are: Kaolinite: 3–15; Illite: 10–40; Montmorillonite: 80–150 (Grim[10]).

Environmental conditions

The environmental conditions under which the groups are at present found are shown in fig. 6. Four groups are caused principally by one dominant factor, consequently the remaining conditions may vary widely. Lithosols are caused mainly by the occurrence of steep slopes, from which soil is removed by denudation relatively quickly after it is formed by weathering. The composition of the parent rock is also relevant; acid (siliceous) rocks weather more slowly than basic, whilst quartzites lack the weatherable minerals necessary for the development of soils other than lithosols. Hydromorphic soils and the lower members of latosol catenas are by definition dependent on drainage conditions only. Ferallitic soils derived from sandy parent materials are in Nyasaland developed very largely from lacustrine sands; consequently they occur close to the altitude of Lake Nyasa, under mean annual temperatures of 75°–77°.

The latosols are distinguished from the alluvial soils in possessing free site drainage. It is most commonly the case that latosols occur in areas having temperatures of 66°–70°, whereas alluvial soils are most extensively developed at lower altitudes with temperatures of 75°–77°. This, however, is principally a consequence of physiographic conditions, drainage impedance and the deposition of alluvium being more common at altitudes close to that of Lake Nyasa. This is shown by the presence of alluvial soils in the Kasitu and South Rukuru Valleys with a temperature of 70°, and the extensive development of ferrisols under temperatures of 71°–75° south and south-west of Nkata Bay. The alluvial soils are developed under mean annual rainfalls varying from 25 ins. near Rumpi to nearly 100 ins. north of Karonga.

In respect of rainfall, the main feature of significance is that ferrisols and humic ferallitic soils are developed under more than 50 ins., in contrast to the ferruginous and sandy ferallitic group. The intermediate sub-group of weakly ferallitic soils is also developed under the lower rainfall characteristic of the sandy ferallitic group. High rainfall keeps the deeper horizons of the soil continuously moist. When combined with moderate or high temperatures this results in the deep weathering characteristic of the ferrisols. The humic ferallitic soils are developed at high altitudes with cooler temperatures; the consequent less rapid weathering is partly the cause of the shallower profiles in this group.

In its most extreme development on the Nyika Plateau, the humic ferallitic group is developed from igneous rocks of acid composition. Ferruginous soils have in most cases been observed to overlie basic rocks. The sandy ferallitic group is probably developed from rocks of varied composition. Its occurs principally on the Mid-Tertiary Surface, on very gentle and gentle slopes. It is provisionally suggested that this group owes its characteristics to the long period of time during which it has been exposed to pedogenic processes, combined with the very slow rate of removal of material from the ground surface by denudation. This has allowed a soil with " old " profile features to develop; on less gentle slopes the profile is maintained at an earlier stage of development through the continuous denudation of the surface soil.

The humic ferallitic soils are developed mainly under a montana grassland vegetation. The ferrisols are associated with moist *Brachystegia* woodland and semi-evergreen forest, whilst the ferruginous and sandy ferallitic groups occur under *Brachystegia* plateau woodland. The alluvial soils, both on the Karonga Lake Shore Plain and in valley floors, are under cultivation savanna, and the hydromorphic soils are occupied by marsh grassland.

Distribution

Map X shows the distribution of the nine principal genetic soil types. Three of the classes shown in table V have been omitted, owing to the small total areas which they cover: namely, sandy ferallitic soils with laterite, ferallitic soils with impeded profile drainage, and alkaline soils. The class of lower members of latosol catenas cannot be represented on the scale employed; it occurs on lower valley sides in all areas occupied by latosols. Each of the main latosol types has been subdivided, regions in which they occur in association with substantial areas of lithosols being shown separately. In the case of alluvial soils, regions in which these are associated with extensive hydromorphic soils have been distinguished.

Soils are influenced by all other factors of the physical environment, a characteristic which they share with vegetation. The principal environmental conditions are represented on maps I–IX, and it is of interest to examine the relative importance of each of these in producing the pattern shown on the soil map.

Ferruginous soils occur in the Misuku Hills (3a, b) (where they are transitional with ferrisols), in the scarp-foot zone south-west of the Misuku (2e), in the Middle Kasitu Valley (15a), and in a small zone north-west of the Nyika (part of 7a). In the last case they are caused primarily by parent rock of basic composition. In the larger areas they occur on moderately or steeply undulating topography, with parent rocks probably of intermediate composition. The association with moderate slopes, and consequently with continuous denudation, is of importance in preventing weathering and leaching processes from reaching an advanced stage; soil is gradually removed from the slopes by natural processes, and the supply of rock minerals in the profile is renewed by the downward penetration of weathering. The absence of acid (quartzitic) rocks prevents the development of lithosols which would otherwise tend to form on such slopes.

Ferrisols are found on the East Misuku Hills (3g, h), the Livingstonia Hills (10b, c, e), the North Vipya (13a), the Nkata Bay Lake Shore Lowlands (21a, b, c, d, f), and the low East Vipya Plateau (19c, d), on the last of which they are transitional with humic ferallitic soils. There is a clear correlation in this case with the high-rainfall belt of climatic regions II and V, having a mean annual rainfall of over 60 ins. The dissected topography of these areas ensures the free site drainage necessary for the development of latosols under high rainfall conditions.

Humic ferallitic soils are coincident with the High Plateau areas (3c, 4a, b, 8a, d, 19a, b). The operative factor here is the lower temperature, which is itself a consequence of altitude, and which causes slower decomposition of organic matter. The characteristically high organic matter content of this group is due partly to this, and partly to the grassland vegetation. The moderately high rainfall of these areas causes strong leaching processes. On the Nyika, acid parent material is partly responsible for the very high degree of leaching of bases.

Weakly ferallitic soils are found principally in association with sandy ferallitic soils, either in catena or in other forms of association. This class occurs in the Upper South Rukuru Valley (16a, d), in two areas to the east of it (17c, 18a, b), and at the scarp-foot of the Mafingi Hills (2c). It is found on the Mid-Tertiary Surface under the lowish rainfalls of climatic regions III and IV. Gentle and very gentle slopes are characteristic; where level plains occur, it tends to give place to the following group.

Sandy ferallitic soils occupy the flattest parts of the Mid-Tertiary Surface, comprising the Fort Hill Plain (2a, b), the plain west of the Nyika (7a), and the Luwewe Plain (11a); they are also found on pediments beneath hills formed of acid rocks (12b). Denudation is exceedingly slow on the plains, and the soils have been subject to leaching processes for a long period of time. Consequently they have acquired a low content of weatherable minerals despite the lowish rainfall and consequent low rate of current leaching. The advanced stage of landform evolution is therefore the dominant causative factor.

Four of the above five groups are found also in association with lithosols; in many cases these associations are of greater extent than the areas occupied by the latosols alone. In every case the sub-groups with lithosols are formed on steeper slopes, with consequent more rapid denudation and therefore a tendency for a thinner soil profile. The operative factors in the case of the lithosol-sandy ferallitic soil association are, however, different. This is a widely distributed class, large zones occurring west of the Nyika (7b), and in the Central Mzimba Hills (17), and smaller areas being found where patches of moderately sloping land occur amid hill areas (1b, 3e, 4f, 6g, 12d). The steep slopes of the hills are covered by lithosols; more gentle slopes permit a somewhat deeper soil to develop, and a gravelly, coarse sandy type of ferallitic soil occurs in patches (in the series descriptions below, the difference in characteristics is exemplified by the Nkamanga series of the plains, and the Kafukule series of dissected areas).

Ferallitic soils developed from sands are by definition a result of parent material. Alluvial and hydromorphic soils are dependent very largely on topography, with its effect upon drainage conditions. It has been shown above (p. 47) that alluvial soils of similar morphology are found under a wide range of climatic conditions.

The lithosols, which in northern Nyasaland greatly exceed all other groups in extent, are caused primarily by steeply-sloping topography. They are also more readily developed upon acid parent materials, and their extent is in part associated with the occurrence of Mañngi System rocks, containing numerous quartzites, and of granite intrusions.

The principal factors which have determined the soil distribution pattern may be summarized as follows:

(i) Two climatic features have sufficiently strong effects to dominate other factors: these are temperatures under 65°, and rainfalls over 60 ins. Other variations in climatic conditions are insufficiently large to be a prime cause of soil type.

(ii) The major relief units cause the broad division between latosols on the Mid-Tertiary Surface and lithosols on the hill units above and below it.

(iii) The stage of physiographic evolution reached on the different parts of the Mid-Tertiary Surface affects the distribution of the classes of latosols.

(iv) The landforms determine the more detailed soil distributions, within the above framework; in particular, they determine the relative importance of lithosols amid areas in which latosols occur. Landforms are also the basic cause of the presence of alluvial and hydromorphic soils.

(v) Parent material causes a number of local soil variations. It should be noted, however, that it will only be possible to assess its true effects when detailed geological surveys have been carried out; it may prove to be of considerable importance in influencing the formation of the different classes of latosols.

A NOTE ON HORIZON NOMENCLATURE

Horizon differentiation is poorly developed in many tropical soils; furthermore, the various systems of horizon designation that have been proposed apply principally to soils of temperate latitudes. Therefore terms defined mainly by depth in the profile have been used throughout the present work, both in the above chapter and in the soil series descriptions given in chapter XI. These are as follows:

Topsoil: from the ground surface usually to between 4 and 8 ins.; in this case, however, a clear boundary where the influence of organic matter on the colour ceases is usually visible.

Subsoil: from the base of the topsoil to c. 18 ins.

Lower subsoil: c. 18–c. 36 ins.

In depth: below 36 ins., particularly from 48 to 60 ins.

It is convenient to have some way of referring to the whole of the profile other than the topsoil; the term *lower horizons* is used with this meaning.

The *textural B horizon* is that part of the entire profile having the maximum clay content, regardless of its depth, origin, or of the extent of textural differentiation in the profile. A *shallow* textural B horizon is one which occurs in the subsoil; a *deep* textural B horizon may occur in the lower subsoil or in depth, including possibly below 60 ins. A *weakly developed* textural B horizon is one in which the clay percentage is only slightly greater than in that part of the profile which lies above it; a *strongly developed* textural B horizon has a substantially higher clay content than that of the horizon immediately above, and usually has at least twice the percentage of clay present in the topsoil.

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CHAPTER V

AGRICULTURE

Northern Nyasaland includes a wide range of topographic conditions, of temperature and rainfall, and consequently of soil types. As a result of this, it is possible to cultivate a considerable variety of both annual and perennial crops. It suffers from the disadvantage of being at the extreme end of a long line of communication with markets of the outside world. Transport costs to the coast are the highest of any part of Nyasaland; it is consequently desirable that cash-crops intended for export should be of high value in relation to bulk. A compensating advantage is that the population density, although very variable between different areas, is on average considerably lower than in the Central and Southern Provinces of Nyasaland; improvements in husbandry, including mechanization, need not therefore be subservient to a critical land shortage. One measure of this advantage is that the number of Master Farmers recognized by the Department of Agriculture in the Northern Province is nearly equal to that of the Central Province, despite the smaller area and a population of only slightly over one third as large.

The agriculture may be discussed in six divisions, proceeding from the shore of Lake Nyasa westwards and, in general, from wetter to drier regions (*see* map XI).

A. *The lake shore plain.* This is a belt varying greatly in width. It includes the Karonga Lake Shore Plain (6), a narrow strip of land at the foot of the Lake Shore Scarp Zone (14) between Florence Bay and Nkata Bay, and the Nkata Bay Lake Shore Lowlands. This division has the cheapest and easiest lines of communication, and a relatively dense population which can engage in fishing and trade in addition to farming. It is at altitudes of below 2,000 ft., and is characterized in all parts by mean annual temperatures of over 75°. Most sections receive a certain amount of dry-season rainfall.

The Karonga Lake Shore Plain (6) has a marked rainfall gradient, increasing from 30 ins. or less near Deep Bay at its southern end to more than 90 ins. on the Tanganyika border in the north. Mean annual temperature is over 75°. Soils are mostly alluvial, and many of them are well supplied with plant nutrients, partly as a result of periodic flooding in the rains. Yields of crops are more dependent on water relationships and weed competition than on the supply of fertilizer or manure. A few cattle are kept for work, but the area does not support a very large or productive cattle population owing to the presence of tsetse fly in the foothills bordering the plain, where wet season grazing would normally be found. This is an intensive farming area with maize, sorghum, groundnuts, winter cotton, and rice being produced. Sun hemp for seed and kenaf have also been shown to grow well. Mafura nuts, from which oil is obtained, are collected from the indigenous tree *Trichilia roka*, and exported to Tanganyika.

The Lake Shore Scarp Zone (14) consists of steep slopes falling directly to the lake, with small patches of alluvial soil at river mouths. The common practice of growing cassava on the steep hillsides should be discouraged, and cultivation concentrated on the small level patches near river mouths, in order to provide food crops for fishermen and for coffee-growers in the hills behind. A considerable amount of food is at present imported from the Nkata Bay area to the South.

The Nkata Bay Lake Shore Lowlands (21) comprise a substantial area with a rainfall of over 70 ins. rising in parts above 90 ins. This region includes the ridge (21b) running southwards from Nkata Bay, between the Limpasa Dambo (21g) and the lake.

TABLE VII—AGRICULTURAL POTENTIAL

Agricultural potential			Natural areas included
A Intensive farming: soil of moderate or high fertility	Ai	Intensive mixed farming; maize, groundnuts, tobacco with livestock	2e; 12b; 15a; 16c, d; 17c
	Aii	Intensive mixed farming, including double-cropping: maize, cotton, groundnuts, rice	6a, b, c, d, e
	Aiii	Intensive farming, primarily food-crops: maize, other food crops, groundnuts	2f; 3i; 4g; 6g, h; 12a; 14d; 21e
B Extensive farming; soil of low inherent fertility: maize, groundnuts, tobacco, with livestock			2a–c; 5b; 6f, i; 7a, c; 11a, b; 12c; 15b, d; 16a, b, e, f; 17a; 18a, b
C Perennial crops: high rainfall	Ci	Coffee, tung, with subsistence food crops; steep slopes are common in in this region	3a, b; 10a, b, c, e; 13a; 19c; 20c, d
	Cii	High-rainfall crops; tea, rubber, cocoa, rice, with subsistence food crops	21b, c, d, f
D Livestock ranching; soils mainly stony, but with pockets of cultivable soil suitable for subsistence food crops; could alternatively be utilized as natural forest			16; 2d; 3e, g; 4f; 5c, g; 6j; 7b, d; 9a; 12d; 13f; 14c; 15c; 17a, d; 18c
E Afforestation; unsuitable for agriculture; in some cases marginal for forestry; alternatively suitable as nature reserves			3c; 4a, b; 13b; 19a, b, e
F Nature reserve; unsuitable for agriculture or forestry; the present Nyika Game Reserve is included			8a, b, c, d
G Marsh; dry-season grazing; in some areas with potential for rice cultivation			11d; 21g
H Natural forest; unsuitable for agriculture; suitable as forest reserves or nature reserves			1a; 3d, f, h; 4c, d, e; 5a, d, e, f; 6k, l; 7e, f; 9b, c, d; 10d, f, g; 13c, d, e; 14a, b; 17e; 18d; 19d; 20a, b; 21a

Class B consists mainly of gently sloping to level land, the principal limiting factor for agriculture being low soil fertility; class D consists mainly of moderately sloping land, the principal limiting factor being stony soils; a further important limiting factor in many parts of classes B and D is availability of a perennial water supply.

Rubber has been grown commercially, and cocoa has been cultivated on a very small scale. Tea-growing has also been embarked upon commercially, though the area of suitable soil is very limited, and the distribution of rainfall is such that west of the Limpasa Dambo, dry-season irrigation becomes advisable if not essential. With adequate water control the considerable dambo areas could grow rice, but the inhabitants are traditionally cassava eaters, and averse to the labour involved in improved farming methods. The potential of this area for perennial plantation crops and rice is fairly high, provided marketing arrangements could be made.

B. The wet eastern hill and scarp regions. This division is characterized by broken topography and high rainfall. It includes the East Vipya Scarp Zone (20), the North Vipya Hills (13) and Livingstonia Hills (10), and the Misuku Hills (3). Altitude ranges from 2,000–6,000 ft. The soils are stony and thin on the steeper slopes, but on the more level crests of ridges, and in the valleys, they often possess a good depth of profile, though they are usually very acid and heavily leached. Where the land has been well bunded or terraced and liberally manured, food crops of maize, beans and groundnuts can give reasonable yields, but this is predominantly country for the growing of coffee or other perennial plantation crops. Because of the nature of the soil farmyard manure and non-acid fertilizers can give good responses. Acidity is probably second only to erosion as a menace to farming in this division. Cattle could be kept, intensively stall-fed for the production of much needed meat and manure. Shelter is another necessity to successful agriculture here, and forest products could well play a major part.

Special mention should be made of the Misuku Land Usage Scheme[1], the pioneer soil conservation project in Nyasaland. By 1938 a large proportion of the original forest cover of this region had been destroyed, timber was in short supply, and soil erosion was occurring on a large scale. An energetic scheme, operated by Major D. N. Smalley of the Nyasaland Agricultural Department, succeeded in greatly reducing erosion by introducing a system of box-ridging, between 1938 and 1943. This scheme considerably antedated the main soil conservation drive in Nyasaland, which commenced in 1949. At the present day, conservation methods of the steep slopes of the Misuku Hills are of a high standard; the area is potentially an important producer of coffee, but it is handicapped by its great inaccessibility.

C. The High Plateaux. This division consists of open rolling grasslands of the plateau surfaces of the Vipya (19), Nyika (8), and smaller outliers including the Mafingi Hills (4a) and the high ridges amid the Misuku Hills (3c). Rainfall varies between 40–60 ins. per annum, and mean annual temperatures are below 65°F. The altitude is mainly over 6,000 ft. Some dry-season precipitation in the form of mists may be expected. These areas, because of their exposure and their inability to produce reasonable food crops of maize, are sparsely populated, and often completely uninhabited on a permanent basis. The soils tend to be acid, though the nutrient status of the soil is fair. On the Vipya, past trials have shown that selected varieties of wheat, rye, oats, and feeding-barley can give yields of about 1,000 lb. per acre, though the most suitable varieties are usually low-quality stock-feeding grains. Potatoes have also given fair yields and sheep have done well on improved pasturage. The disadvantage is that there are no close markets for such produce and transport costs make development uneconomic at present. The Vipya offers very promising conditions for forestry. On the Nyika conditions are rather more intractable, the temperatures being lower and the soil more highly leached. Here a forestry project has been abandoned, as the trees have not grown well, and the difficulties of economic extraction appear at present to make the project valueless. The high grasslands of the other outlying areas of this division are likewise most suited to forestry, provided that economic extraction is possible.

D. The Kasitu-Lower South Rukuru Valleys. This division includes the narrow valleys of the South Rukuru from below Lake Kazuni to the Pwezi Rapids, the Lower Kasitu Valley (12), and the broader area of the Middle Kasitu Valley (15). Rainfall is 25–40 ins. The division is characterized by flat valley floors of fertile alluvium, flanked by pediments of varying widths with older latosols which are inherently less fertile. The population is comparatively dense and has been stationary for many years. On the alluvium, monocropping with maize has produced soils which respond well to nitrogen, even in the rich valley floors. The pediment soils respond also to applications of phosphate, and sulphur may be in short supply for groundnuts. Very few cattle are kept, though most of the cultivated soils could be ploughed and crop-production mechanized. It is possible that this area would be suitable for a co-operative or contract tractor cultivation service, as cultivation is intense and the road network good. This area is the granary of the north, given over to intensive production of food crops, largely maize with some groundnuts and beans, and its central position indicates that it should remain so. Development of the alluvial soils would appear to require tractor cultivation and the use of fertilizer with little room for cattle. On the poorer pediments and surrounding foothills, however, there may be scope for the development of a beef or, where perennial streams exist, ghee or dairy industry to feed the large local population. Fish farming may also play its part in the peripheral foothills, with limited vegetable production for the local market.

E. The dry western hill and scarp regions. These regions contrast with division "B" above in having a rainfall of less than 50 ins. They have in common a long dry season, broken topography with shallow lithosols containing pockets of deeper and more fertile soil, and a sparse population, due in part to lack of a perennial water supply.

The Central Mzimba Hills (17) and the *Upper Kasitu Valley* (18) have a rainfall of 35–40 ins., and lie at an altitude of 4,000–5,500 ft. Agricultural potential is not high except in the pockets of good soil, population is sparse, and the country carries *Brachystegia* woodland of a poor type. Subsistence food crops, grown with the help of farmyard manure and nitrogenous fertilizer for a small cattle-ranching population, would probably fulfil the potential of the area More broken parts should be left to the exploitation of indigenous timber.

The majority of the *Nyika Hills* (9) should be left to indigenous forest. Parts of this area may be suited to ranching, to produce beef, work animals, and store stock for the more fertile and populous river valleys. *The Plains and Hills West of the Nyika* (7) and of the *Upper Lufira* (4) have a rainfall of 40–50 ins. There are a number of narrow, fertile valleys in these regions, but the population is sparse and communications are bad. This is also probably best suited to hide, beef, and store-cattle production, supported by food crop farming for the local inhabitants. Until communications are improved, little development is likely to take place and the indigenous forest should remain undisturbed.

On the *Karonga Scarp Zone* (5), despite a rainfall of 40–50 ins., the combination of thin, stony soils, steep slopes, a severe dry season, and tsetse fly make this area an almost uninhabited wilderness of bush. If the tsetse fly could be removed the area would have a potential for beef and store-cattle production for the populous and fertile Karonga lake shore plain. In the *Ruwenya Hills* (1), markets and centres of population are remote, and only high-value cash crops are likely to stand the transport costs. Limited cattle production supported by food crops grown in the more fertile pockets to feed the local population is the most likely development, with the steeper slopes and catchments left to indigenous timber. Cash income in this area comes largely from exported labour.

F. The dry western plains. The two main sections of this division are the Upper South Rukuru Valley (16), with which may be included the Luwewe Plain (11), and the Fort Hill Plain (2). These regions have rather sandy soils of moderate to low fertility on gentle slopes which can be cultivated easily by ox- or tractor-implements.

By the use of farmyard manure and artificial fertilizers supplying nitrogen, phosphates, and sulphur, good yields of arable crops may be obtained, but in the absence of good farming practices the land soon degenerates and produces very low yields. On the extensive *dambo* areas cattle are kept, and a system of mixed husbandry is not only practicable but desirable and necessary if yields are to be maintained. Ley farming, though not entirely proven, is probably desirable, with relatively short periods of cropping alternating with similar periods under ley, e.g. 3 years crop—3 years ley, or 4 years crop—4 years ley. Population is not yet large and there is still room for farmers to have holdings of 20 acres and over, making mechanization of some sort desirable, and it is in the South Rukuru basin that ox cultivation is the most highly developed in the Northern Province.

In the *Upper South Rukuru Valley* rainfall is in the region of 30–35 ins., although it is probable that areas with less than 30 ins. occur; mean annual temperatures are 68°–70° and altitude ranges from 3,500–4,500 ft. In this region mixed farming on medium-sized holdings of 20 acres or more is developing, with cultivation done by ox-drawn implements, farmyard manure and fertilizer being applied; a rotation is practised which produces maize and finger millet for local consumption, and groundnuts and Turkish tobacco for sale. The people are traditionally herdsmen, and cattle are being incorporated into the farming system. The local network of roads is fair, and produce can be extracted and taken to the lake at Nkata Bay or to the railhead at Salima without too much difficulty. It is from this division that most of the exportable surplus of annual crops can be expected to come.

On the *Fort Hill Plain* rainfall is of the order of 35–40 ins., temperature is 65°–70°, and altitude ranges from 4,000–5,000 ft. The potential here is similar to that of the South Rukuru Valley except that the lines of communication are longer and the soils are poorer. Higher valued cash crops than groundnuts are really needed here, possibly Turkish tobacco or essential oils. Ideally products should be processed locally in order to give local employment and to reduce the bulk of the exportable commodity. Cattle are kept in fair numbers producing hides, ghee and beef for local consumption. As incomes increase so the local demand for beef should increase considerably and there is room for expansion of the cattle population to the limits of the rather poor grazing.

The potentialities for future agricultural development are summarized in map XI and table VII. The main regions suited for the production of food crops and annual cash crops are the dry western plains (2, 11, 16), and the Karonga Lake Shore Plain (6). The former at present produce tobacco and groundnuts, and the latter cotton and rice. Environmental conditions favour the cultivation of perennial cash crops, including coffee and tung, in the wet eastern hill and scarp regions (3, 10, 13, 20); limited production of high-rainfall plantation crops, namely tea, rubber, and cocoa, is possible on the Nkata Bay Lake Shore Lowlands (21). Extensive cattle-ranching associated with limited production of food crops may develop in the dry western hill and scarp regions (1, 4, 5, 7, 9, 17, 18), together with limited areas of intensive livestock husbandry and cash crop production. The High Plateaux (8, 19) have environmental conditions suited to forestry.

More detailed considerations of agricultural practices are given in the sections on the agronomy of each soil series contained in Part Two.

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CHAPTER VI

NATURAL REGIONS

A *natural region* is a part of the earth's surface within which the characteristics of the physical environment are relatively uniform. When originally defined by Herbertson[1] it was applied to regions of continental extent, but it has since been used to refer to considerably smaller units[2]. The present survey follows the practice of the Agro-Ecological Survey of Southern Rhodesia[3] in employing the term *natural area* to denote a sub-division of a natural region. In northern Nyasaland, the natural regions that have been mapped are of the order of 500 square miles in extent; the natural areas are mainly of the order of 100 square miles, but a number of distinctive areas covering as little as five square miles have been included.

The method employed in distinguishing regions and areas is that of building up from smaller units to larger; in this respect it differs from the Southern Rhodesian survey[3]. In the initial stage of mapping from air photographs, any substantial section of country having a uniform appearance was numbered, and its characteristics noted; boundaries were drawn along all substantial changes in the appearance of the photographs, viewed stereoscopically. By this means nearly 300 primary mapping units were distinguished. Following a comparison with field observations, these were then combined into natural areas. In the further stage of grouping these areas into natural regions, climatic data were also taken into account.

It was found convenient to distinguish five " extra-regional " areas, i.e. areas common to all regions. The two most important of these are *hills*, of which the dominant environmental factors are steep slopes and lithosols, and *marshes*, subject to annual flooding and with hydromorphic soils. Two other areas are special types of hill zones, namely *scarps* and *gorges*. A fifth area is that formed of *lacustrine sands*, which occurs in all regions that adjoin the shore of Lake Nyasa.

The key to the map of natural regions and areas summarizes the environmental conditions for the 122 areas shown. The following account is intended to supplement this key. Firstly, it indicates the environmental conditions that are characteristic of each region as a whole, and which give to it a unity. In most cases at least three factors are relatively uniform throughout the region, together with other factors which are uniform except for one or two areas. Secondly, it gives the major environmental characteristics associated with each of the component natural areas; commonly one factor only is sufficiently dominant to give a distinctive character to an area.

1. *The Ruwenya Hills.* This is a hill region which forms the north-western extremity of Nyasaland; it has no generally accepted name, and has therefore been named after Ruwenya Hill (6,233 ft.). Lithosols are dominant, and the population is very sparse. Valley-floor patches and dissected plateaux with moderate slopes are distinguished as area 1b.

2. *The Fort Hill Plain.* A sector of the Mid-Tertiary Surface, lying mainly at 4,000–4,500 ft. and draining principally towards the Songwe. Temperatures are moderate, and the mean annual rainfall is 35–40 ins.; *Brachystegia-Isoberlinia* savanna woodland and sandy ferallitic soils are predominant. Population is sparse except in small patches.

The main part of the plain, area 2a, has very gentle slopes, with broad zones of impeded drainage in the valley floors. Area 2b, adjacent to the Songwe, is somewhat less gently sloping, and includes isolated hills with their surrounding pediments. The dissected pediment zone lying below the scarp of the Mafingi Hills, and in which Chisenga is situated, forms area 2c. Area 2d results from the dissection of the plain by tributaries of the Luweya. Areas 2e and 2f carry a higher population: 2e is the scarp-foot zone below the Misuku Hills, in which ferruginous soils occur, and 2f is the Songwe valley floor.

3. *The Misuku Hills.* A hill region in which relief is dominated by the east-south-east strike direction of the Misuku Series rocks; high sub-parallel ridges and deep valleys are characteristic. Rainfall decreases from east to west, the central areas receiving 50–60 ins. Despite the predominantly steep slopes, deep red soils occur, and parts of the region are closely settled.

3a and 3b comprise the main cultivated areas, slopes being less steep in 3b. Three High Plateau remnants, retaining montane forest patches, form 3c. 3d consists of uncultivated high ridges formed of more quartzitic rocks, with lithosols predominant, and 3f is the scarp facing the Fort Hill Plain. To the east occurs a densely-wooded dissected plateau, 3h, with a high rainfall but no cultivation; 3g appears to have characteristics intermediate between this and the cultivated areas. It is not known whether these two areas consist mainly of lithosols, or whether cultivable soils occur. 3i is a valley-floor area of Karroo beds, the Nkana coalfield.

4. *Plateaux and hills of the Upper Lufira.* No single name exists for the hill region, which lies mainly above 4,500 ft. It includes two of the High Plateaux, the Mafingi Plateau (4a) and the Pirewombe Plateau (4b), together with their bounding scarps (4c). There is also an extensive hill zone, with steep slopes and lithosols; this has been sub-divided into hills carrying grassland (4d) and woodland (4e). All the above areas are without settlement. A closely-cultivated patch of fertile alluvial soils forms a lens-shaped area in the Upper Lufira valley floor (4g).

5. *The Karonga Scarp Zone.* This is entirely unpopulated, and contains the most inaccessible country in Nyasaland. It is a hill region, with *Brachystegia* hill woodland and lithosols predominant in almost all areas.

The region may be sub-divided on the basis of landforms and structure. 5a is a plateau on which structural trends are very clearly visible; it carries numerous low ridges, probably formed by quartzites of the Mafingi System. 5b is a level, undissected raised-beach remnant of Tertiary rocks, probably with ferallitic soils developed from sands. Easterly-dipping Karroo beds underlie both 5c and 5e, forming a micro-cuesta topography. 5d is a deeply-dissected hill area, underlain at least in part by Mafingi System rocks. 5f is formed of Cretaceous rocks, which have undergone very closely-spaced dissection.

6. *The Karonga Lake Shore Plain.* A plain, primarily depositional in origin, at an altitude of 1,550–2,000 ft. Temperatures are uniformly high, but rainfall varies between wide limits. Alluvial soils, hydromorphic soils, and ferallitic soils derived from sands are predominant. The population as a whole is relatively high, but large contrasts in density occur.

The alluvial plain proper comprises areas 6a–6g. The northern sector, 6a, has a high rainfall and extensive areas of dambo soil, and is densely settled. The southern sector is sub-divided into a densely settled area with cultivation savanna (6b), and a sparsely settled area with thorn scrub (6c). 6d, the Wovwe dambo, and 6e, the Hara Plain, have large areas of hydromorphic soils. 6f and 6g have coarse sandy soils, the former from alluvial deposition and the latter from lacustrine deposition. 6h is a dissected raised beach.

West of the alluvial plain, Tertiary and Pleistocene rocks occur at a slightly higher altitude. This sub-region includes a series of raised beaches (6i), and an area of very-closely spaced dissection with lithosols (6j). Hill areas occur west of Florence Bay (6k), and north of Deep Bay (6l). Population in these latter four areas is confined to a few small patches.

7. *Plains and Hills West of the Nyika.* A region lying mainly at 4,000–4,500 ft., with moderate temperature and rainfall. The gentler slopes have sandy ferallitic soils of low fertility, and the hill areas lithosols. *Brachystegia-Isoberlinia* and *Brachystegia-Cryptosepalum* woodland predominates; the population is sparse. The region may be divided into plains (7a, 7c), areas of moderate slopes (7b, 7d), and hill areas (7e, 7f). Further sub-division is made on the basis that 7c is underlain by Karroo beds, 7d has closely-spaced dissection, and 7e consists of ridges with strong structural influence.

8. *The Nyika Plateau.* This is the most distinctive of all regions in northern Nyasaland, on the basis of its uniformity of environmental characteristics, and the substantial differences from the characteristics of adjacent regions; its boundary is clearly-defined, although in places very irregular. It is a high-altitude, undulating plateau, formed of granite. Temperatures are low and rainfall is highish, rising to high along the south-eastern margin. The vegetation is montane grassland, and the soils are of the humic ferallitic group. Most of the region is a game reserve; it is unsettled apart from a small area of forest plantation.

The best preserved section of the plateau comprises area 8a. 8b and 8c have moderate slopes, and the latter is characterized by numerous rock outcrops. Hills rising above the plateau (8d) include the highest point in northern Nyasaland, Nganda Hill (8,551 ft.).

9. *The Nyika Hills.* An unpopulated region of deep dissection, steep slopes, and lithosols. The scarps surrounding the Nyika Plateau are distinguished as 9b. 9a differs from the other areas in that although the valleys are deep, slopes are frequently only moderate; it represents a cycle of erosion intermediate between that of 9d and that of the plateau.

10. *The Livingstonia Hills.* A high-rainfall region with ferrisols predominant. Steep slopes with limited patches of gently-sloping land are characteristic. An original vegetation of moist *Brachystegia* woodland has largely given place to grassland as a result of clearance and burning. Population is low, becoming moderate in patches.

Areas 10a–c and 10g are underlain by Basement Complex rocks, and 10d–f by Karroo beds. The most fertile area is the dissected pediment zone which includes Nchenachena. 10b consists largely of moderate to steep slopes, whereas in 10c level patches remain on the interfluves. 10d consists of structurally-controlled plateau remnants, one of which provides a spectacular site for the Livingstonia Mission.

11. *The Luwewe Plain.* Of the regions which form part of the Mid-Tertiary Plain, this is the most nearly level. It is dry, with a rainfall of below 30 ins., and carries a vegetation varying between poor *Brachystegia-Julbernardia* woodland and thicket. Soils are strongly ferallitic and of low fertility, with extensive areas of impeded drainage. Settlement is confined to a few small patches

Area 11a comprises the plain. Within it occur the Vwaza Marsh (11d), and extensive areas which have a characteristic appearance on air photographs due to regularly-spaced large termite mounds (11c). Small areas with more fertile soils, and a vegetation in which *Combretum ghazalense* is very common (11b), are cultivated.

12. *The Lower South Rukuru-Lower Kasitu Valley.* This region, which includes also the valleys of the Luviri and Mwazisi, has the characteristic relief shown in fig. 1d. At the valley sides rise steep hills or scarps. Pediments (12b), with sandy ferallitic soils, lead down from these to river terraces and flood-plains (12a), with highly fertile alluvial soils. These valleys have a low rainfall, 25–30 ins., but are moderately densely settled. Also included in the region are level surface remnants (12c), and an area of low hills (12d).

12. *The North Vipya Plateau and Hills.* High rainfall, above 50 ins. and partly above 60 ins., and highish altitude are characteristic. This combination of factors results in a vegetation cover of either moist *Brachystegia* woodland or grassland. Steep slopes with shallow soils are common, otherwise ferrisols occur. Settlement is sparse.

Area 13a consists of plateau remnants, and 13b comprises hills rising above the plateau. The surrounding deeply dissected hill zone is sub-divided into hills with a grassland (13c) and with a woodland (13d) vegetation. The Kandoli Hills (13e), a high, massive, wooded ridge, form a southward extension of the region.

14. *The Lake Shore Scarp Zone.* A steep, high, dissected scarp, dropping from over 4,000 ft. to the lake shore at 1,550 ft. Rainfall is high, but lithosols predominate owing to the steep slopes. The northern section, 14b, has a capping of Karroo beds. Cultivation is confined to dissected raised beach remnants, 14c, and deltaic alluvial deposits at the river mouths, 14d.

15. *The Middle Kasitu Valley.* This region, which lies north-west of Mzuzu, has deep, red, moderately ferruginous soils. The topography is undulating, with moderate and gentle slopes predominant. Rainfall decreases from 50 ins. in the east to 30 ins. at the western margin.

The Mamazi Valley, 15b, is sparsely settled, and somewhat more steeply dissected than the main part of the region, 15a, which has a moderate population. North-east of Bwabwa Hill is a small area, 15c, with very much poorer soils, and it is possible that other such patches occur in the region. 15d is an area with marsh grassland.

16. *The Upper South Rukuru Valley.* This is the largest natural region that has been distinguished in northern Nyasaland; its northern margin grades without any clear change in characteristics into the Luwewe Plain. It is part of the Mid-Tertiary Surface, lying at 3,500–4,400 ft., with gentle and very gentle slopes predominant. Mean annual temperature is 68°–70°; rainfall is certainly below 35 ins. in all parts, and possibly falls as low as 25 ins. or lower in the northern section. *Brachystegia-Julbernardia* woodland predominates.

Soil fertility and density of settlement increase from north to south. Area 16a has weak ferallitic and sandy ferallitic soils, with sparse cultivation; 16b is probably still poorer, resembling the Luwewe Plain. The level interfluves in 16c and 16d carry weak ferallitic soils of somewhat higher fertility, and are densely cultivated; in 16d these soils predominate, whilst in 16c they are interspersed with poor very sandy soils on valley sides. 16f has poor soils, with a pattern of large termite mounds prominently visible on air photographs.

17. *The Central Mzimba Hills.* A north–south belt lying along the South Rukuru-Kasitu watershed, mainly at 4,500–5,200 ft. The majority of the land is dissected, with moderate slopes. Rainfall is 30–35 ins. Both lithosols and sandy ferallitic soils of low fertility are extensive. *Brachystegia-Julbernardia* and *Brachystegia-Cryptosepalum* woodlands of a poor, degenerate nature are characteristic. Although the population is low, large areas are subject to temporary cultivation.

17a and 17d are low hill areas, the latter characterized by broad ridges. 17c is an undulating plain. 17e consists of a dissected zone at the head of tributaries of the South Rukuru. An area of moderately fertile red soils, 17c, occurs around Mount Hora, principally on pediments of a group of hills.

18. *The Upper Kasitu Valley.* The east side of this valley is formed by the scarp of the Vipya Plateau (18d), while the west side leads down from the Central Mzimba Hills. Pediments, with gentle slopes, predominate both in the valley proper, 18a, and in an area with hills common, 18b. 18c consists of valley-floor zones amid hills. The population of the region is moderate. The rainfall is probably 35–40 ins., although records are lacking.

19. *The Vipya Plateau.* This is characterized by highish rainfall and a montane grassland vegetation. The western part, areas 19a and 19b, has a high altitude and low temperatures; humic ferallitic soils are common, and forest plantations are the principal land use. Bare rock hills form a striking feature of the scenery of this sub-region.

An eastward-facing scarp, 19e, separates this from an eastern sub-region. This is of moderate altitude only, and the gentler slopes are occupied by ferrisols. Moist *Brachystegia* woodland occurs in addition to grassland, and estate cultivation of tung is practised.

20. *The East Vipya Scarp Zone.* A deeply dissected, inaccessible hill area, in which lithosols are predominant, and settlement is confined to a few small parts. It is characterized by a high rainfall, and by the presence of very deep, steep gorges, 20b, along the main tributaries of the Luweya River. An area of less high relief and moderate slopes, 20c, includes ferrisols on which coffee is grown. 20d is an inaccessible dissected plateau, without settlement.

21. *The Nkata Bay Lake Shore Lowlands.* Dissected topography with moderate slopes but lowish relief is characteristic. Temperatures are high, rainfall exceeds 70 ins., and winter rain occurs. The soils comprise an association of ferrisols and lithosols; semi-evergreen forest occurs on the former, and moist *Brachystegia* woodland on the latter. Population is moderately high along the coast, becoming sparse inland.

21a and 21b are dissected areas lying respectively west and east of the Limpasa Dambo (21g), a broad marsh; slopes are less steep, and lithosols less extensive, in 21b. 21c and 21d comprise level, undissected surface remnants, with deep, stoneless, ferrisols; the latter is underlain by sandstones. 21f has similar topography, but the nature of its soils is not known. 21e consists of fertile areas of sandy alluvium, entirely under cultivation.

References

[1] HERBERTSON, A. J., 1905. The major natural regions. *Geogr. J.*, **25**, 309.

[2] GILBERT, E. W., 1960. The idea of the region. *Geography*, **45**, 157–175.

[3] VINCENT, V., and R. G. THOMAS, 1961. *An Agricultural survey of Southern Rhodesia; Part I. Agro-Ecological survey.* Fed. Govt., Salisbury, 124 pp.

Part Two

SOIL SERIES

CHAPTER VII

SOIL SERIES: INTRODUCTION

This section gives descriptions of the soil series that have been identified in northern Nyasaland. These are named after localities in which they are well developed. In the majority of cases they have been defined by means of morphological characteristics, observable from a soil inspection pit. Analytical properties are given as accessory characteristics, although in a few instances limited use has been made of them in the definitions. A classification of the series into soil groups is given in table V (p. 41). Chapter IV gives descriptions of these groups, and a discussion of their relation to environmental conditions. Keys to the identification of series within each natural region are contained in chapter VIII.

The *soil series* is defined as a group of soils having horizons similar in differentiating characteristics and arrangement in the soil profile, and developed from a particular type of parent material[1]. In carrying out an extensive survey it would be possible to classify almost every profile encountered as a separate series, which would be of very limited value either in increasing knowledge or with respect to practical applications. There is the converse danger, in seeking to avoid this, of classifying together soils having substantially different characteristics, including agricultural properties. The policy adopted has been firstly, to allow a certain latitude in the series definition in cases of profiles occurring in contiguous areas; for example a range of two, or occasionally three different subsoil textures, or structural grades, is permitted in one series, provided that the profiles are not separated by any great distance and provided that other environmental factors, such as altitude and vegetation, are similar. But secondly, soils having fairly similar characteristics but occurring in widely separated areas or under substantially different environmental factors have been distinguished as separate series, owing to the probability that their agricultural properties will differ. This is particularly the case with the ferrisols; examination of the morphological descriptions of the Chinyakula, Mazamba, and Uzumara series will show that they are not wholly distinguishable on the basis of differentiating characteristics, but they occur in separate areas, each with a different altitude range.

A total of 31 series have been defined, together with four soil classes that have not been examined in sufficient detail for series to be determined: these are dambo (hydromorphic) clays, sandy dambo soils, alkaline soils, and lithosols. In six cases *phases* of a series have been distinguished; these have the same general properties as the series but differ from it in respect of one characteristic (in three cases profile depth).

In subsequent more detailed mapping it will be necessary to subdivide many of the series described here. It is suggested that this should be done by restricting the present series name to a more closely-defined combination of characteristics, and establishing new series to include soils which do not conform to these. It will also be necessary to create a number of new series on the lower parts of catenas, which have not been examined in detail in the present survey.

In each of the following accounts of series the *differentiating characteristics* are given in the first paragraph of the description of morphology. These are the characteristics which fundamentally affect the form and behaviour of the soils[2], and which have been used to define the series. Subsequent paragraphs give the *accessory characteristics*; these are properties which normally accompany the differentiating characteristics, but which may vary somewhat beyond the stated limits without affecting the basic form or behaviour of the soil, and therefore without excluding it from the series.

Owing to the fact that in each series some features are of basic significance whereas others are of subsidiary importance, it has been found unsatisfactory to prepare a dichotomous key to the identification of series. Instead, the morphological and analytical characteristics of all the series are shown in tables VIII and IX; by inspection of these it should be possible to see which of two or three series a profile encountered in the field is likely to belong to; reference can then be made to the descriptions of these series, from which those characteristics that are of fundamental importance can be seen. It should be noted that to determine a series a soil inspection pit and a Munsell colour chart are necessary, since in the series definitions considerable use has been made of (i) the grade of structure (absent, weak, moderate, or strong) in the subsoil and lower subsoil*, and (ii) the Munsell hue (i.e. the page of the Munsell colour book) of the reddest horizon. The colours given are in every case those of the moist soil examined in the field.

The environmental conditions associated with each series are shown in table XI, and the range of nutrient status that has been recorded up to the present in table X.

References

[1]Soil Survey Staff, 1951. *Soil survey manual.* 2nd Edn., U.S. Dept. Agric., Washington D.C., 503 pp.; *see* p. 280.

[2]Kellogg, C. E., 1959. *Soil classification and correlation in the Soil Survey.* U.S. Dept. Agric. soil cons. Serv., 17 pp.; *see* p. 7.

* See note on horizon nomenclature, p. 49.

CHAPTER VIII

SOIL SERIES: REGIONAL KEYS

Maps of soil series, showing the precise boundaries between each series, can only be produced as a result of detailed surveys on a scale at least as large as 1 : 50,000. In the present more extensive survey it is only possible to give the series that are most likely to be encountered within each natural region and area.

The following keys enable a soil encountered in the field to be identified as belonging to a particular series. The series known to occur in each area are given in the legend to the map of natural regions and areas. It is probable that additional series will be found to occur in many of these areas, and therefore the keys have been constructed to apply to all areas of a region. Since both lithosols and hydromorphic soils occur in almost all regions, the key to these is given separately, preceding the regional keys.

To identify to which series the soil at a particular site belongs, the procedure is as follows:

1. Find the position of the site as closely as possible on the map of natural regions and areas. In some cases it may be necessary to take a compass bearing and pace the distance to the nearest point identifiable on the map. Note from the map the natural region and natural area in which the site lies.

2. Dig a soil inspection pit 5 ft. in depth. Examine the following four horizons: *topsoil*, *subsoil* (i.e. at *c.* 12 ins. depth), *lower subsoil* (*c.* 24–30 ins.), and *in depth* (*c.* 48–60 ins.). Record for each of these horizons the *colour*, including whether mottling occurs, the *texture*, and the *structure*. Note if *stones*, *gravel*, *weathered rock*, or *iron concretions* are present. Observe any other salient features of the profile, particularly if any *sharply defined boundaries between horizons* occur. Reference may be made to standard works on soil profile description [1, 2].

3. From the key to all regions (p. 66), determine whether the soil belongs to the groups of Lithosols, Dambo Clays, or Sandy Dambo Soils. If so, it will not have been defined as a series.

4. Consult the map of natural regions and areas. Note which series are known to occur in the natural area in which the soil is situated.

5. Consult the relevant regional key. Consider first whether the characteristics given under " A " are present in the soil profile. If not, consider " B ", and if the characteristics given there are again not present, proceed successively to the other sets of characteristics headed by capital letters, until one is found to which the profile conforms. Either one series is given corresponding to this, or alternatively it will be necessary to consider whether the additional characteristics given under " a " or " b " are present. This gives a provisional identification of the series.

6. Turn to the relevant series description (*see* pp. 75–107). The first paragraph of the description of morphology in this gives the differentiating characteristics, which define the series. If the profile conforms to these, then the identification is confirmed.

Stages 5 and 6 may be illustrated from the key to region 12 (p. 68). Considering " A ", suppose that there are no iron concretions in the topsoil, subsoil, or lower subsoil of the profile examined. " B " covers soils in which depositional bedding occurs; this is indicated by sharply-defined changes in texture, and usually in other properties, between adjacent horizons. Supposing that this feature is observed in the profile, consider "a" and "b"; if the topsoil does not consist predominantly of coarse sand, but all horizons are greyish brown and there is a mottle in depth, then the profile is provisionally identified as belonging to the Rukuru series. From the series description (p. 101), this is confirmed if any clay horizons present possess a strongly developed, coarse, angular blocky structure. In this instance two analytical features are included in the definition, but the morphological characteristics, combined with the area in which the soil occurs, provide a satisfactory identification.

It may be noted that in constructing a key of this nature, soils with exceptional characteristics are inevitably placed first. The normal, and most extensively developed, soils of the region are in most cases found at the end of the key.

References

[1] CLARKE, G. R., 1957 *The study of the soil in the field.* 4th Edn., Oxford, 204 pp.

[2] SOIL SURVEY STAFF, 1951 *Soil survey manual* 2nd Edn, U.S. Dept. Agric., Washington, D.C., 503 pp.

REGIONAL KEYS

All regions	Series
A. Stones or gravel abundant in the subsoil, and/or weathered rock commencing at a depth of less than 18 ins; often *Brachystegia boehmii* and/or *Uapaca kirkiana* common ..	Lithosols
B. All horizons black, dark grey or mottled; valley-floors, marsh grassland:	
a. All horizons with the possible exception of the topsoil, clay ..	Dambo Clays
b. At least one horizon, other than the topsoil; sandy clay loam or lighter ..	Sandy Dambo soils

1. *Ruwenya Hills*	Series
A. Topsoil and subsoil sand to loamy coarse sand, not red in any horizon ..	*Kafukule*

2. *Fort Hill Plain*	
A. Depositional bedding present; greyish brown, mottled in depth; level valley floors ..	Alluvial, possibly *Rukuru*
B. Subsoil with strong blocky structure, sandy clay or clay, at least as red as 2.5 YR ..	*Chiwunku*
C. Subsoil almost structureless, sandy loam or sandy clay loam, contrasting with dark red of lower subsoil ..	*Chisenga*
D. Topsoil sandy loam or loamy sand; massive or with weak structure in all horizons:	
a. Lower subsoil dark red ..	*Fort Hill, Mafingi phase*
b. Lower subsoil yellowish red; abrupt increase in clay content from topsoil to subsoil ..	*Fort Hill*
c. Sandy and no redder than 7.5 YR in all horizons; often mottled in depth ..	*Fort Hill lower catena associates*

3. *Misuku Hills*	
A. Depositional bedding present, greyish brown, mottled in depth; level valley floors ..	Alluvial, possibly *Rukuru*
B. Topsoil dark brown or black, with many roots and strong crumb structure; high altitude ..	Humic ferallitic

C. Lower horizons purplish-red, with much mica .. .. .. *Misuku, Windindi phase*

D. From subsoil downwards red or dark red, sandy clay or clay:

- a. Lower subsoil with strong blocky structure .. .. *Misuku*
- b. Lower subsoil with weak or moderate structure, texture relatively uniform throughout profile .. .. .. Ferrisols

4. *Plateaux and Hills of the Upper Lufira*

A. Depositional bedding present, greyish brown, mottled in depth; level valley floors .. .. Alluvial, probably *Rukuru*

B. Topsoil dark brown or black, with many roots and strong crumb structure; high altitude .. .. Humic ferallitic, possibly *Nyika*

C. Topsoil sandy loam or loamy sand; massive or with weak structure in all horizons:

- a. Lower subsoil dark red .. .. *Fort Hill, Mafinga phase*
- b. Gravel absent; lower subsoil yellowish red, at least as red as 5 YR .. .. *Fort Hill*
- c. Gravel or stones present above 60 ins.; massive and less red than 5 YR in all horizons .. .. *Wenya*

5. *Karonga Scarp Zone*

A. Topsoil and subsoil sand to coarse sandy loam, no horizon redder than 5 YR:

- a. Weathered rock or gravel above 60 ins., parent material crystalline rock; sloping site .. .. *Kafukule*
- b. Profile deep, no gravel present, parent material sedimentary rock; level site .. .. *Mankhambira*, possibly *Florence Bay phase*

6. *Karonga Lake Shore Plain*

A. Coarse sand present in substantial amounts, often exceeding fine; no horizon heavier than sandy clay loam:

- a. Coarse sand or loamy coarse sand in all horizons .. .. *Kashata*
- b. Slight downward increase in clay, heaviest horizon sandy loam *Mankhambira*
- c. Substantial downward increase in clay, heaviest horizon sandy clay loam, subsoil dark reddish brown .. .. *Mankhambira, Florence Bay phase*

B. Fine sand dominant over coarse, depositional bedding present, greyish brown:

- a. Subsoil clearly mottled, roots in topsoil stained reddish brown; subject to annual flooding .. .. *Mwenitete*
- b. Subsoil unmottled or with faint mottle; at least one sandy clay or clay horizon above 36 ins. .. .. *Karonga*
- c. Subsoil unmottled; no horizon above 36 ins. heavier than sandy clay loam .. .. *Lughali*

7. *Plains and Hills West of the Nyika*

A. Subsoil with strong blocky structure, sandy clay or clay, at least as red as 2.5 YR .. .. *Chinunka*

B. Topsoil sandy loam or loamy sand, all horizons massive or with weak structure:

- a. Gravel absent; lower subsoil yellowish red, at least as red as 5 YR .. .. *Fort Hill*
- b. Gravel or stones present above 60 ins.; massive and less red than 5 YR in all horizons .. .. *Wenya*

8. *Nyika Plateau*

A. Topsoil dark brown or black, with many roots and strong crumb structure:
   a. Weathered rock commencing between 18 and 36 ins., not red in any horizon .. .. *Nyika*
   b. No weathered rock above 36 ins., becoming red in depth .. *Nyika, deep phase*

9. *Nyika Hills*

A. Topsoil and subsoil sand to loamy coarse sand, not red in any horizon .. *Kafukule*

10. *Livingstonia Hills*

A. Weathered rock present above 48 ins.:
   a. Subsoil yellowish red; overlying sedimentary rocks .. Ferallitic soils derived from Karroo sediments
   b. Subsoil dark; overlying crystalline rocks .. .. *Uzumara, shallow phase*

B. No weathered rock above 48 ins.; from subsoil downwards red or dark red:
   a. Subsoil and lower subsoil clay, lower subsoil with strong blocky structure .. .. *Livingstonia*
   b. Subsoil sandy clay or clay, lower subsoil with weak or moderate structure .. .. *Uzumara*
   c. Subsoil sandy clay loam, lower subsoil with weak or moderate structure .. .. *Nchenachena*

11. *Luwewe Plain*

A. Massive laterite, or abundant iron concretions, present above 36 ins.; topsoil sandy .. .. *Jalira*

B. Depositional bedding present, greyish brown, mottled in depth; level site, tall *Acacia albida* trees common .. .. .. *Ruhuru*

C. Greyish brown in all horizons, usually mottled in depth, but no depositional bedding; *Combretum ghazalense* bushes common .. .. *Kapemba*

D. Very sandy, no horizon heavier than sandy clay loam, coarse sand exceeds fine; valley sides .. .. *Bulala*

E. Abrupt textural change between sandy topsoil, and subsoil at least as heavy as sandy clay loam; subsoil massive:
   a. Lower subsoil yellowish red or reddish brown (5 YR), massive *Nkamanga*
   b. Lower subsoil red or reddish brown (2.5 YR), with weak or very weak blocky structure .. .. *Rumpi*

F. Topsoil sandy, but downward increase in clay gradual; lower subsoil yellowish red .. .. *Mpherembe*

12. *Lower South Rukuru—Lower Kasitu Valley*

A. Massive laterite, or abundant iron concretions, present above 36 ins.; topsoil sandy .. .. *Jalira*

B. Depositional bedding present; alluvial parent materials, level site:
   a. Topsoil sand or loamy coarse sand .. .. .. *Kashata*
   b. Greyish brown in all horizons, mottled in depth; tall *Acacia albida* trees common .. .. *Ruhuru*

C. Topsoil and subsoil sand or coarse sandy loam, but no depositional bedding, parent material rock .. .. *Kafukule*

D. Greyish brown in all horizons, usually mottled in depth, but no depositional bedding; *Combretum ghazalense* bushes common .. .. *Kapemba*

E. Abrupt textural change between sandy topsoil, and subsoil at least as heavy as sandy clay loam; subsoil massive:
   a. Lower subsoil yellowish red or reddish brown (5 YR), massive *Nkamanga*
   b. Lower subsoil red or reddish brown (2.5 YR), with weak or very weak blocky structure .. .. *Rumpi*

13. *North Vipya Plateau and Hills*

A. From subsoil downwards red or dark red, and sandy clay or clay:
- a. No weathered rock above 48 ins. .. .. .. *Uzumara*
- b. Weathered rock present above 48 ins. .. .. .. *Uzumara shallow phase*

B. Topsoil dark brown or black with high organic matter, subsoil yellowish red; altitude above 5,500 ft. .. .. Humic ferallitic soils

14. *Lake Shore Scarp Zone*

A. From subsoil downwards red or dark red, and sandy clay or clay:
- a. No stones, gravel, or weathered rock above 60 ins. .. .. *Chinyakula*
- b. Stones, gravel, or weathered rock present above 60 ins. .. *Nkata Bay*

B. Topsoil and subsoil sandy, with a substantial proportion of coarse sand:
- a. Coarse sand or loamy coarse sand in all horizons .. .. *Kashata*
- b. At least a slight downward increase in clay, usually with the heaviest horizon sandy clay loam .. .. .. *Mankhambira*

C. Greyish-brown in all horizons, usually mottled in depth, sand fraction mainly fine sand, depositional bedding present:
- a. At least one sandy clay or clay horizon above 36 ins. .. *Karonga*
- b. No horizon above 36 ins. heavier than sandy clay loam .. *Lughali*

15. *Middle Kasitu Valley*

A. Extremely red (10 R) from subsoil downwards, moderate or strong fine-medium blocky structure in subsoil .. .. *Ekwendeni*

B. Sandy topsoil, subsoil mottled, but site drainage free .. .. *Bwabwa*

16. *Upper South Rukuru Valley*

A. Massive laterite, or abundant iron concretions, present above 36 ins.; topsoil sandy .. .. *Jalira*

B. Very sandy, no horizon heavier than sandy clay loam, coarse sand exceeds fine; valley sides .. .. *Bulala*

C. Greyish brown in all horizons, usually mottled in depth; *Combretum ghazalense* bushes common .. .. *Kapemba*

D. Heaviest horizon sandy clay loam; lower subsoil yellowish red .. *Mpherembe*

E. Heaviest horizon sandy clay or clay:
- a. Subsoil massive, yellowish red or reddish brown (5 YR) .. *Rumpi*
- b. Subsoil with weak fine-medium blocky structure, usually red or dark red .. .. *Loudon*

17. *Central Mzimba Hills, and* 18. *Upper Kasitu Valley*

A. Topsoil and subsoil sand or coarse sandy loam; not red in any horizon *Kafukule*

B. Red from the subsoil downwards:
- a. No clay horizon; on pediments .. .. *Jandalala*
- b. Clay horizon usually present . .. . Ferrisols

19. *Vipya Platau*

A. Topsoil dark brown or black, with many roots and strong crumb structure; grassland:
- a. No weathered rock above 36 ins. .. .. .. *Vipya*
- b. Weathered rock present above 36 ins. .. .. .. *Vipya shallow phase*

B. Topsoil dark reddish brown; no weathered rock above 60 ins. .. *Masamba*

20. *East Vipya Scarp Zone*

A. Topsoil dark brown or black, with many roots and strong crumb structure; grassland .. .. *Vipya*

B. From subsoil downwards red or dark red, and sandy clay or clay:
- a. No stones, gravel, or weathered rock above 60 ins. .. .. *Chinyakula*
- b Stones, gravel, or weathered rock present above 60 ins. .. *Nkata Bay*

21. *Nkata Bay Lake Shore Lowlands*

A.	Topsoil and subsoil sandy, with a substantial proportion of coarse sand:	
	a. Coarse sand or loamy coarse sand in all horizons	*Kashata*
	b. At least a slight downward increase in clay, usually with the heaviest horizon sandy clay loam	*Mankhambira*
B.	Topsoil and subsoil coarse sandy loam or coarse sandy clay loam, lower sub-soil red	*Chombe*
C.	From subsoil downwards red or dark red, and sandy clay or clay:	
	a. No stones, gravel, or weathered rock above 60 ins.	*Chinyakula*
	b. Stones, gravel, or weathered rock present above 60 ins. ..	*Nkata Bay*

TABLE VIII—MORPHOLOGICAL CHARACTERISTICS OF SOIL SERIES

X : Normal values
O : Permitted values

Group	Characteristics		Chinseka	Emmadasi	Lisingilonia	Mizala	Cuiliyatula	Mtala Bay	Chamba	Ntchimadambo	Mzuzuma	Upumuru	Vipya	Nyika	London	Mphereula	Jambalala	Chirangi	Rumpi	Nkamanga
Colour	1. Mottle present																			
	2. Reddest Munsell hue above 60 ins.:	7.5 YR 5 YR 2.5 YR 10 YR	X X	X	X	X O	X X	X	X	O X	X	O X	X	X O	X O	X X	X	X	X	X
Texture	1. Topsoil:	Loamy sand Sandy loam Sandy clay loam Sandy clay	O X O	O X X	X	(3) O X	X	O X	O X	X	O X	X O	X	X	X X	X X	X	O X	O X O	O X
	2. Heaviest horizon above 60 ins.:	Sand or loamy sand Sandy loam Sandy clay loam Sandy clay Clay	O X	O X	X	X	X X	X X	X	X X O	X X	X X	X	O X O	X O	X	X O	X	X X	O X
	3. Textural B horizon:	Weakly developed, shallow Weakly developed, deep Strongly developed, shallow Strongly developed, deep Depositional bedding present	X O	X O	X	O X	X	X X	X	X	O X	X O	X	O X X	X	O X	X	X	X	X
Stones	Stoniest horizon above 36 ins.:	<20% stones and gravel 20–50% stones and gravel > 50% stones and gravel	X	X	X	X	X	O X	X	X	X	X	X	X X	X	X	X	X	X	X
Structure	Strongest grade above 36 ins., fine, medium, or coarse blocky:	Massive or single grain Very weak Weak Moderate Strong or very strong	X	O X	X	X	O X O	O X	X X	X X	X O	X O	X O	X O	X	X	O X	X	X X	X O

Group	Characteristics		Fort Hill	Wenya	Kafukule	Balala	Jalira	Mankhambira	Resinde	Buchao	Kapandwe	Rukuru	Karonga	Lughali	Masasatale	Dambo Clays	Sandy Dambo Soils	Alkaline Soils	Lithosols
Colour	1. Mottle present									X	O	X	X	O	X	X	X	X	O
	2. Reddest Munsell hue above 60 ins.:	7.5 YR 5 YR 2.5 YR 10 YR	X	X O	X	X	X O	X X	X O	X	X	X	X	X	X	X	X	X	O X X X
Texture	1. Topsoil:	Loamy sand Sandy loam Sandy clay loam Sandy clay	X X	O X	X X	X X	X	(1)	(2)	X X	X	(3) X X X	(3) X X X	X	(3) X X X	(3) O X	X X	(3) X X X	X X X O
	2. Heaviest horizon above 60 ins.:	Sand or loamy sand Sandy loam Sandy clay loam Sandy clay Clay	O X	O X	O X X	O X	O X	X O	X	X	O X O O	O X	O X X	X X	O X O	X	X X X O	O O X X	X X X X X
	3. Textural B horizon:	Weakly developed, shallow Weakly developed, deep Strongly developed, shallow Strongly developed, deep Depositional bedding present	X	O O X	X X	X X	X X	O X	X	X	X O	X	X	X	X	X	X	X	X X X X
Stones	Stoniest horizon above 36 ins.:	<20% stones and gravel 20–50% stones and gravel > 50% stones and gravel	X	O X	O X O	X	X	X	X	O X O	X	X	X	X	X	X	X	X	X
Structure	Strongest grade above 36 ins., fine, medium, or coarse blocky:	Massive or single grain Very weak Weak Moderate Strong or very strong	X O O	X O	X	X	X	X O	X	X X O O	X X X O O	O X	X X	X X X	O X	X	X X X O	X	X X X O O

(1) Loamy sand or sand. (2) Sand. (3) Clay lumps may occur.

TABLE IX—ANALYTICAL CHARACTERISTICS OF SOIL SERIES

Characteristics			*Chiamvia*	*Ekwendeni*	*Lisingutsula*	*Misuku*	*Chinyakula*	*Nkata Bay*	*Chombe*	*Nchenachena*	*Mazamba*	*Uzumara*	*Vipya*	*Nyika*	*London*	*Mpherembe*	*Jandalale*
REACTION :	pH, lower horizons:	7.0–6.0 6.0–5.6 5.6–5.0 5.0–4.5 4.5–4.0	X	X	X	X X	X	X	X	X	X	X	X X	X X	X	X X	X X
ORGANIC MATTER :	Topsoil :	0.5–2 % 2 –5 % 5 –10%	X X	X X	X	X	X	X	X	X	X	X		X	X	X	X
BASE SATURATION :	Lower horizons:	10–20 % 20–40 % 40–80 % 80–100 %	X	X X	X	X	X	X X	X X	X X	X X	X		X	X	X	X
EXCHANGE CAPACITY :	Lower horizons, cation exchange capacity per 100g. of clay*:	5 –15 m.e. % 15–40 m.e. % 40–80 m.e. %	X	X	X	X	X	X	X	X	X	X		X	X	X	X

Characteristics	*Chisenga*	*Rumpi*	*Nkhamanga*	*Fort Hill*	*Wenya*	*Kafukule*	*Bulala*	*Jalira*	*Mankhambira*	*Karkala*	*Sumbuwa*	*Kuparina*	*Rukuru*	*Karonga*	*Lughali*	*Mwirufira*
REACTION	X X	X	X	X X	X X	X	X	X X	X X	X X	X X	X X X	X X	X X X	X X X	X X
ORGANIC MATTER	X	X	X	X	X	X	X	X	X X	X	X	X X	X	X X	X X	X X
BASE SATURATION	X X	X	X	X	X		X	X	X X X	X X X	X	X X	X	X	X	X
EXCHANGE CAPACITY	X	X X	X	X	X X		X	X X	X X	X X	X X	X X	X	X	X	X

* This parameter indicates the nature of the clay minerals present. The exchange capacity of the principal clay minerals, in m.e. % per 100g. of clay, are (Grim[18]) :

Kaolinite	3–15
Illite	10–40
Montmorillonite	80–150

Organic matter = 1.724 × organic carbon; organic carbon determined by Walkley-Black method, uncorrected.

TABLE X—NUTRIENT STATUS OF SOIL SERIES

Nutrient	Level	*Topsoil values*	*Chitumuhe*	*Bhawandezi*	*Livingstonia*	*Misuku*	*Caingululu*	*Nkata Bay*	*Chombe*	*Nchenachena*	*Mazamba*	*Uzumara*	*Vipya*	*Nyika*	*Loudon*	*Mphetemba*	*Jenjelele*	*Chisenga*	*Rumpi*
NITROGEN :	Low :	0.04–0.1 %		X			X								X	X	ND	X	X
	Medium :	0.1–0.2 %	X		X	X	X	X	X	X	X	X							
	High :	0.2–0.4 %				X								X					
AVAILABLE PHOSPHORUS :	Low :	0–20 p.p.m.	X	X	X	X	X	X		X	X	X		X		X	ND	X	X
	Medium :	20–50 p.p.m.					X		X	X	X				X				
	High :	50–100 p.p.m.					X				X								
EXCHANGEABLE POTASSIUM	Low :	0.03–0.2 m.e. %			X	X	X		X		X	X			X		ND		
	Medium :	0.2–0.4 m.e. %	X	X		X	X	X		X	X			X	X	X		X	X
	High :	0.4–0.8 m.e. %		X		X				X	X			X					

Nutrient	Level	*Topsoil values*	*Nkamanga*	*Fort Hill*	*Wenya*	*Kafukule*	*Bulala*	*Jalira*	*Mankhambira*	*Kasbata*	*Rwaban*	*Kapemba*	*Rukuru*	*Karonga*	*Lupkali*	*Mwanalele*
NITROGEN :	Low :	0.04–0.1 %	X	X	X		X	ND	X	ND	ND	ND				
	Medium :	0.1–0.2 %											X	X	X	X
	High :	0.2–0.4 %														
AVAILABLE PHOSPHORUS :	Low :	0–20 p.p.m.	X	X	X		X	ND		ND	ND	ND	X			X
	Medium :	20–50 p.p.m.		X			X		X				X		X	
	High :	50–100 p.p.m.							X				X	X	X	
EXCHANGEABLE POTASSIUM	Low :	0.03–0.2 m.e. %		X			X	ND	X	ND	ND	ND				
	Medium :	0.2–0.4 m.e. %	X	X	X				X							X
	High :	0.4–0.8 m.e. %	X	X					X				X	X	X	

The following very high values have been recorded. Available phosphorus . Rukuru series 113 p.p.m.
Mankhambira series 200 p.p.m.
Exchangeable potassium : Karonga series 4.8 m.e. %
Rukuru series 1.46 and 1.70 m.e. %

(It should be noted that phosphorus and potassium values in some cases vary considerably within a single series; the above table shows the range of values recorded, but should not be taken to imply that other values will not be encountered).

Available phosphorus by Bray's method (NH_4F extract).

TABLE XI—ENVIRONMENTAL CONDITIONS OF SOIL SERIES

		Chiwanda	Ekwendeni	Livingstonia	Misale	Chingumula	Nkata Bay	Chasole	Nchenachena	Mzambe	Uzumara	Vipya	Nyika	London	Mpherembe	Jandalala	Chisenga	Rumphi	Nkhamanga
ALTITUDE:	6,000–8,000 ft.												X						
	5,000–6,000 ft.				X						X	X					X		
	4,000–5,000 ft.	X	X						X	X	X			X		X			
	3,000–4,000 ft.		X	X		X									X			X	X
	2,000–3,000 ft.					X	X												
	1,300–2,000 ft.					X	X	X											
MEAN ANNUAL RAINFALL:	60–100 ins.					X	X	X			X								
	50–60 ins.			X	X				X	X		X	X						
	40–50 ins.	X	X						X										
	30–40 ins.	X	X											X		X	X		
	25–30 ins.														X			X	X
MEAN ANNUAL TEMPERATURE:	75–77°F.							X											
	70–75°F.					X	X	X											
	65–70°F.	X	X	X	X	X			X	X	X			X	X	X	X	X	X
	60–65°F.				X						X	X							
	55–60°F.												X						
SITE DRAINAGE:	Free	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Imperfect																		O
	Impeded																		
	Poor																		

		Fort Hill	Wenya	Kafukule	Bulala	Jalira	Mankhambira	Kachela	Nyakhou	Kaporoka	Ruarwe	Karonga	Lupembe	Mwatete	Dambo Clays	Sandy Dambo Soils	Alluvial Soils	Lithosols
ALTITUDE:	6,000–8,000 ft.														X			X
	5,000–6,000 ft.														X			X
	4,000–5,000 ft.	X	X	X	X										X	X		X
	3,000–4,000 ft.				X	X			X	X	X				X	X		X
	2,000–3,000 ft.														X	X		X
	1,300–2,000 ft.						X	X				X	X	X	X	X	X	X
MEAN ANNUAL RAINFALL:	60–100 ins.						X	X						X	X	X	X	X
	50–60 ins.						X	X				X	X	X	X	X	X	X
	40–50 ins.	X	X									X	X	X	X	X	X	X
	30–40 ins.	X	X	X	X	X			X			X	X	X	X	X	X	X
	25–30 ins.				X	X				X	X				X	X	X	X
MEAN ANNUAL TEMPERATURE:	75–77°F.						X	X				X	X	X	X	X	X	X
	70–75°F.														X	X		X
	65–70°F.	X	X	X	X	X			X	X	X				X	X		X
	60–65°F.														X	X		X
	55–60°F.														X			X
SITE DRAINAGE:	Free	X	X	X	X	X	X	X	X									X
	Imperfect		O			X	O	O	O	X	X	X	X				X	O
	Impeded						O	O			X	X	O				X	O
	Poor													X	X	X	X	

CHAPTER IX

SOIL SERIES: DESCRIPTIONS AND AGRONOMY

BULALA SERIES

DESCRIPTION

Genetic type: Strongly ferallitic sandy latosol.

Parent material: Basement Complex rocks.

Site: Gently sloping valley sides, 2°–4°, 3,500–4,500 ft.

Vegetation: *Brachystegia-Julbernardia* woodland *Xeromphis obovata* common.

Occurrence: Upper South Rukuru Valley. Natural areas 16c–e. In catena below the Loudon and Mpherembe series.

Morphology: In all horizons the colour becomes no redder than the 7.5 YR hue, the texture no heavier than sandy clay loam, the coarse sand fraction exceeds the fine (normally by 50 per cent. or more), and the structure is from single grain to weakly massive.

The topsoil is a loamy coarse sand or sandy loam. There is a continuous downward increase in clay to a maximum of 20–35 per cent. Despite a low organic matter content the topsoil is very dark grey (10 YR 3/1), contrasting clearly with the brown subsoil. The clay minerals are predominantly kaolinitic, as indicated by subsoil base saturation values close to 10 per cent. per 100 g. clay.

In one profile of this series certain resemblances to features of a podzol were observed. From 36–48 ins. a patchy grey organic matter staining occurred; below 48 ins. the colour was strong brown, and small ferric iron concretions were common.

AGRONOMIC DATA

Type Sites: The lower slopes of the gardens of A.I. at Kanyanji and A.I. at Bulala. The nursery and land below the training school at Mbawa.

Potential: A soil of moderate potential only for arable farming. Sparsely cultivated.

Nutrient status of topsoil: Grey brown sandy loams or loamy sands (colour range moist 10 YR 3/1) which may get rather acid. Total nitrogen is low (.05 per cent. or less). Available phosphate status is variable from adequate to low and the soil should be sampled before phosphate recommendations are made. Sulphur may be a limiting factor for groundnut production.

Agricultural characteristics: The profile is deep and offers no hindrance to root development. Drainage is free. The soil is easily worked and easily eroded, as ridges rapidly get flattened in heavy rain. Well cultivated local maize should yield 4 or 5 bags per acre, groundnuts 500–800 lb. per acre, and finger millet 800 lb. per acre. This soil should not be cultivated without the use of manure or fertilizer for more than two or three years.

The soil is moderately responsive to fertilizers and manures, but would probably do better as permanent pasture or trees, as it lies in catena below the Loudon and Mpherembe series which have a better farming potential.

Responses to fertilizers: (Data from Mbawa '57 and Bulala '58 and '59). Nitrogen and phosphate at low levels give large responses. Sulphate of ammonia will give increases of 5 bags, 2 bags and 1 bag per acre maize for successive increments of 100 lb. per acre S/A up to a limit of 300 lb. The maximum economic dressing of single superphosphate, 200 lb. per acre, will give increases of up to 2 bags per acre maize. No figures are available for responses to F.Y.M. A 200 lb. per acre dressing of S/A has raised finger millet yields by 1,000 lb. seed. A 200 lb./acre dressing of gypsum has raised groundnut yields by 300 lb. per acre seed.

F.Y.M. should give big increases, if it contains adequate nitrogen.

Suitable crops for the area:

Turkish tobacco

Groundnuts

Finger millet

Maize

Grass

BWABWA SERIES

DESCRIPTION

Genetic type: Ferallitic soil with impeded profile drainage.

Parent material: Basement Complex rocks, probably mainly schists.

Site: Gentle and moderate slopes, 3,900–4,000 ft.

Vegetation: *Brachystegia-Julbernardia* woodland; *Acacia albida* and *Piliostigma thonningii* common.

Occurrence: North-east of Bwabwa Hill, natural area 15c; possibly also in parts of natural areas 15a, b.

Morphology: This series is characterized by an abrupt textural change between a sandy topsoil and a heavy-textured subsoil. The topsoil is a sandy loam or loamy sand, with massive structure. The lower horizons are sandy clays, and are mottled; typically the mottle is faint in the subsoil and clear or prominent in the lower subsoil. The profile is often shallowish, becoming gravelly or stony at between 18 and 36 ins.

This combination of characteristics gives the series a particularly high susceptibility to erosion. Due to overgrazing this has in fact occurred, and it is possible that the soil as described represents a truncated profile.

AGRONOMIC DATA

Type sites: North east of Bwabwa Hill. No data available. A highly eroded and erodible soil type best put down to permanent pasture and utilized through livestock products.

CHINUNKA SERIES

DESCRIPTION

Genetic type: Ferruginous latosol.

Parent material: Basement Complex rocks, of basic composition. Including a charnockitic granulite, with biotite, hypersthene, plagioclase, quartz, and microcline.

Site: Level to moderately sloping, 0°–8°, 4,200–4,500 ft.

Vegetation: *Brachystegia-Isoberlinia* woodland; *Piliostigma thonningii* and *Parinari mobola* common.

Occurrence: Close to hills which form the northern margin of the Fort Hill Plain, including at Nkangwa, Chinunka, and Ibanda. Also west of Ntalire. Natural area 2e.

Morphology: The subsoil is clay or sandy clay, and at least as red as the 2.5 YR hue. The lower subsoil has a strong fine blocky structure, with strong or moderate ped cutans. There is a strongly developed, usually shallow, textural B horizon.

The topsoil is typically sandy clay loam. A moderate blocky structure is present in the subsoil. The colour below the topsoil is red or dark red within the peds, but the principal colour seen is the reddish brown of the ped cutans. Permeability is moderate. There is a substantial mineral reserve in the lower horizons. Depth is moderate, rock commencing at between 36 and 60 ins. Acidity is moderate in all horizons.

AGRONOMIC DATA

Type sites: Nkhangwa, the A.I.'s garden at Chinunka and the garden of J. Msupole, Ibanda Village.

Potential: A soil of moderate potential for arable crops if well managed.

Nutrient status of topsoil: Dark brown sandy clay loam (or sandy loam) (colour range moist 7.5 YR 2/2) in which acidity should not normally be a problem. Total nitrogen is moderate to borderline (about .10 per cent.), available phosphate is variable but often very low, and potash is adequate.

Agronomic characteristics: The profile is of moderate depth varying from 3 to 6 ft. The soil is moderately easy to work, but a heavy clay horizon not far below the surface may give rise to a hard pan. Permeability is only moderate. Well cultivated but unmanured maize yields may rise to 12 bags per acre in a good season. Groundnut yields of about 800 lb. per acre may be expected. In spite of a substantial mineral reserve in the subsoil, it is unlikely that this series will support arable cultivation for more than 3 or 4 years without manure and fertilizer. The soil will however respond readily to fertilizer and good management.

Responses to fertilizers: (Nkangwa '59 and '60, Ibanda '59 and '60, Chinunka). Sulphate of ammonia may be expected to give large responses, increments of 8 bags and 7 bags per acre maize being obtained from successive increments of 100 lb. per acre S/A up to 200 lb. per acre. This appears to be by no means the economic limit, and dressings of 400 lb./acre or more may be worthwhile. Where available phosphate is low large responses may be expected from a 200 lb./acre dressing of single superphosphate, amounting to some 5 bags per acre maize. It is not likely that heavier dressings will be economic. In the one trial on this soil type, groundnuts have not responded to either N, P or S, though yields were low and available phosphate negligible. This finding needs to be checked.

Suitable crops for the area:

Maize

Groundnuts

Grass

CHINYAKULA SERIES

DESCRIPTION

Genetic type: Ferrisol.

Parent material: Basement Complex rocks.

Site: Frequently on nearly level areas, 1,700–1,900 ft.; also on moderate slopes up to 3,000 ft.

Vegetation: Semi-evergreen forest.

Occurrence: Limited areas of level ground south-west of Nkata Bay, particularly near Chinyakula. Ferrisols near Chikwina have provisionally been included with this series. Natural areas 20c, 21c, f.

Morphology: From the subsoil downwards the colour is between the 2.5 YR and 10 YR hues and the texture sandy clay or clay. The textural B horizon is weakly developed and deep. The series is strongly acid. The profile is deep and stoneless, with no signs of weathered rock at 60 ins.

Even under forest, the topsoil reaches the 5 YR hue, with an organic matter content of 2–3 per cent. The lower horizons are weakly structured, freely permeable, and easily friable.

This series was previously described in *Ann. Rep. Dept. Agric. Nyas.* Pt. II 1958/9, p. 148.

AGRONOMIC DATA

Type sites: Chikwina coffee nursery; Chinyakula.

Potential: A soil of moderate to good potential for acid tolerant crops. Widely cultivated.

Nutrient status of topsoil. Dark reddish brown sandy clay loams (colour range moist 2.5 YR 3/4) which are distinctly acid (pH 4.7 or lower). Total nitrogen is borderline to low (.10 per cent. or less) and phosphate and potash are variable but usually moderate.

Agronomic characteristics: The profile is deep and freely draining. The soil is friable and easily worked. With adequate manure and fertilizer it should yield good arable crops, but is probably better utilized for plantation crops such as coffee, citrus, bananas and pineapples.

Responses to fertilizers: No data.

Suitable crops for the area:

Coffee

Citrus

Maize (subsistence)

Cassava (subsistence)

Grass

Timber

CHISENGA SERIES

DESCRIPTION

Genetic type: Latosol, ferallitic in the upper horizons but ferruginous in depth.

Parent material: Basement Complex rocks of the Mafingi Series, and colluvium derived from these.

Site: Dissected pediments, gentle and moderate slopes, 2°–8°; 5,000–5,300 ft.

Vegetation: *Brachystegia-Cryptosepalum* woodland *Anisophyllea pomifera* common.

Occurrence: South of Chisenga, close to the scarp-foot of the Mafingi Hills. Natural area 2c.

Morphology: The topsoil and subsoil are sandy clay loams or sandy loams, massive or with very weak blocky structure only, and with no ped cutans. At approximately 18 ins. this gives place to a strongly-developed B horizon of clay, with a weak medium blocky structure and weak ped cutans; in depth the structure and cutans become of moderate grade

The subsoil is dark reddish brown (5 YR) and the clay horizons dark red (2.5 YR). 60 per cent. of clay has been recorded in depth, but the soil remains friable and with moderate permeability. This is due to the dominance of kaolinitic clay minerals, indicated by the very low base saturation values (9–12 m.e. per cent. per 100 g. clay). The mineral reserve is very low in the subsoil, but high in depth. The series is moderately to strongly acid.

AGRONOMIC DATA

Type sites: 2 miles south of Chisenga on the main road.

Potential: A soil of moderate potential for annual arable crops, similar to but poorer than that of the Chinunka series.

Nutrient status of topsoil: Dark red brown sandy clay loam (colour range moist about 5 YR 3/3) inclined to be acid. Total nitrogen is low (.06 per cent. or thereabouts), as is available phosphate (15 p.p.m. or thereabouts). Potash status is adequate for the present.

Agronomic characteristics: The profile is deep, but root room may be restricted by compacted subsoil. Structure is massive, but the clay fraction is kaolinitic so that the soil is fairly friable and permeable. Mineral reserves are very low and the soil should not be expected to grow crops without fertilizer for more than 2 or 3 years. There are no data available for this soil type, and pending further information it should be treated as a poorer version of the Chinunka series soil, to which reference should be made.

CHOMBE SERIES

DESCRIPTION

Genetic type: Ferrisol, with sandy parent material.

Parent material: Gritty coarse sandstone, of Cretaceous or Tertiary age.

Site: Level surface remnants, 1,800–1,900 ft.

Vegetation: Semi-evergreen forest.

Occurrence. Chombe Estate, west of the Limpasa Dambo, natural area 21d; possibly also in other level areas south of Nkata Bay, natural area 21f.

Morphology: The series is characterized by over 40 per cent. of coarse sand in all horizons, and is very strongly acid. The colour reaches the 2.5 YR hue in the lower subsoil.

The topsoil is a dark reddish brown sandy clay loam or sandy loam. Below this the texture remains uniformly a sandy clay loam with approximately 30 per cent. clay. The lower horizons are easily friable, with rapid permeability and a weak or very weak blocky structure.

Catenary associates: On gentle slopes which border the surface remnants carrying the Chombe series, the topsoil becomes less sandy and reddish. Bordering valley floors the colour becomes yellowish red and the subsoil mottled.

This series and catena has been previously described in *Ann. Rep. Dept. Agric. Nyas.* Pt. II, 1955/6, pp. 85–86, and *ibid.* 1958/9, pp. 147–8.

AGRONOMIC DATA

Type sites: Chombe Estate tea soils.

Potential: Moderate for tea (rather too light). Too acid for most arable crops.

Nutrient status of topsoil: Dark reddish brown sandy clay loam or sandy loam (colour range 5 YR 3/4 to 7.5 YR 3/2) with over 40 per cent. of coarse sand. It is very strongly acid (pH 4.2). All nutrients are borderline to low. The profile is well leached and low in nutrient reserves.

Agronomic characteristics: The profile is deep and drainage free. Topsoil is easily worked and liable to erosion. The permeability and lightness of the soil makes irrigation of the tea in the dry season advisable if not essential.

Response to fertilizers: No data.

Suitable crops for the area:

Tea (borderline)
Rubber (borderline)
Grass
Cassava (subsistence)

Main weed species:

Cuscuta—Dodder.
Cryptosepalum sp.—shrub-like miniature *Brachystegia.*
Pteridium sp.—Brachea.
Imperata cylindrica—Lalang or spear grass.

EKWENDENI SERIES

DESCRIPTION

Genetic type: Ferruginous latosol, tending towards ferrisol.

Parent material: Basement Complex rocks. Including a biotite-feldspar gneiss, with biotite, quartz, andesine, and microcline.

Site: Moderately undulating, typically on moderate slopes, 5°–15°, 3,700–4,200 ft.

Vegetation: Moist *Brachystegia* woodland.

Occurrence: Middle Kasitu Valley. Natural areas 15a, b.

Morphology: A very red soil reaching the 10 R hue, usually in the subsoil. It has a strongly developed textural B horizon at moderate depth, consisting of clay (or sandy clay with a clay content exceeding 40 per cent.). There is a moderate fine blocky structure, breaking into weak fine crumb. The soil is easily friable when moist, with a characteristic soft, floury consistence.

The topsoil is at least as red as the 5 YR hue, and varies from sandy loam to sandy clay. The profile is deep, and the colour uniformly dark red. In the lower subsoil the structure becomes strong. Acidity is moderate, with the most acid horizon close to pH 5.0.

A phase of this series with iron concretions in depth has been recorded at Zombwe.

AGRONOMIC DATA

Type sites. Zombwe station, Ekwendeni township, Lupaso coffee nursery and Choma School.

Potential: A soil of high potential for arable cropping. Widely cultivated.

Nutrient status of topsoil: Red or red brown sandy loam to sandy clay (colour range moist 5 YR 3/4–10 YR 3/4) in which acidity is not likely to be a problem. Total nitrogen is low (.08 or lower) and available phosphate is borderline to low. Potash status is adequate for present farming practice. There appears to be no shortage of sulphur.

Agricultural characteristics: The profile is deep, but there is a well developed illuvial clay horizon at 1 to 2 feet below the surface which may cause trouble with water-logging. The topsoil when moist has a characteristic soft floury consistency and is easily friable. It may therefore erode easily. Well cultivated local maize, grown without fertilizer, should give 7 or 8 bags per acre on recently opened land, while groundnuts should give 800–1,000 lb. per acre. In spite of its texture, the reserves of nutrients do not appear to be large and if no fertilizer or manure is to be used, land should be rested after 3 or 4 arable crops. It is probable that with adequate manure and fertilizer this soil could maintain a high level of continuous crop production (*see* the Loudon series).

Responses to fertilizers: (Data Zombwe '56). Data are very sketchy but one may expect sulphate of ammonia to give increases of 2 bags and 1 bag per acre maize for successive increments of 100 lb. per acre S/A up to 200 lb. per acre. If soil phosphate is low a 200 lb. per acre dressing of single superphosphate should give increases of one or two bags per acre. Farmyard manure *with* added nitrogenous fertilizer should give worthwhile responses, but there are as yet no figures to prove this or show whether continuous cultivation at a high yield level is possible.

Groundnuts have shown no response to S, P or N in the one trial conducted.

Suitable crops for the area:

Low rainfall: Maize
Groundnuts
Finger millet
Turkish tobacco

High rainfall: Coffee
Vegetables
Fruit
Grass

FORT HILL SERIES

DESCRIPTION

Genetic type: Strongly ferallitic sandy latosol.

Parent material: Basement Complex rocks. Including: 1. Quartzofeldspathic granulite, with quartz, plagioclase, muscovite, biotite, and epidote; 2. Granitic gneiss, with quartz and microcline; 3. Biotite-hornblende-gneiss, largely microcline, with subordinate quartz and plagioclase.

Site: Gently undulating surface, 0°–3°, 4,200–4,600 ft.

Vegetation: *Brachystegia-Isoberlinia* woodland.

Occurrence: Plain south-east of Fort Hill. Natural areas 2a–e; Mafingi phase in natural area 2c.

Morphology: The topsoil is sandy, either sandy loam or loamy sand. Below this the clay percentage increases rapidly, giving a strongly developed, shallow textural B horizon. The subsoil is a yellowish red sandy clay with massive structure, becoming very hard when dry. At no depth does the colour reach the 2.5 YR hue.

In the lower subsoil a very weak or weak blocky structure may occur, and ped cutans are weakly developed or absent. The mineral reserve is very low. Permeability is rapid in all horizons. Acidity is moderate.

Catenary associates: Owing to the very gently sloping valleys which occur in the area occupied by this series, soils with impeded drainage occupy a substantial proportion of the catena, possibly 30–40 per cent. With imperfect drainage the subsoil colour becomes no redder than the 7.5 YR hue, with a mottle appearing in depth. The texture is sandier, the lower horizons being sandy clay loam or sandy loam, and the structure remains massive throughout. In one valley-floor profile examined the upper 15 ins. consisted of a loamy coarse sand; this passed sharply into a heavy clay, almost white in colour (N/9), with a very prominent yellowish red medium mottle.

Mafingi Phase: This phase differs from the normal Fort Hill series in that the colour reaches the 2.5 YR hue, becoming dark red from 16 ins. downwards. The transition from the sandy topsoil to the textural B horizon is less abrupt, an intervening sandy clay loam horizon forming the upper subsoil. The phase is developed on pediments of gentle to moderate slope, developed below foothills of the Mafingi Hills near Chisenga.

AGRONOMIC DATA

Type sites: Gardens of A.I. at Nthalire or of Malukwe or Kapera villages north-west of Fort Hill. The Mafingi phase is typified by the A.I.'s garden at Chisenga.

Potential: A soil of low to moderate potential for annual arable crops; probably best given over predominantly to livestock production.

Nutrient status of topsoil: Dark brown sandy loams or loamy sands (colour range moist 10 YR 5/3–7.5 YR 3/2) of moderate acidity. Total nitrogen level is low (.07 per cent. or less); available phosphate variable, but usually low 20 p.p.m. or less and potash status is adequate.

Agronomic characteristics: The profiles are deep, but root room is often restricted by a high water table, arising from impeded site drainage, and a compacted subsoil. Topsoil is fairly easy to work, but the subsoil rapidly becomes very heavy as one goes down the profile and it gets very hard when dried out. Mineral reserves are very low and it is unlikely that these soils will be able to sustain reasonable yields for more than 2 or 3 years unless fertilizer and manure is liberally used. Unfertilized yields of well cultivated local maize are very variable ranging from 3 to 10 bags per acre. Groundnuts might be expected to give 600 lb. per acre. Finger millet may give up to 1,000 lb. per acre.

Responses to fertilizers: (Data from Nthalire '60, Fort Hill '54). There is not a great deal of reliable data, but it would appear that there should be responses to nitrogen of the order of 3 bags of maize for a 200 lb. per acre dressing of S/A. A similar increase might be expected from a dressing of 200 lb. per acre superphosphate, where soil phosphate is low.. Groundnuts may give responses of 200 lb. nuts to a 200 lb. dressing of single superphosphate; they do not appear to respond to sulphur on these soils. Finger millet will give responses of about 250 lb. per acre seed per 100 lb. per acre S/A applied up to a limit of 200 lb. per acre with similar increases to superphosphate, where soil phosphate is short.

Suitable crops for the area:

Finger millet

Groundnuts

Maize

Grass

JALIRA SERIES

DESCRIPTION

Genetic type: Strongly ferallitic sandy latosol, with laterite.

Parent material: Basement Complex rocks.

Site: Dambo margins, on the lower parts of very gently sloping valley sides, 3,400–3,600 ft.

Vegetation: Combretum ghazalense-Acacia savanna of lower valley sides, and *Acacia-Combretum* thicket of plateaux.

Occurrence: North and west of Rumpi, natural areas 11a, 12b; also recorded at Kameme Mission, north-west of Fort Hill. Commonly in catena below the Nkamanga and Rumpi series.

Morphology: A horizon of massive laterite, or consisting predominantly of pea-iron concretions, occurs at a depth of less than 36 ins., usually between 18 and 30 ins. Above this the soil is at least as sandy as sandy clay loam, no redder than the 5 YR hue, and has massive structure.

The topsoil is a sand, loamy sand, or sandy loam. Site drainage may be imperfect.

Profiles with laterite at a depth greater than 36 ins., or in which iron concretions form a small proportion of the lateritic horizon, have been excluded from this series. Such profiles have been recorded in association with the Ekwendeni and Loudon series.

AGRONOMIC DATA

Type sites: Garden of the A.I. at Jalira (Rukwapaliza). There are no data available for this series which is virtually uncultivated, as the root room is limited to $1\frac{1}{2}$ to 2 ft. by a layer of massive laterite. It occurs in catena below the very poor but slightly better soils of the Rumpi and Nkamanga series and should be under trees or permanent grass.

JANDALALA SERIES

DESCRIPTION

Genetic type: Weakly ferallitic latosol.

Parent material: Basement Complex rocks, granitic intrusions, and colluvium derived from these.

Site: Gentle slopes, up to 4°, particularly pediments; 4,600–4,900 ft.

Vegetation. *Brachystegia-Julbernardia* woodland.

Occurrence: Pediments of Mount Hora and hills near to it; pediment of Bwabwa Hill. Natural areas 17c, 18b.

Morphology: The colour is dark red (2.5 YR) from the subsoil downwards. The texture is sandy clay loam or sandy clay throughout, with the textural B horizon weakly developed and deep. The subsoil and lower subsoil have a weak blocky structure.

The topsoil is a dark reddish brown (5 YR) sandy clay loam. The colour and texture remain relatively uniform with depth. The profile is deep, with no weathered rock above 60 ins. On the pediment of Bwabwa Hill over 110 ins. of soil was observed; in this case a moderately developed angular blocky structure with ped cutans commenced below 76 ins. The series is moderately to strongly acid.

AGRONOMIC DATA

Type sites: Garden of Master Farmer Mwanza at Jandalala.

Potential: This soil would appear to have high potential, but it is of limited area and so intensely cultivated that the soil is often worn out.

Nutrient status of topsoil: Dark reddish brown sandy clay loam (colour range 5 YR). No soil analyses are available from sites guaranteed to lie on this series, but both nitrogen and phosphate status may be expected to be low.

Agricultural characteristics. The profile is very deep and drainage is fair. The soil is moderately heavy to work and may get very hard in the dry season. As most of the soil has been overcropped, unfertilized crops of local maize might be expected to yield about 4 bags per acre. There are no records for groundnuts.

Responses to fertilizers: (Data from Hora '54, Mzimba '57, Mombera '60). Maize yields may be more than doubled by small dressings of nitrogen. Sulphate of ammonia has given increases of 3 bags and 2 bags per acre maize for successive increments of 100 lb. per acre S/A, and economic responses may be expected to dressings of over 200 lb. per acre. Phosphate has given small responses of about 2 bags per acre maize per 200 lb. single superphosphate where soil phosphate has been low.

Not enough experimental work has yet been done to show with any certainty how yields can be raised to the potential one would expect from such a soil.

Suitable crops for the area:

Maize

Groundnuts

KAFUKULE SERIES

DESCRIPTION

Genetic type: Strongly ferallitic sandy latosol.

Parent material: Basement Complex rocks.

Site: Gentle and moderate slopes, 4,400–5,000 ft.

Vegetation: *Brachystegia-Cryptosepalum* woodland.

Occurrence: Dissected country of moderate relief north of Mzimba. Natural areas 17a–d.

Morphology: The combined percentages of coarse sand and gravel amount to more than 50 per cent. in the topsoil and subsoil, and more than 40 per cent. in the lower subsoil. In all horizons the structure is single grain to weakly massive. The lower horizons are brown, strong brown, or yellowish red, becoming no redder than the 5 YR hue.

The topsoil is a brown or dark brown loamy coarse sand or coarse sandy loam, with a very low organic matter content. The texture may either remain as sandy as this throughout, or the clay content may increase downwards to a coarse sandy clay loam in depth. Quartz gravel is common at all depths, but apart from this and mica there are few minerals present in the subsoil. The series is strongly acid, pH 4.5–5.0.

The profile is from moderate depth to shallowish. It is found in association with lithosols.

AGRONOMIC DATA

Type sites: This series covers a range of gravelly or sandy soils of reasonable depth in dissected country north and south of Mzimba.

Potential: A soil of moderate potential only for arable farming, occurring in pockets among uncultivable lithosols. Best used for subsistence food and fodder crops for animals. Sparsely cultivated.

Nutrient status of topsoil: Brown or dark brown coarse sandy loams or loamy sands with a fair proportion of gravel (colour range moist 10 YR 5/3 to 10 YR 4/3). The soils *may* be distinctly acid. Total nitrogen is very low (.04 or less) and available phosphate likewise will probably be low (20 p.p.m. or less). Potash supplies are not good. The soils do not seem to suffer sulphur deficiency however.

Agricultural characteristics: Depth of profile is moderate to shallow (4 to 5 ft.). Drainage is good. As the soils are often on fair slopes and are light, soil conservation measures are essential. The soil is fairly easy to work, though gravel may wear tools rather quickly. Well cultivated local maize may give 5–7 bags per acre on newly opened land, and groundnuts 800–1,000 lb. per acre, but the yields deteriorate very badly and if no fertilizer or manure is used gardens should be returned to fallow after two or three years cultivation.

The soil can give large responses to low levels of fertilizer but needs very careful management if good yields are to be sustained.

Responses to fertilizers: (Data from Jandalala '59, Mzimbamuli and Madise '60). Sulphate of ammonia will give responses of the order of 3 bags and 1½ bags per acre maize to successive increments of 100 lb. per acre S/A up to a maximum of

200 lb. per acre. Where no F.Y.M. has been applied in the past and soil P is low, a 200 lb. per acre dressing of single superphosphate should give a response of up to 3 bags per acre maize.

No other data are available.

Suitable crops for the area:

Finger millet
Groundnuts
Maize
Grass and fodder crops

KAPEMBA SERIES

DESCRIPTION

Genetic type: Lower member of latosol catena, with impeded site drainage.

Parent material: Basement Complex rocks, and colluvium derived from these.

Site: Lower parts of gently sloping valley sides, 0°–2°, 3,500–4,000 ft.

Vegetation: *Combretum ghazalense-Acacia* savanna of lower valley sides; *Bauhinia petersiana* common in parts.

Occurrence: Plains and valleys west and north-east of Rumpi. Natural areas 11a, b, 12b, 16a, b. In catena below the Nkamanga and Rumpi series.

Morphology: The series has imperfect or impeded site drainage, as a result of which greyish brown colours predominate, with no horizon redder than the 7.5 YR hue. A mottle may or may not be present in the lower horizons. With the possible exception of a clay horizon, the structure is massive or very weak blocky.

The topsoil is very dark grey to very dark brown (10 YR 3/1 to 2/2), and is typically a sandy loam. The lower horizons are mainly sandy clay loams or sandy clays, but one clay horizon may occur. The soil becomes very hard when dry. Despite the greyish colours the series is moderately acid, pH 5.0 to 6.0

AGRONOMIC DATA

Type sites: S. Rukuru valley margins, margins of Lake Kazuni and Vwaza marsh, especially garden of Master Farmer near Diere village.

Potential: A soil of fairly high potential provided water-logging does not occur.

Nutrient status of topsoil: Very dark grey to very dark brown sandy loams (colour range moist 10 YR 3/1 to 10 YR 2/2) in which acidity should be no problem. Available nitrogen is borderline to low (.08 per cent. or less) and phosphate is adequate.

Agronomic characteristics: The profile is fairly deep, but root room may be limited by a high water table. Lower horizons are sandy clay loams or heavier and water-logging may be a problem. Owing to the massive structure the soil becomes very hard when dry. Unfertilized maize yields of about 6 bags per acre maize can be expected.

Responses to fertilizers: (Maradade '58–'60). Responses to sulphate of ammonia have been very variable, and though a straight line response of 3 bags per acre maize per 100 lb. S/A was obtained in one year up to a limit of 200 lb. per acre S/A, responses have more frequently been very small. There have been no responses to phosphate.

Suitable crops for the area:

Maize
Groundnuts
Finger millet

KARONGA SERIES

DESCRIPTION

Genetic type: Alluvial, calcimorphic soil, with impeded site drainage.

Parent material: Alluvium and colluvium.

Site: Almost level lake-shore plain, 1,500–1,800 ft.

Vegetation: *Acacia-Adansonia-Hyphaene-Sterculia* cultivation savanna of the lake shore; *Trichilia emetica* and *Combretum ghazalense* common.

Occurrence: Lake-shore plain north, west and south of Karonga. Natural areas 6a-e.

Morphology: A greyish brown soil, with no horizon redder than the 7.5 YR hue, and a mottle commencing in the subsoil or lower subsoil. Depositional bedding is present. By definition the series includes at least one horizon above 36 ins. formed by sandy clay or clay, with a moderate or strong, medium or coarse angular blocky structure; a soil from which this feature is absent is classed with the Lughali series.

Fine sand normally exceeds coarse sand in all horizons, with the exception of beds of almost pure coarse sand which commonly occur in depth. Horizons of sandy loam or loamy sand have massive structure. The soil is micaceous, often highly so. Site drainage may be imperfect or impeded. The series is weakly acid, normally with a pH of 6.0–6.5 throughout.

AGRONOMIC DATA

Type sites: Agricultural demonstration plot, Baka.

Potential: A soil of good potential for arable cropping provided that water relationships are suitable.

Nutrient status of topsoil: Very dark grey to grey brown soils (colour range moist 2.5 Y 3/2–9 YR 3/2) ranging from sandy loams to sandy clay loams. The soils are very weakly acid (pH 6.0–6.5). Total nitrogen content is moderate (about .10 per cent.), and available phosphate and potash are adequate to high.

Agronomic characteristics: A deep profile showing marked stratification in which at least one horizon above 36 ins. is sandy clay or clay. Site drainage is impeded and water-logging is very likely to occur. High water tables may reduce root room. Nutrient reserves of the soil are good and cropping may take place for a considerable period without marked declines in yield. Weed competition and soil moisture relationships are likely to have more effect on yield than fertilizer treatments. Unfertilized yields of crops are variable, depending on season, but can be high. 15 bags per acre of maize and more have been recorded, with groundnuts at 1,200–1,500 lb per acre and finger millet at about 1,500 lb. per acre.

Responses to fertilizers: (Data from Baka and Lupembe '57–'60). Sulphate of ammonia has usually given insignificant increases in maize yields, but finger millet has responded markedly—a 100 lb./acre dressing of S/A giving an increase of about 300 lb. per acre. It is unlikely that higher dressings will be much more effective. There has been no response to phosphate application recorded.

Suitable crops for the area:

Maize

Finger millet

Groundnuts (short or medium term varieties usually best)

Cotton

Grass

KASHATA SERIES

DESCRIPTION

Genetic type: Strongly ferallitic sandy latosol, derived from sandy parent materials.

Parent material: Sands of lacustrine origin.

Site: Lacustrine constructional features, including sand bars and spits.

Vegetation: Specialized vegetation of sands; *Magnistipula bangweolensis* and *Parinari mobola* common in places.

Occurrence: Lake shore areas, principally where the shoreline faces south-east. Natural area Lacustrine Sands.

Morphology: Coarse sand or loamy coarse sand throughout, with single-grain structure. The only profile development to have occurred is the formation of a dark brown topsoil. Other horizons retain the colour of the parent material. Profile drainage is excessive, site drainage varies from free to impeded.

Soils consisting predominantly of coarse sand have been observed in three other sites: 1. Immediately north of Karonga, where a recent flooding of the North Rukuru has deposited up to 36 ins. of sand on top of a former soil of the Karonga Series; 2. In the lower Kasitu valley, also on spreads of sand produced by river flooding; 3. On a 3° pediment 9 miles north-west of Karonga.

Catenary associates: In the hollows between sub-parallel sand-bars the soil has poor drainage, but in most cases also consists predominantly of coarse sand. Marshy clay deposits, however, may also occur.

AGRONOMIC DATA

Type sites: None. Sand bars and dunes generally.

These are found mostly on the lake shore, though they occur occasionally in the alluvial deposits of the lower South Rukuru. They are of no value for arable cropping and should be left to indigenous vegetation.

LIVINGSTONIA SERIES

DESCRIPTION

Genetic type: Ferrisol, tending towards ferruginous latosol.

Parent material: Basement Complex rocks.

Site: Steep and moderate slopes, 3,500–4,000 ft.

Vegetation: Moist *Brachystegia* woodland.

Occurrence: South-west of Livingstonia, in valleys of tributaries of the North Rumpi. Natural areas 10b, c.

Morphology: The texture is clay from the subsoil downwards. The lower subsoil colour is 10 R 4/6 red, with a strong blocky structure. The profile is very strongly acid.

The topsoil is reddish and relatively heavy-textured, a reddish brown (5 YR 4/3) sandy clay. Ped cutans are weak in the subsoil, becoming moderate in depth. The profile is deep, with rapid permeability. The clay has a base exchange capacity of less than 10 m.e. per cent. per 100 g. clay, indicating a predominance of kaolinitic clay minerals.

It should be noted that Livingstonia Mission is *not* situated on this series, but on soils developed from sedimentary sandstones and mudstones of Karroo age. This soil has not been fully examined. It is of shallow to moderate depth and with a yellowish red subsoil, differing greatly from the Livingstonia series.

AGRONOMIC DATA

Type sites: (Not wholly typical): the coffee plot at the junction of the Livingstonia Mission road with the main road.

Potential: A soil of fairly high potential for acid tolerant perennial crops.

Nutrient status of topsoil: Red brown sandy clay (colour range moist 5 YR 4/3), very acid (pH 3.6) with all nutrients at a low level. The profile is however very deep and drainage no problem. With proper manuring it should produce good crops.

Responses to fertilizers: No data.

Suitable crops for the area: Perennial tree crops, e.g. coffee.

LOUDON SERIES

DESCRIPTION

Genetic type: Weakly ferallitic latosol.

Parent material: Basement Complex rocks. Including: 1. Feldspathized hornblende-gneiss, with microcline, quartz, hornblende, and biotite; 2. Sheared biotite-granite, with quartz, microcline, and biotite.

Site: Level to very gently sloping surface remnants, mainly 0°–1°, 4,000–4,400 ft.

Vegetation: *Brachystegia-Julbernardia* woodland; *Ochna schweinfurthiana* common.

Occurrence: Southern part of the Upper South Rukuru Valley, principally south of the latitude of Mzimba, near Loudon and Mbawa, but also extends onto the Nkata Bay map sheet. Natural areas 16c, d. Normally in catena above the Bulala series.

Morphology: The topsoil is a sandy clay loam or sandy loam, below which there is a strongly developed shallow textural B horizon of sandy clay or clay (35–50 per cent. clay), with a weak fine to medium blocky structure. In the lower subsoil the colour is red or dark red (2.5 YR or redder), but the structure remains weak.

The colour increases in redness from the subsoil downwards but this change is very gradual, the profile presenting a uniform appearance. It is deep, one case of weathered rock commencing at 108 ins. being recorded. All horizons are easily friable and have moderate or rapid permeability. The series is moderately acid and has a moderate base saturation in the subsoil, 60–80 per cent.

A phase with abundant pea-iron concretions below 36 ins. has been recorded at Mbawa.

AGRONOMIC DATA

Type sites: Mbawa station, the garden of the A.I. at Chimsolo and the upper slopes of the garden of the A.I. at Kanyanje.

Potential: A soil of high arable potential given suitable management. Widely cultivated.

Nutrient status of topsoil: Reddish brown sandy clay loams to sandy loams (colour range moist 5 YR 3/4–7.5 YR 3/2) in which acidity is normally no problem. Total nitrogen is low (.09 per cent. or less). Available phosphate is adequate in newly opened soil (50 p.p.m.), but reserves are limited and phosphate will become limiting after a number of years cultivation. Potash levels are adequate for normal farming practice, though under continuous and intensive cultivation they will need to be bolstered up. Sulphur may be limiting for groundnuts on worn out soils.

Agricultural characteristics: The profile is deep and offers no hindrance to root growth. Drainage is free, though water may stand for some time after heavy storms. The soil is easy to work either by hand, ox or tractor. Owing to its friable nature it is liable to erode easily unless effective measures are taken to conserve the soil. Fortunately slopes are very gentle. Well cultivated local maize without fertilizer or manure should give 7–8 bags per acre on recently opened land and groundnuts 1,000–1,200 lb. per acre. The nutrient reserves of the soil are soon dissipated however and without the use of fertilizer the land should be returned to a resting crop or ley after three or four years arable cultivation. Groundnuts have a markedly beneficial effect as a rotation crop. Improved varieties can also markedly increase yields e.g. Hybrid maize

This soil is very responsive to treatment, showing up in no uncertain terms both good and bad management.

Responses to fertilizers: (Data from Mbawa 1951–61). Any practice that will return nitrogen and organic matter in that order will show great benefits. Sulphate of ammonia may be expected to give increases of 4 bags, 3 bags, 2 bags and 1 bag per acre maize for successive increments of 100 lb. per acre S/A up to 400 lb. per acre on open pollinated maize. The increases may be more on suitable hybrids. After four or five years cultivation, if soil analysis shows low phosphate status single superphosphate may be expected to give increases of 2½ bags, 2 bags, 1½ bags and 1 bag per acre for successive increments of 100 lb. superphosphate up to 400 lb. per acre. Farmyard or khola manure, if rich in nitrogen, will also give increases of about 7 bags of maize from a 5 ton dressing, 4 bags of maize from a 2½ ton dressing.

On worn out soils nitrogen is essential. Green manures give excellent increases in yield if a small dressing of nitrogen is applied to the following maize crop. Broken fallows also greatly benefit from added nitrogen. On worn soils sulphur may become limiting to the growth of both maize and groundnuts. This can be remedied by the application of gypsum, but the indisposition should not arise if sulphur containing sources of nitrogen and phosphorus are regularly used.

The residual effects of fertilizers have not been carefully studied, but evidence points to benefits lasting at least two seasons after that in which phosphate, sulphur or F.Y.M. have been applied. Nitrogen as such shows little residual effect.

It has been shown that this soil can be continuously cultivated with maize for at least 6 years using annual application of 5 tons per acre F.Y.M., 200 lb. per acre S/A and 125 lb. per acre single supers. Maize yields currently stand at 20–25 bags/acre.

Suitable crops for the area:

Maize (open pollinated, e.g. Namlenga and Askari or hybrid, e.g. Mthenga)

Groundnuts (long term varieties, Mwitunde, Dixie Runner, Chalimbana)

Turkish tobacco

Ground beans (N. Rhodesian or Mbawa D.)

Soya beans (Medium term, e.g. Pelican)

Grass leys (Napier, rhodes, makarikari, possibly with stylosanthes)

Finger millet

LUGHALI SERIES

DESCRIPTION

Genetic type: Alluvial calcimorphic soil, with impeded site drainage.

Parent material: Alluvium and colluvium.

Site: Almost level lake-shore plain, 1,500–1,800 ft.

Vegetation: Lake shore thorn scrub; also *Acacia-Adansonia-Hyphaena-Sterculia* cultivation savanna of the lake shore.

Occurrence: Lake-shore plain north, west, and south of Karonga. Natural areas 6a–f.

Morphology: A greyish-brown soil, with no horizon redder than the 7.5 YR hue. Depositional bedding is present. It is distinguished from the Karonga series by the absence, above 36 ins., of any horizon of clay or sandy clay. The structure is from massive to weak medium or coarse blocky in all horizons.

Either coarse or fine sand may predominate. Ped cutans are normally absent, but may be weakly developed in some horizons. Site drainage is imperfect or impeded. The series is weakly acid, pH 5.8–6.8.

One alkaline soil observed resembled the Lughali series in morphology, but has been excluded from the series.

AGRONOMIC DATA

Type sites: The garden of the A.I. at Wovwe, S. Karonga.

Potential: A soil of good potential for arable cropping provided water relationships are suitable.

Nutrient status of topsoil: Very dark grey brown to black sandy loams (colour range moist 10 YR 5/3–10 YR 2/1) with a pH between 6.5 and 7.0. Total nitrogen levels are fairly high (.10 or more) as are levels of available phosphate. Potash status is high.

Agronomic characteristics: The profile is deep with stratified layers apparent, none of which are heavier than sandy clay loam. Profile drainage is free but level sites giving rise to high water tables are likely to restrict the root room. The soil is fairly easy to work. Nutrient reserves are good and the soils may be cultivated for a considerable period without showing marked deterioration. Weed competition and soil moisture relationships are likely to affect yields more than fertilizers. Because of the free draining nature of the soil any droughts early in the season are likely to be seriously felt by the crops. Unfertilized yields of crops are variable (*see* Karonga series).

Responses to fertilizers: (Data- -taken as similar to Karonga series). There is unlikely to be a marked response to any applied fertilizer.

Suitable crops for the area:

Maize

Sorghum

Finger millet

Groundnuts (short or medium term varieties usually best)

Cotton

Grass

MANKHAMBIRA SERIES

DESCRIPTION

Genetic type: Strongly ferallitic sandy latosol, derived from sandy parent materials.

Parent material: Sands of lacustrine origin.

Site: Level coastal plains and low raised beach platforms, 1,500–1,900 ft.

Vegetation: Specialized vegetation of sands; *Piliostigma thonningii* common where drainage impeded.

Occurrence: Raised beach platforms south of Karonga, a few miles inland from the present lake shore. Close to the lake shore south of Nkata Bay. Natural areas 6g, i, 14d, 21e, and Lacustrine Sands: Florence Bay phase in natural area 6h.

Morphology: The texture is predominantly sandy loam or loamy sand, becoming no heavier than sandy clay loam in any horizon. There is at least a slight increase in clay with depth. The structure is single grain to weakly massive throughout.

Profile differentiation is at a relatively early stage, and indications of depositional bedding may still be present. Either coarse or fine sand may be predominant. The topsoil is from very dark grey brown to dark brown, with a lowish organic matter content. The subsoil colour is normally brown or dark brown, or yellowish red, never becoming red. Profile drainage is excessive; site drainage varies from free to impeded. With free drainage the profile is moderately or strongly acid. Where drainage becomes poor the soil is classed as a sandy dambo soil.

Florence Bay Phase: This occurs in dissected country of low relief but moderate slopes, immediately west of Florence Bay. The parent material is Tertiary sandstones. Textural horizon differentiation is weakly but definitely developed, and the subsoil is dark reddish brown (5 YR).

AGRONOMIC DATA

Type sites: N.A. Mankhambira's Court and at the garden of Master Farmer near Deep Bay.

Potential: A soil of moderate potential for arable crops. Widely cultivated.

Nutrient status of topsoil: Dark grey brown sandy loams or loamy sands (colour range moist 2.5 Y 5/2) which are decidedly acid (pH 5.0–6.0). Total nitrogen is borderline (.09 per cent. or less), available phosphate very high (150 p.p.m.) and potash borderline (.15 m.e. per cent.). Base exchange capacity of the soil is fairly good for so light a soil, but the saturation percentage is very low (20 per cent.).

Agronomic characteristics: The profile is moderately deep and the profile drainage is excessive, accounting for the very leached character of the soil, which is nevertheless easily worked. Unfertilized yields of maize recorded are of the order of 9 bags per acre. Cassava is widely grown yielding about 6 tons per acre at 12 months and 12 tons per acre at 24 months, and groundnuts may do well. Unless heavily manured and fertilized this soil should not be cultivated for more than two or three years at a stretch.

Responses to fertilizers: (Banga '57). In the one experiment recorded sulphate of ammonia gave increases of 4 bags/acre maize for each 100 lb./acre S/A applied up to the limit of 200 lb. per acre. It would appear that this soil is very responsive to nitrogen and possibly also to F.Y.M. There was no response to phosphate.

Suitable crops for the area:

Maize
Groundnuts
Cassava

MAZAMBA SERIES

DESCRIPTION

Genetic type: Ferrisol.

Parent material: Basement Complex rocks. Including a charnockitic gneiss, with quartz, biotite, and hypersthene.

Site: Gentle and moderate slopes, 4,000–4,500 ft; the type-profile is sited on a 4° pediment.

Vegetation: Moist *Brachystegia* woodland and montane grassland.

Occurrence: Low east Vipya Plateau, including south and west of Mzuzu, and near Mazamba. Natural area 19c.

Morphology: The colour, texture and other characteristics are relatively uniform from the subsoil to a depth of 72 ins. and more. The lower horizons are formed by a dark red (reaching the 10 R hue in the lower subsoil or often in the subsoil) sandy clay or clay with little textural differentiation, having a weak blocky structure breaking into weak fine crumb.

The topsoil is a dark reddish brown sandy clay. All horizons are easily friable and with rapid permeability. The profile is strongly acid, with kaolinitic clay minerals.

This series has previously been described by C.V. Cutting (unpublished manuscript).

AGRONOMIC DATA

Type site: At Mazamba, under tung.

Potential: A soil of fairly high potential for arable and plantation crops, notably tung and coffee.

Nutrient status of topsoil: Dark red brown sandy clays or sandy clay loams (colour range when moist 2.5 YR 2/4) which are rather acid (pH 5.0–5.8). Total nitrogen is borderline (.18–.10 per cent.), available phosphate and potash normally adequate in newly opened soil, but becoming fairly rapidly depleted on cultivation. Base exchange capacity is not high.

Agronomic characteristics: The profile is deep and free draining. The topsoil is friable and easily worked. Unfertilized yields of maize are recorded at about 6 bags per acre, but this soil and climate are probably better adapted to plantation crops, fruit trees, vegetables etc. With management aimed at reducing the acidity, the soil should be very fertile.

Responses to fertilizers: (Data Mazamba '55). In the only experiment on record, 100 lb. per acre S/A gave an increase of 3 bags per acre maize and 200 lb. single superphosphate gave 2½ bags per acre maize. There was no interaction. Farm-yard manure may give great benefit.

Suitable crops for the area:

Tung
Coffee
Fruit
Vegetables
Grass

MISUKU SERIES

DESCRIPTION

Genetic type: Ferrisol, tending towards ferruginous latosol.

Parent material: Basement Complex rocks, of intermediate and acid composition. Including: 1. Feldspathized biotite-gneiss, with microcline, biotite, and quartz; 2. Muscovite-biotite gneiss, with biotite, quartz, and plagioclase; 3. Magnetite quartzofeldspathic gneiss, with magnetite, quartz, microcline, and plagioclase; 4. Muscovite-quartz-schist.

Site: Moderate slopes and some steep, up to 25°, 5,000–5,500 ft.

Vegetation: Moist *Brachystegia* woodland and semi-evergreen forest; now mainly cleared, with *Parinari mobola* bushes and the creeper *Smilax kraussiana* common

Occurrence: Misuku Hills. Natural areas 3a, b.

Morphology: From the subsoil downwards the colour is red (2.5 YR) and the texture clay. The lower subsoil is characterized by a very strong fine blocky structure, with strong or moderate ped cutans.

In cultivated areas the topsoil is dark reddish brown (5 YR). Under the forest patches which remain, however, it has a highish organic matter content, becoming dark brown. Below this, the clay content is very high at all depths, 50–65 per cent. But kaolinitic clay minerals are dominant (base exchange capacity 9–12 m.e. per cent. per 100 g. of clay), and the soil is freely permeable and easily friable. The series is strongly to very strongly acid. On the upper parts of slopes depth is sometimes about 48 ins., but normally the profile is very deep, one profile showing no signs of weathered rock at 10 ft.

Windindi Phase: On the Windindi Ridge a distinctive parent material results in a highly micaceous soil with a purplish tinge. It is derived from a magnetite-muscovite-schist. This soil has not been fully examined

AGRONOMIC DATA

Type sites: The departmental plot at Katobo and the Catholic Mission, Misuku.

Potential: A soil of fair to good potential for acid tolerant and plantation crops.

Nutrient status of topsoil: Dark red brown clays or clay loams (colour range moist 5 YR 3/3–5 YR 5/6) which are very acid, with pH usually well below 5.0. Total nitrogen is moderate to high (over .15 per cent.), available phosphate is very low and potash often borderline. Trace element deficiencies are likely to become apparent under these conditions.

Agronomic characteristics: The profiles are deep, ranging from 4 ft. or so on upper slopes to over 10 ft. in places. The soil is freely permeable and very leached. Though of high clay content, it is friable and easily worked. Nutrient reserves are not high and these soils will not stand production of high yielding arable crops for long. As slopes are often steep high priced permanent cash crops should be grown rather than annual food crops.

Responses to fertilizers: (Data from Katobo). Nitrogen has given no response on maize crops and little on coffee. Sulphate of ammonia being an acid fertilizer reduces yields. Maize has given marked responses to single superphosphate in microplot trials. Lime has not been effective in raising yields in the year of application. In a groundnut fertilizer experiment there were no responses to sulphur, calcium or nitrogen.

Suitable crops for the area:

Coffee

Grass

MPHEREMBE SERIES

DESCRIPTION

Genetic type: Weakly ferallitic latosol.

Parent material: Basement Complex rocks, including a biotite-feldspar gneiss, with andesine, quartz, and garnet.

Site: Level surface remnants and gentle slopes, 3,500–4,000 ft.

Vegetation: *Brachystegia-Julbernardia* woodland; *Reissantia indica* common.

Occurrence: Extensively developed in the Upper South Rukuru Valley, particularly between Mpherembe and Eutini, and south of the latter. Natural areas 16a, c. In places in catena above the Bulala series.

Morphology: The topsoil is a sandy loam or loamy sand; there is a downward increase in clay to between 20 and 30 per cent., giving a moderately developed but usually deep textural B horizon of sandy clay loam. The colour reaches in depth to between the 5 YR and 2.5 YR hues. The subsoil structure is weak blocky.

The profile presents a uniform appearance, with no clear horizons; it is usually of moderate depth. The subsoil, and usually also the lower subsoil, is yellowish red (5 YR); downwards this may either remain the same colour or merge gradually into red. The structure remains weak blocky at all depths. In the sand fraction, coarse sand exceeds or is equal to fine. The series is moderately to strongly acid.

AGRONOMIC DATA

Type sites: The gardens of A.I. at Mpherembe and the A.I. at Bulala (on the upper slopes and ridge crest). Mzambazi Mission, Eutini.

Potential: A soil of moderate to high arable potential given suitable management. Widely cultivated.

Nutrient status of topsoil: Dark brown sandy loams and loamy sands (colour range moist 7.5 YR 3/2–10 YR 4/3) in which acidity may become a limiting factor for intolerant crops. Total nitrogen is very low (.05 per cent. or less). Available phosphate is also low under natural conditions (15 p.p.m. or less). Potash levels are adequate for normal farming practice at the present. Sulphur may be limiting for groundnuts.

Agricultural characteristics: The profile is of moderate depth, and quite adequate for most annual crops. Drainage is fairly free, though water will stand for some time after heavy rain. The soil is easy to work by hand, ox or tractor and is liable to erosion on the steeper slopes. Well cultivated local maize without fertilizer should give about 5 bags per acre on recently opened land, and groundnuts 800–1,000 lb. per acre. Nutrient reserves are very poor indeed and without fertilizer and manure, this soil should be returned to fallow or ley after 2 or 3 years cropping.

This soil is very responsive to treatment, showing up in no uncertain terms both good and bad management.

Responses to fertilizers: (Data from Njinje '59 and '60, Manyamula '59 (maize); Njinje '59 and '60 and Kamanga, Kapando, and Manyamula '60 (groundnuts)). Any practice that will return nitrogen, organic matter or phosphate to the soil will give big returns. Sulphate of ammonia may be expected to give increases of 4 bags and 2½ bags and 1 bag per acre maize for successive increments of 100 lb. per acre S/A up to a maximum of 300 lb. per acre. Superphosphate at 200 lb.

per acre may give increases of up to 5 bags per acre if soil analysis shows a low level of available P. Higher dressings are not worth while. F.Y.M. will give large responses, but these have not yet been measured.

On these soils, if no fertilizer containing sulphur has been added in the past, groundnuts will give a response of 400–600 lb. per acre shelled nuts to a 200 lb. per acre dressing of gypsum, and a response of 300–400 lb. per acre shelled nuts to a 200 lb. dressing of single superphosphate. This may also indicate shortage of available calcium on these rather acid soils.

Residual effects of fertilizers and manures are likely to be good.

Suitable crops for the area:

Maize (open pollinated, e.g. Namlenga and Askari or hybrid e.g. Mthenga)

Groundnuts (long term varieties. Mwitunde, Dixie Runner, Chalimbana)

Turkish tobacco

Grass leys

Finger millet

MWENITETE SERIES

DESCRIPTION

Genetic type: Hydromorphic soil.

Parent material: Alluvium.

Site: Level area on lake-shore plain.

Vegetation: Low-altitude marsh grassland; scattered trees of *Acacia albida*, *Combretum ghazalense*, and *Piliostigma thonningii*.

Occurrence: Karonga lake-shore plain, particularly between the Lufira and Songwe rivers, north of Karonga, and on the Hara Plain west of Young's Bay. Natural areas 6a, d, e.

Morphology: This is a hydromorphic soil with poor site drainage, but which dries out seasonally in the upper horizons, permitting cultivation. A mottle reaches to the surface or immediate subsoil. Depositional bedding is present, and the series differs from dambo clays in that the texture is not normally dominantly clay, although clay horizons may occur.

Textures are very variable, with fine sandy clay loams and clay loams the most common; silt often exceeds 10 per cent. Structure varies with texture, being massive in sandy horizons and strong coarse blocky in clays. The series is weakly acid, pH 5.5–7.0.

Alkaline profiles, occurring in association with the Mwenitete series, and with similar morphology, have been excluded from the series.

Previous observations of this series have been made by G. Jackson (*Ann. Rep. Agric. Nyas.* Pt. II, 1956/7, pp. 138–9).

AGRONOMIC DATA

Type sites: Mwenitete plot and Hara plain.

Potential: A soil of fair potential for rice cultivation.

Nutrient status of topsoil: Very dark grey or grey brown soils (colour range moist 10 YR 3/2) of varying texture but usually sandy clay loams or clay loams. The soils are weakly acid, but acidity should be no problem. Total nitrogen is variable, borderline to high (.10 per cent. or thereabouts). Available phosphate is low (12 p.p.m. or less). Potash is quite adequate and base exchange capacity is quite high.

Agronomic characteristics: The profiles are deep, stratified and often overlie sand beds at depth. The soils are flooded for part of the year, but dry out enough to enable them to be ploughed by oxen. Weed control is the main problem. Unfertilized yields of rice vary from 1,000 to 2,000 lb. per acre paddy depending on weed and water control. Dry season crops do not appear to be grown. It appears to be advisable to plough directly after harvest, bare fallow in the dry season and sow or plant the rice in February on weed-free land.

Responses to fertilizers: (Data from Mwenitete '59–'60 and Kaporo '61). Responses to sulphate of ammonia have been very variable, depending on weed competition and time of application of the fertilizer. As flooding is uncontrolled, sulphate of ammonia should be applied to the seed bed and worked in, or possibly top dressed before the floods descend. A 200 lb. application of S/A can give an increase of 500–600 lb. paddy and higher dressings up to 400 lb./acre can give up to 1,000 lb. per acre increase if the rice does not lodge.

Suitable crops for the area:

Rice

NCHENACHENA SERIES

DESCRIPTION

Genetic type: Ferrisol.

Parent material: Granitic instrusions, and colluvium derived from these. Including a biotite-granite, with microcline, biotite, and quartz.

Site: Pediments, 2°–4°, 4,000–4,300 ft.

Vegetation: Moist *Brachystegia* woodland.

Occurrence. East Nyika scarp foothills, near Nchenachena and Lura. Natural areas 10a, b.

Morphology: From the subsoil downwards the colour is dark red, between hues 2.5 YR and 10 R, and the structure weak blocky or massive. It differs from most ferrisols in being sandier, with the topsoil and subsoil sandy clay loam.

In the lower horizons the texture may remain sandy clay loam or become sandy clay; the textural B horizon is weakly developed and deep. The profile is normally deep, with no weathered rock above 60 ins.

AGRONOMIC DATA

Type sites: Nchenachena station, Lura.

Potential: A soil of good potential for acid tolerant crops. There are potentials for irrigation of these soils.

Nutrient status of topsoil: Dark red brown sandy clay loams which are distinctly acid (pH below 6.0). Total nitrogen is borderline to low (.12 per cent. or less) as is available phosphate (12–36 p.p.m. recorded). Potash would appear to be adequate.

Agricultural characteristics: The profile is deep but massive, and so may suffer waterlogging in heavy rain where the topography is level or only gently sloping. Usually slopes are steep and soil conservation measures essential. Well cultivated local maize without fertilizer should yield 7–8 bags per acre, groundnuts about 700 lb. per acre.

Responses to fertilizers: (Data from Nchenachena '57–'60). Responses to fertilizers have been variable, but where the soil is not too acid, and the soil has been cultivated for a number of years sulphate of ammonia has given increases of 4 bags and 1 bag per acre maize for successive increments of 100 lb. per acre S/A up to a limit of 200 lb. per acre. In other experiments however there has been no marked response. A 200 lb./acre dressing of single superphosphate has given an increase of 4 bags per acre maize. F.Y.M. has not been tested.

On coffee, there would appear to be an increase in *yield per tree* from nitrogen and farmyard manure but not from phosphate. Farmyard manure has apparently encouraged the incidence of the prevailing dieback, so that *yield per acre* is only markedly increased by nitrogen.

Suitable crops for the area:

Maize

Groundnuts

Coffee

Fruit trees

Grass

NKAMANGA SERIES

DESCRIPTION

Genetic type: Strongly ferallitic sandy latosol.

Parent material: Basement Complex rocks and granitic intrusions. Including a muscovite-biotite-granite, with quartz, microperthite, plagioclase, muscovite, and biotite.

Site: Level to very gently sloping plain, and gently-sloping pediments; 3,400–4,000 ft. In association with the Rumpi series, and commonly in catena above the Kapemba series.

Vegetation: *Brachystegia-Julbernardia* woodland, *Acacia-Combretum* thicket of plateaux, and *Combretum ghazalense-Acacia* savanna of lower valley sides.

Occurrence: Extensively developed west, north-west, and north-east of Rumpi including on the Nkamanga Plain. Natural areas 11a, 12b, c.

Morphology: The topsoil is sandy loam or loamy sand; there is a moderately developed, shallow textural B horizon, not heavier than sandy clay loam. The subsoil is massive, with ped cutans completely absent. The colour does not become redder than the 5 YR hue at any depth.

Despite a low organic matter content the topsoil contrasts markedly in colour with the subsoil, being very dark grey to very dark brown (10 YR); there is a clear boundary between this and the subsoil, which is yellowish red or reddish brown (5 YR). In depth a very weak blocky structure may just be distinguishable. The mineral reserve is very low in all horizons. The profile is moderately to strongly acid, tending to increase in acidity with depth. This series may occur with imperfect site drainage.

AGRONOMIC DATA

Type sites: Pit on the track from the main road to Kapemba village.

Potential: A soil of moderate potential for arable cultivation, probably better used for livestock production. Very sparsely cultivated.

Nutrient status of topsoil: A very dark grey to very dark brown (colour range when moist 10 YR 2/2–10 YR 3/1.5) sandy loam changing abruptly to a reddish or yellowish brown sandy clay loam subsoil. The soil is moderately acid, has a moderate to low total nitrogen (.01 or less), a moderate to low available phosphate (15 p.p.m. or less) and an adequate supply of potash. Sulphur deficiency may occur. The mineral reserve in all horizons is low as is the base exchange capacity.

Agricultural characteristics: This soil appears to have little power to give sustained high yields and when it is cropped it should be returned to rest after 2 or 3 years arable. Unfertilized maize yields are of the order 6 or 7 bags per acre maize, though groundnut yields can be high, over 1,000 lb. per acre. It is probably best used for a short arable long ley system.

Responses to fertilizers: (Bolero '54 and Katowo '54). Moderate responses only have been obtained from sulphate of ammonia on maize—of the order of 2–3 bags maize for a 100 lb./acre dressing. Finger millet yields can be doubled by the same dressing. Groundnuts show little response to phosphate, but a 50 lb./acre application of gypsum has given an increase of some 400 lb. of shelled groundnuts.

Suitable crops for the area:

Turkish tobacco

Maize

Grass

NKATA BAY SERIES

DESCRIPTION

Genetic type: Ferrisol.

Parent material: Basement Complex rocks.

Site: Dissected country, gentle and moderate slopes, 1,800–2,200 ft.

Vegetation: Semi-evergreen forest and moist *Brachystegia* woodland.

Occurrence: Extensive areas of dissected country south and west of Nkata Bay. Natural areas 20c, 21a, b.

Morphology: A ferrisol characterized by the occurrence of 1–10 per cent. gravel or stones in the lower horizons. The subsoil and lower subsoil are red or dark red (2.5 YR) sandy clay or clay.

Stone lines frequently occur in this series; these consist of horizons, normally with sharp upper and lower boundaries, with a much higher proportion of stones than in the adjoining horizons. In this series they are typically 4 ins. thick, and frequently occur at a depth of 18 to 30 ins.; they consist of between 25 and 90 per cent. quartz stones, mainly 1–2 ins. in diameter. The series is of moderate depth, weathered rock commencing at between 24 and 48 ins. Within this rock, however, weathering extends to considerable depths.

The Nkata Bay series is frequently found in association with lithosols. In steeply dissected areas a catena may occur consisting of lithosols on ridges and the upper parts of slopes, passing downslope into the Nkata Bay series. This was previously described as the *Mweza Catena* (*Ann. Rep. Dept. Nyas.* Pt. II, 1958/9, p. 148).

AGRONOMIC DATA

Type sites: Near Timbiri track in steeply undulating country.

Potential: A soil of moderate to low potential where slopes are gentle enough to make soil conservation measures reliable. Scattered cultivation.

Nutrient status of topsoil: Dark red brown sandy clay loam (colour range moist 5 YR 4/6 to 7.5 YR 5/4) of moderate acidity. Total nitrogen is moderate to adequate (.10 per cent. and above). Available phosphate is inclined to be low (10 p.p.m. or less). Potash status is perfectly adequate. Base exchange capacity is fair as is base saturation percentage.

Agronomic characteristics: The depth of profile is very variable ranging from 2 to 4 ft. in depth. Root room is further restricted by the presence of stone lines of quartz stones some 4 inches thick. Commonly found between lithosols on the ridges and the dambo soils of the river valleys with patches of Chinyakula or Chombe series on their lower margins. Unfertilized maize yields are only about 5 bags per acre and fertilizer does not increase yield much. These soils are best left to afforestation or grass, being too shallow for coffee and arable crops.

Responses to fertilizers: (Data from Luwazi '55). No significant response to either nitrogen or phosphate.

Suitable crops for the area:

Maize (subsistence)

Cassava (subsistence)

Grass

Afforestation

NYIKA SERIES

DESCRIPTION

Genetic type Humic ferallitic latosol, strongly ferallitic.

Parent material: Principally biotite-granites, including in varying proportions quartz, plagioclase, microcline, muscovite, and biotite; also recorded in a gneiss, with quartz, microcline, plagioclase, cordierite, and biotite.

Site: Dissected high-altitude plateau, gentle and moderate slopes, 7,500–8,000 ft.

Vegetation: Montane grassland.

Occurrence: Nyika Plateau. Natural areas 8a–d.

Morphology: In the upper 2–4 ins. there is a dense mat of grass roots, associated with a dark brown topsoil having a high organic matter content (5–10 per cent.) and a strong crumb structure. The subsoil is a yellowish red (5 YR) sandy clay loam, sandy clay or clay, and has massive structure. This series has the lowest base saturation figures of any in northern Nyasaland, 5–15 per cent. in the lower horizons. Weathered rock commences at between 18 and 36 ins., passing rapidly into fresh rock.

Deep phase: A deep phase is distinguished where weathered rock commences at depths exceeding 36 ins. The colour becomes red in depth, with a deep textural B horizon of clay.

Catenary associates: Profiles with impeded drainage are fairly extensive in the area occupied by this series. Besides occurring on lower valley sides, they are found in valley-head areas and in shallow depressions which occur on many slopes. The subsoil colour is less red, becoming strong brown or dark yellowish brown, with a mottle in depth. Texture is clay from the lower subsoil downwards.

The dambo soils in the valley floors remain water-logged for all or the greater part of the year.

AGRONOMIC DATA

Type sites: Top of Nyika Plateau generally. These are shallow soils, usually between 18 and 30 ins. in depth but occasionally more, which are very acid and low in phosphate (15 p.p.m. or less) though nitrogen and potash appear adequate. These soils hold a rather doubtful potential for extensive grazing or afforestation on the deeper phases. Success at utilization has not been conspicuous however as the altitude and climatic conditions are not favourable.

RUKURU SERIES

DESCRIPTION

Genetic type: Alluvial calcimorphic soil, with impeded site drainage.

Parent material: Alluvium.

Site: Low river terraces, almost level; 3,400–3,600 ft.

Vegetation: *Acacia* cultivation savanna of valley floors.

Occurrence: Lower Kasitu and Lower South Rukuru Valley floors. Natural area 12a, possibly also 2f, 3i, 4g.

Morphology: Due to imperfect or impeded site drainage, with seasonal flooding, greyish brown colours predominate. The topsoil and the subsoil are from very dark brown to black; mottling occurs in the subsoil, lower subsoil, or in depth. Depositional bedding is present; the sandy horizons are massive, whilst the clay horizons have a strong coarse blocky structure with strongly developed ped cutans. The series is characterized by a high base saturation, 70–90 per cent., and a very high nutrient status.

The texture is very variable, but normally at least one clay horizon is present; a horizon of almost pure coarse sand has been recorded in depth. The series is moderately acid, normally with pH values of 5.5–6.0

AGRONOMIC DATA

Type sites: Level valley floors with *nsangu* (*Acacia albida*) trees growing.

Potential: A soil of very high potential, at present cultivated year after year to maize and beans.

Nutrient status of topsoil: Very dark brown to black clays or clay loams (colour range moist 10 YR 2/2–10 YR 3/2) on which acidity should be no problem. Total nitrogen is moderate (*circa* .16 per cent.), available phosphate is usually adequate and potash is high.

Agricultural characteristics: Profiles are deep with strata of varying texture down the profile. Nutrient status should offer no problems, yield being controlled rather by the amount of water that has to be contended with. Layers of coarse sand or sandy loam at about 3 ft. may help drainage. Unfertilized yields of well cultivated maize have been variable, depending on the wetness of the season and the site but yields of over 15 bags/acre maize and 1,000 lb. per acre groundnuts or finger millet are not uncommon. These soils with proper management could certainly sustain high yields under continuous cropping, provided flood damage were avoided.

Responses to fertilizers: (Data Katowo '58 and '59, Bolero '58, Ng'onga '58). In spite of the comparatively high level of soil nitrogen, the potential is so good that marked responses to nitrogen are obtained, though there is no response by maize to other fertilizers. Sulphate of ammonia may be expected to give increases of 4 bags and 2 bags per acre maize for successive increments of 100 lb. per acre S/A up to a limit of 200 lb. per acre.

Suitable crops for the area:

Maize
Groundnuts ?
Finger millet
Soya beans
Beans

RUMPI SERIES

DESCRIPTION

Genetic type: Moderately to strongly ferallitic sandy latosol.

Parent material: Basement Complex rocks and granitic intrusions.

Site: Principally on pediments, 2°–5°; also found on very gently sloping surface, 1°; 3,400–4,000 ft.

Vegetation: *Brachystegia-Julbernardia* woodland and *Acacia-Combretum* thicket of plateaux; *Reissantia indica* common.

Occurrence: Lower valley sides north-west and north-east of Rumpi, including Rumpi township area. Natural areas 11a, 12b, c. In association with Nkamanga series, and commonly in catena above the Kapemba series.

Morphology: The topsoil is a loamy sand or sandy loam. Below this there is a rapid increase in clay with depth, passing through an intermediate sandy clay loam horizon to a strongly developed, moderately shallow textural B horizon of sandy clay or clay. The subsoil is massive or with very weak fine blocky structure. In depth the colour reaches or nearly reaches the 2.5 YR hue.

The lower subsoil has a very weak or weak fine blocky structure, with ped cutans no more than weakly developed. The mineral reserve is low. Slight profile drainage impedance may occur, due to the downward increase in clay. The clay is moderately to strongly acid; in one profile the acidity increased progressively downwards, from pH 5.8 in the topsoil to 4.2 at 36 ins.

AGRONOMIC DATA

Type sites: Ng'onga, and S.A.I. two miles north-west of Rumpi.

Potential: A soil of fair potential for arable crops, quite widely cultivated.

Nutrient status of topsoil: Dark brown sandy loams or loamy sands (colour range moist 7.5 YR 3/2) of moderate acidity. Total nitrogen status is low (.07 per cent. or less) and available phosphate is low (20 p.p.m. or less), though supplies of potash appear to be adequate. These soils may suffer sulphur deficiency. The mineral reserve is low as is the base exchange capacity.

Agronomic characteristics: The profile is moderately deep (about 4 ft.) and drainage is adequately good. The soil is only moderately easy to work and may get very hard when dry. Nutrient reserves are low and this soil should not be expected to sustain arable cultivation for more than three or four years without fertilizer. Unfertilized yields on record vary vastly, but 10 bags per acre maize may be expected with good rotation, together with 1,000 lb. per acre unthreshed heads of finger millet, 800–1,000 lb. per acre groundnuts, and 600–800 lb. per acre soya seed.

Responses to fertilizers: (Luvire '59 and '60, Pharasitiwe '60, Ng'onga '59). Replicated experiments available have given remarkably high control yields with little response to nitrogen. However one would expect a response of up to 3 bags per acre maize from a 100 lb. per acre dressing of S/A—but no more. Phosphate is short and a 200 lb. per acre dressing of superphosphate may give an increase of about 5 bags per acre maize. Groundnuts following maize will respond to the residual effects of such dressings of phosphate. Gypsum may also be expected to increase groundnut yields. Finger millet yields can be increased by the application of sulphate of ammonia and superphosphates at 100 lb. per acre each.

Suitable crops for the area:

Turkish tobacco
Maize
Groundnuts
Soya beans
Grass

UZUMARA SERIES

DESCRIPTION

Genetic type: Ferrisol, tending towards humic ferallitic latosol.

Parent material: Basement Complex rocks. Including: 1. Biotite-quartzofeldspathic-gneiss, with quartz, microcline, plagioclase, and biotite; 2. Hornblende-gneiss, with oligoclase and hornblende.

Site: Moderate slopes, 4,600–5,800 ft.

Vegetation: Montane grassland and moist *Brachystegia* woodland.

Occurrence: North Vipya plateau and hills, natural areas 10b, c, 13a, c.

Morphology: From the subsoil downwards the colour is between the 2.5 YR and 10 R hues, and the texture clay or sandy clay. The textural B horizon may be absent or weakly developed and deep. The lower horizons have a weak or moderate fine or medium blocky structure. The profile is very strongly acid.

The topsoil is dark reddish brown. A small proportion of gravel, approximately one per cent., is characteristically present in all horizons. By definition no weathered rock occurs above 48 ins.

Shallow Phase: This phase is probably more extensive than the soil described above; in it, weathered rock commences at between 18 ins. and 48 ins. depth. Shallower profiles than this are classed as lithosols. A common catenary association is lithosols on ridge crests, Uzumara series, shallow phase on convex slopes, and the normal Uzumara series on lower valley sides.

On certain areas between 6,000 and 6,500 ft., including Uzumara hill, the series passes into a humic ferallitic soil. This has a deep, dark brown topsoil with high organic matter content, overlying a reddish brown (5 YR 4/4) almost structureless subsoil.

AGRONOMIC DATA

Type sites: The coffee gardens of the A.I. at Mphompha and of J. Mzumara, Mzumara Village.

Potential: A soil of moderate potential for acid tolerant perennial crops.

Nutrient status of topsoil: Dark reddish brown clay (colour range moist 10 YR 2/2), moderately acid (pH 5.7) with all nutrients at a low level, especially phosphate. The profile is only of moderate depth (4 ft. or more).

Responses to fertilizers: No data.

Suitable crops for the area: Perennial tree crops, e.g. coffee.

N.B. The shallower phases where the profile is less than 4 feet should not be used for coffee, but for afforestation.

VIPYA SERIES

DESCRIPTION

Genetic type: Humic ferallitic latosol, tending towards ferrisol.

Parent material: Basement Complex rocks.

Site: Plateau, dissected in most parts, gentle and moderate slopes, 5,000–5,800 ft.

Vegetation: Montane grassland *Erythrina tomentosa* common.

Occurrence: High Vipya Plateau. Natural areas 19a, b.

Morphology: The topsoil has abundant grass roots, giving rise to a strong crumb structure. The subsoil is dark reddish brown, and is weakly or very weakly structured. The clay content shows a continuous increase downwards in the profile, with the textural B horizon deep and fairly weakly developed. The lower subsoil is a sandy clay, in the 2.5 YR hue or slightly redder.

There is a moderate to high (4–10 per cent.) organic matter content in the topsoil; this is black or dark brown in colour, with a sandy clay loam texture. Fine sand predominates over coarse in all horizons. In the lower subsoil or in depth the structure reaches the moderate grade, with ped cutans present. The profile is moderately or strongly acid, pH 4.5–5.5.

Shallow phase: A shallow phase is distinguished where weathered rock commences at between 18 and 36 ins.

AGRONOMIC DATA

Type sites: Champoyo and Luwawa.

Potential: Soils of moderate potential for a specialized type of agriculture, but excellent for reafforestation.

Nutrient status of topsoil: Black or dark red-brown sandy clay loam (colour range moist 10 YR 2/1.5 to 5 YR 3/3) of moderate acidity (pH 5.5 to 6.0). Total nitrogen level is moderate to high (.175 or over), available phosphate is low (20 p.p.m or less) and potash is high. Nutrient reserves appear to be fair and organic matter is high.

Agricultural characteristics: The profile is deep and fairly well drained. The topsoil, abounding in grass roots, has a good crumb structure and is fairly easily worked. Maize is out of its element and is not expected to yield more than 6 bags per acre unfertilized. Potatoes have given yields of 3 to 5 tons per acre and temperate cereals have given yields ranging as follows:

Wheat, 600–800 lb. per acre

Rye, 200–600 lb. per acre

Oats, 1,000–1,400 lb. per acre

Barley 800–1,000 lb. per acre.

Sheep have thrived on planted pastures.

Responses to fertilizers: (Data from North Vipya and South Vipya '51–'53 and Luwafwa '55). On these soils farmyard manure and phosphate have increased yields. Farmyard manure has given increases of 1 to 2 tons per acre of potatoes. 200 lb. per acre sulphate of ammonia has increased yields of barley and oats by a bag per acre and maize by 2 bags per acre but this does not always occur. 200 lb. per acre superphosphate will almost certainly increase yields of barley, oats, wheat, maize, and rye by a bag per acre, lime had if anything a deleterious effect in the year of application. There were no residual responses.

Suitable crops for the area:

Potatoes

Maize (subsistence)

Barley and oats (feeding)

Grass

WENYA SERIES

DESCRIPTION

Genetic type: Strongly ferallitic sandy latosol.

Parent material: Basement Complex rocks.

Site: Gentle slopes, 4,500–5,000 ft.

Vegetation: *Brachystegia-Isoberlinia* and *Brachystegia-Cryptosepalum* woodland; *Combretum ghazalense* may be present.

Occurrence: South-east of Chisenga, between Wenya and Ntalire. Natural areas 7a, b.

Morphology: The topsoil is sandy loam or loamy sand. Downwards the texture becomes sandy clay or sandy clay loam, characteristically with a small or moderate gravel content (1–6 per cent.). The colour is reddish brown, brown, or dark brown, becoming no redder than the 5 YR hue in any horizon, and the texture remains massive throughout.

The lower horizons become very hard when dry. The profile is of moderate depth, and in one case a stone line at 30–39 ins. was observed. The mineral reserve is very low. This series may occur with imperfect site drainage.

AGRONOMIC DATA

Type sites: Gardens of H. Simwaka at Mfinda Village or D. Muwowo at Mwenje Village, north of Nthalire.

Potential: A soil of low to moderate potential for annual arable crops, very similar to Fort Hill series.

Nutrient status of topsoil: Very dark grey gravelly sandy loam (colour range moist about 2.5 Y 5/2) which is inclined to be acid. Total nitrogen is low (less than .10 per cent.), available phosphate is borderline (20 p.p.m. or less) and potash just adequate.

Agronomic characteristics: This soil type is a rather shallower and stonier version of the Fort Hill series, and until more experimental work is done, Wenya and Fort Hill series should be treated alike from a farming angle.

Suitable crops for the area:

Finger millet
Groundnuts
Maize
Grass

DAMBO CLAYS

DESCRIPTION

Genetic type: Hydromorphic soil.

Parent material: Alluvial clays.

Site: Level valley-floor areas.

Vegetation: Marsh grassland.

Occurrence: Most valley floors in all areas; particularly along the Upper South Rukuru, including near Lake Kazuni. Extensively developed in the Vwaza Marsh, areas in the south-west of the Upper South Rukuru Valley, and the Limpasa Dambo. Natural areas 11d, 15d, 16f, 21g.

Morphology: No systematic observations of these soils have been made, consequently they have not been defined as a series. They have poor site and profile drainage, and the texture is clay throughout, with the possible exception of the topsoil. All horizons are either mottled or are black to dark grey. There is a strong coarse blocky structure, with strongly developed clay skins. Iron concretions, either soft or hard, commonly occur in depth.

Marsh soils, remaining continuously waterlogged, occur in the Vwaza Marsh, Lake Kazuni, and the Chiwondo and Mlali Lagoons ; no observations of these have been made.

AGRONOMIC DATA

The proper dambo clays will be for a great part of the season water-logged and have a potential for rice cultivation if flooding is even and intense, and for dry season grazing where the waters recede.

One or two experiments on dambo margin soils have been recorded, grey or black clay loams, rather acid but otherwise apparently of good nutrient status. These sites (Lazaro Jere '59 and '60 and Zombwe '57) produced unfertilized yields of maize of some 6 to 10 bags per acre maize and 1,100 lb. per acre of finger millet. Sulphate of ammonia has nevertheless given increases of 3 bags and 1½ bags per acre maize to successive increments of 100 lb. per acre S/A up to a maximum of 200 lb. per acre. The response of finger millet to 200 lb./acre S/A was to double the yield. These responses are surprising in view of the high soil analysis for total nitrogen (.20 or over). More information is certainly needed on these soils if they are to be to any great extent cultivated.

SANDY DAMBO SOILS

DESCRIPTION

Soils with poor site drainage but with a more sandy texture than the Dambo Clays have been recorded. Mottling reaches close to the surface.

AGRONOMIC DATA

As for Dambo Clays.

ALKALINE SOILS

DESCRIPTION

Only one alkaline profile was observed during the present survey, a soil at Mpata, west of Karonga, having the profile morphology of the Lughali series; but previous observations by G. Jackson (*Ann. Rep. Dept. Agric. Nyas.* Pt. II, 1956/7, pp. 138–9, and unpublished manuscript) suggest they may occur fairly extensively amid the Mwenitete series. The division between the Mwenitete series and alkaline soils may be placed according to whether any alkaline horizon occurs above 48 ins.

AGRONOMIC DATA

Type site: Master Farmer Kishombe, Mpata, West of Karonga.

Agronomic characteristics: Soils of Lughali, Mwenitete and Karonga type may become alkaline in certain parts. The soils are similar to these series, but may be more difficult to work and will give lower yields of crops, which will not respond to the normal fertilizers. Well cultivated maize is unlikely to give more than 6–7 bags per acre grain.

LITHOSOLS

DESCRIPTION

These occur very extensively. They include all soils that are sufficiently stony, bouldery, or thin to prevent cultivation. The definition of the group is that either or both of the following characteristics are present:

1. Stones and gravel exceeding 20 per cent. in the subsoil.
2. Weathered rock commencing at a depth of less than 18 ins.

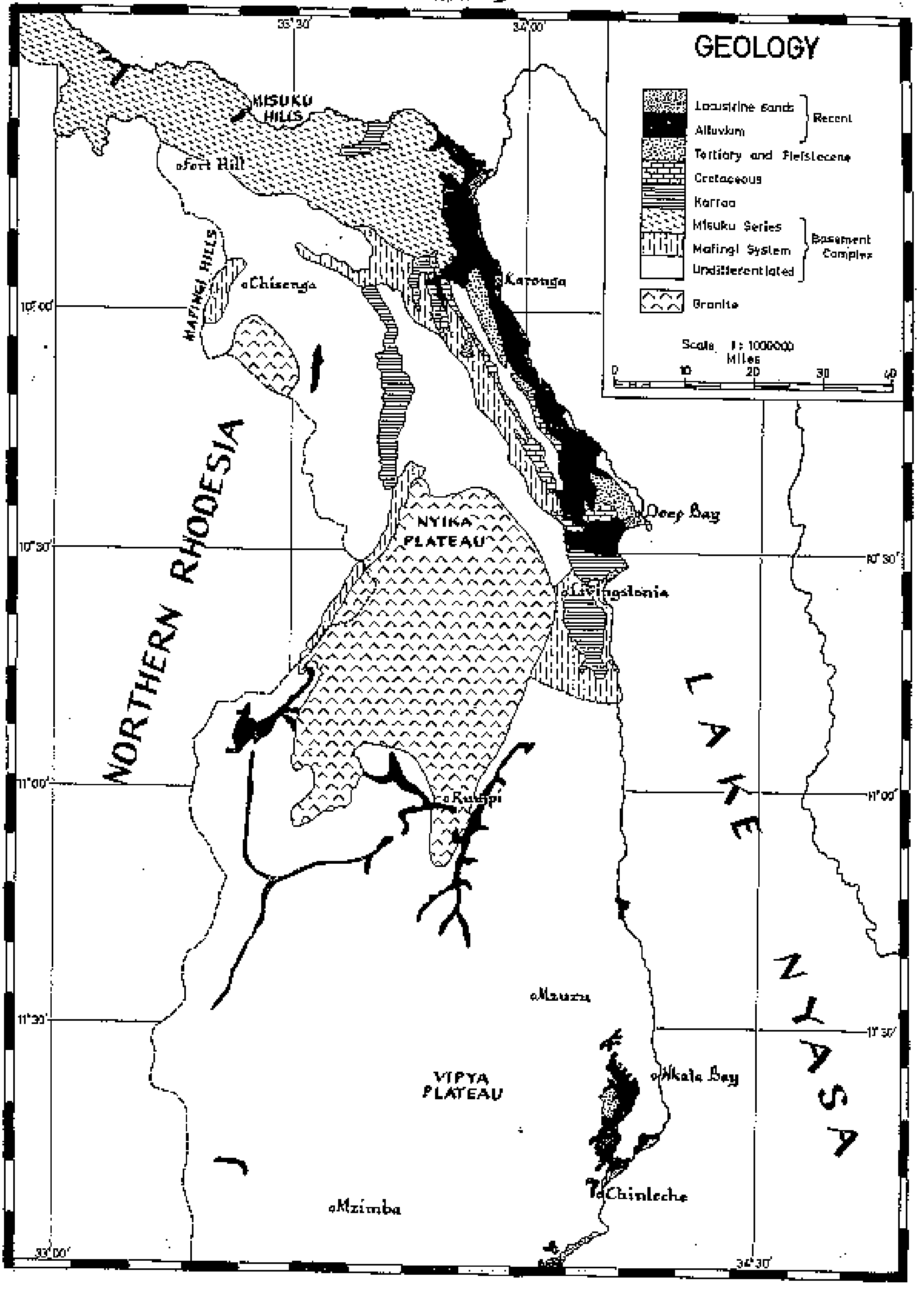
There are no accessory characteristics to this group. The fine fraction most frequently has the properties of sandy ferallitic soils, but ferruginous-type profiles are not uncommon.

The vegetation is *Brachystegia* hill woodland.

AGRONOMIC DATA

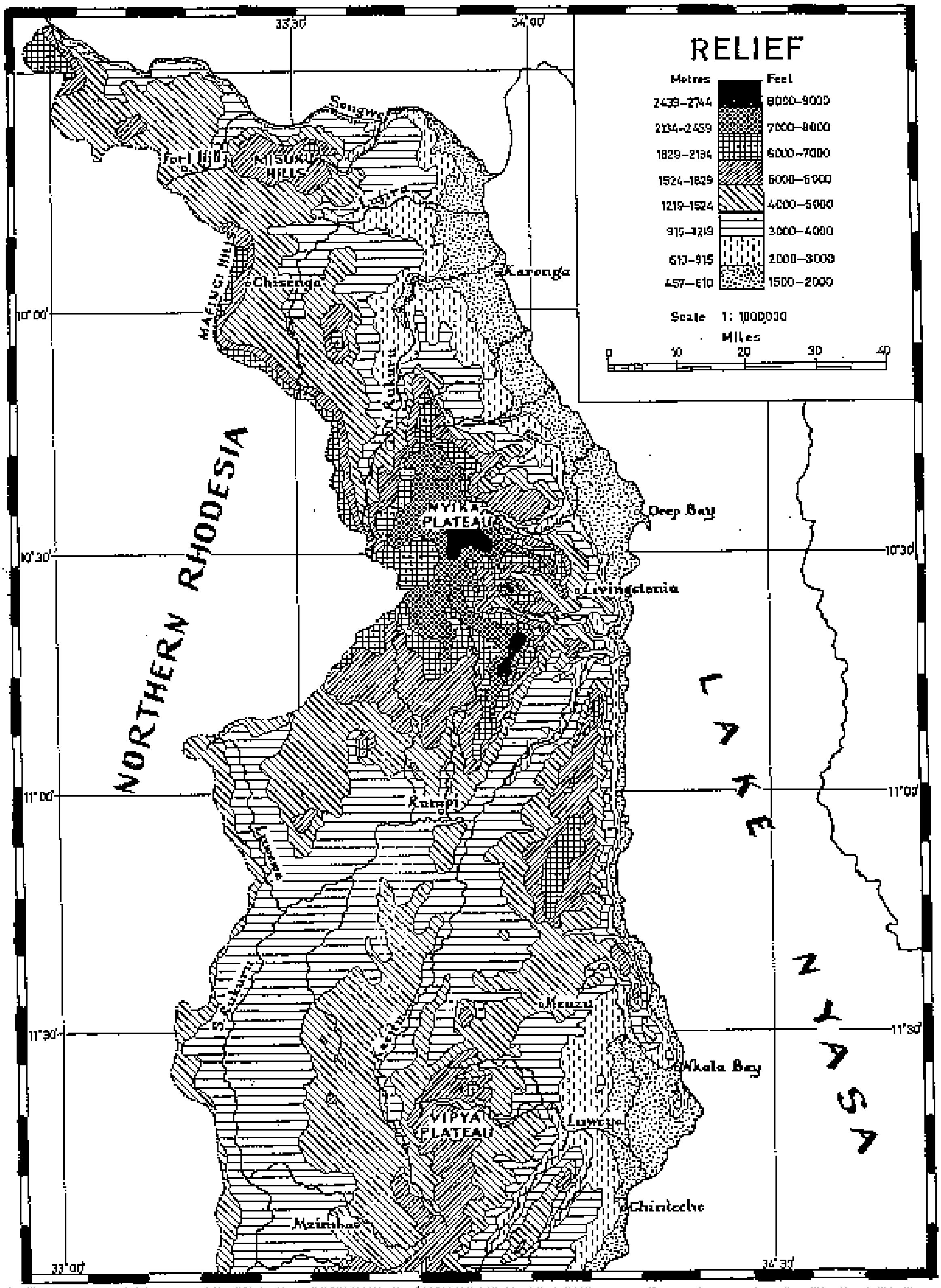
These are widespread in the foothill and escarpment areas of the Vipya, Uzumara and Nyika plateaux. They are too stony or shallow for efficient cultivation and should be used for range grazing where the gradients are gentle or indigenous forest or game reserve where the gradients are steep.

MAP I



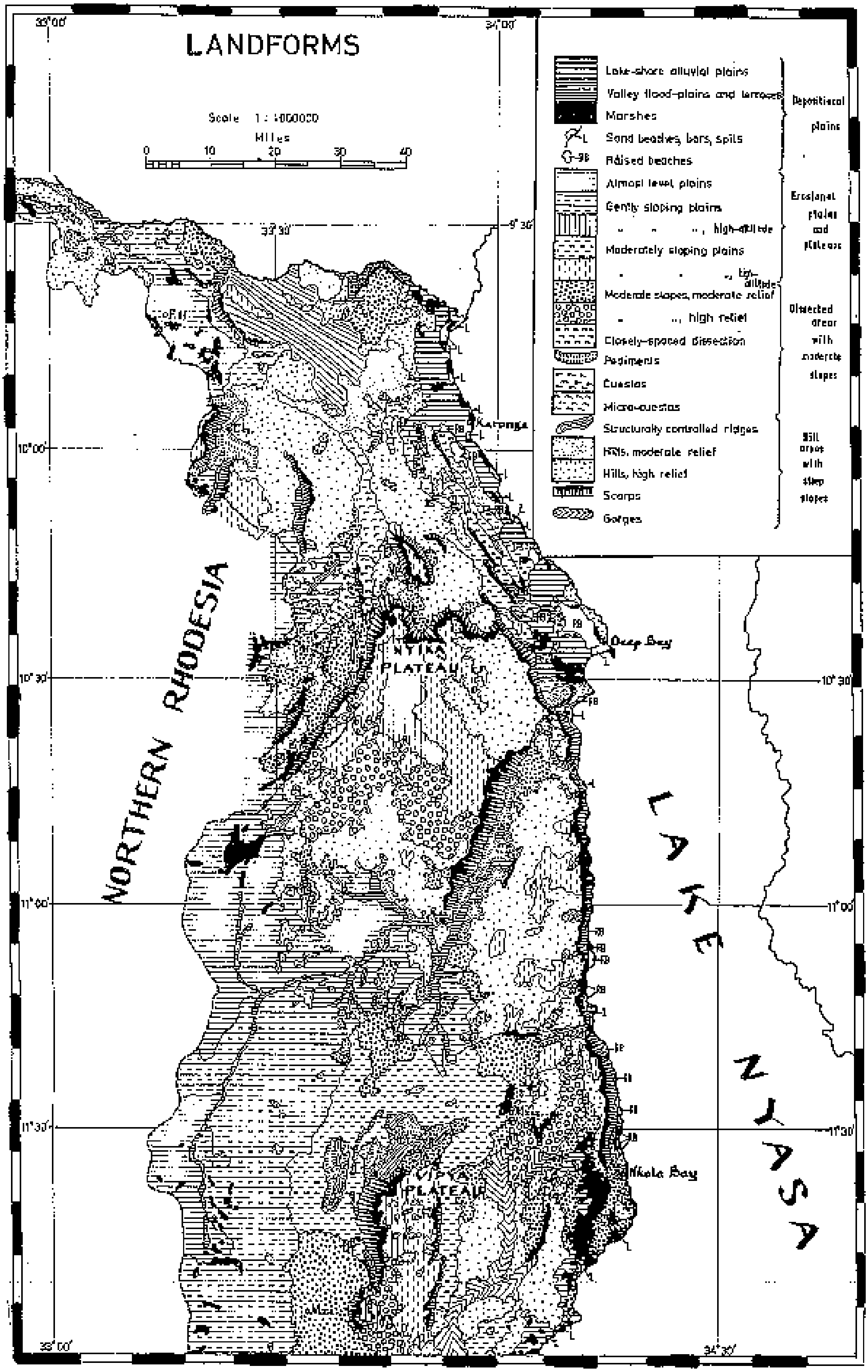
GEOLOGY
Lacustrine sands
Alluvium
Recent
Tertiary and Pleistocene
Cretaceous
Karroo
Misuku Series
Mafingi System
Undifferentiated
Basement Complex
Granite
Scale 1: 1000000
Miles
0
10
20
30
40
33°30'
34°00'
10°00'
10°30'
11°00'
11°30'
33°00'
34°30'
MISUKU HILLS
Fort Hill
MAFINGI HILLS
Chisenga
Karonga
NORTHERN RHODESIA
NYIKA PLATEAU
Deep Bay
Livingstonia
LAKE NYASA
Rumpi
Mzuzu
VIPYA PLATEAU
Nkata Bay
Chinteche
Mzimba

MAP II

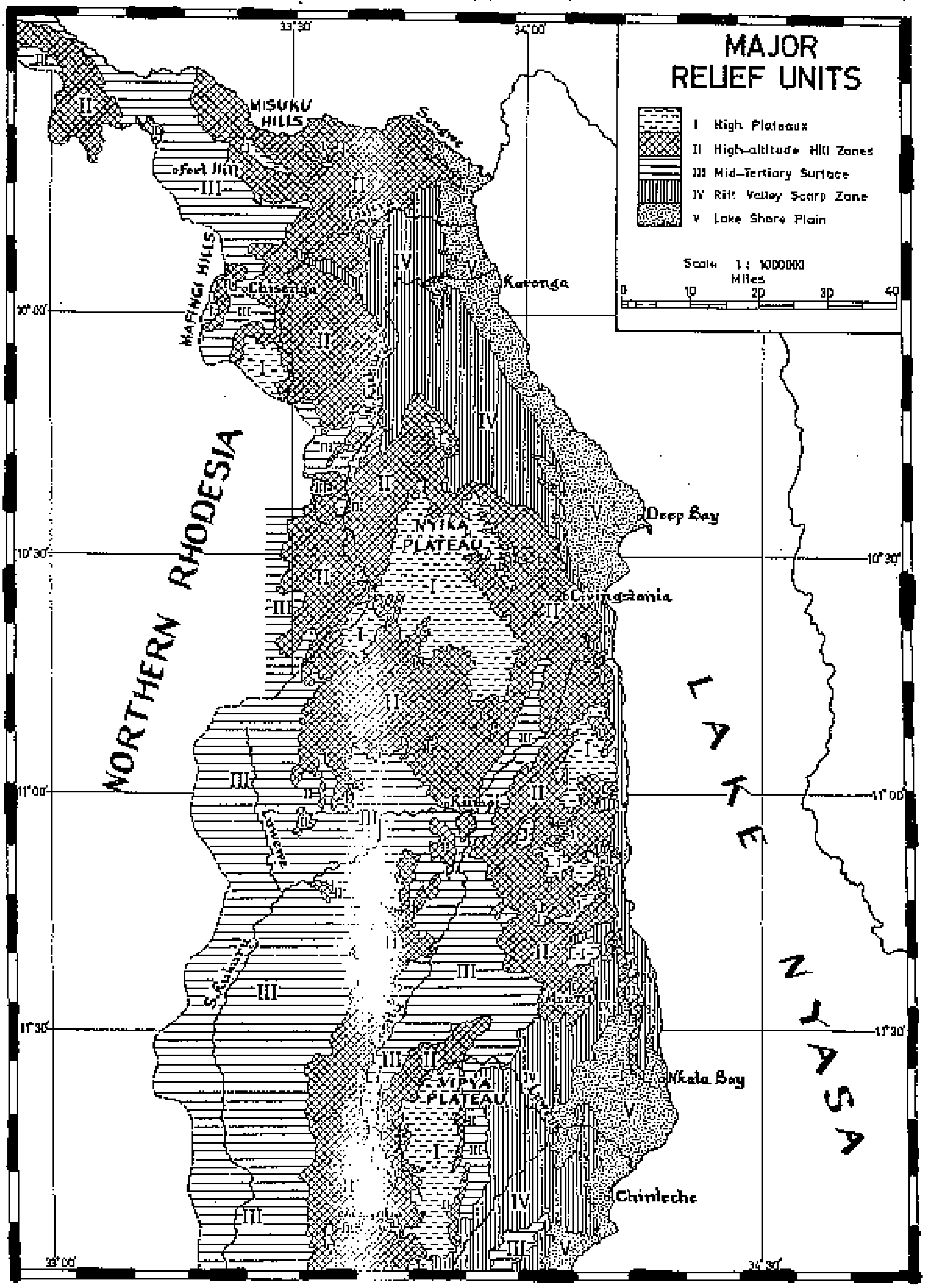


RELIEF
Metres
Feet
2439–2744
8000–9000
2134–2439
7000–8000
1829–2134
6000–7000
1524–1829
5000–6000
1219–1524
4000–5000
915–1219
3000–4000
610–915
2000–3000
457–610
1500–2000
Scale 1: 1000000
Miles
0
10
20
30
40
NORTHERN RHODESIA
LAKE NYASA
NYIKA PLATEAU
VIPYA PLATEAU
MISUKU HILLS
MAFINGI HILLS
Fort Hill
Chisenga
Karonga
Deep Bay
Livingstonia
Rumpi
Mzuzu
Nkata Bay
Luweya
Chintechi
Mzimba
Songwe
33°30'
34°00'
10°00'
10°30'
11°00'
11°30'
33°00'
34°30'

MAP III

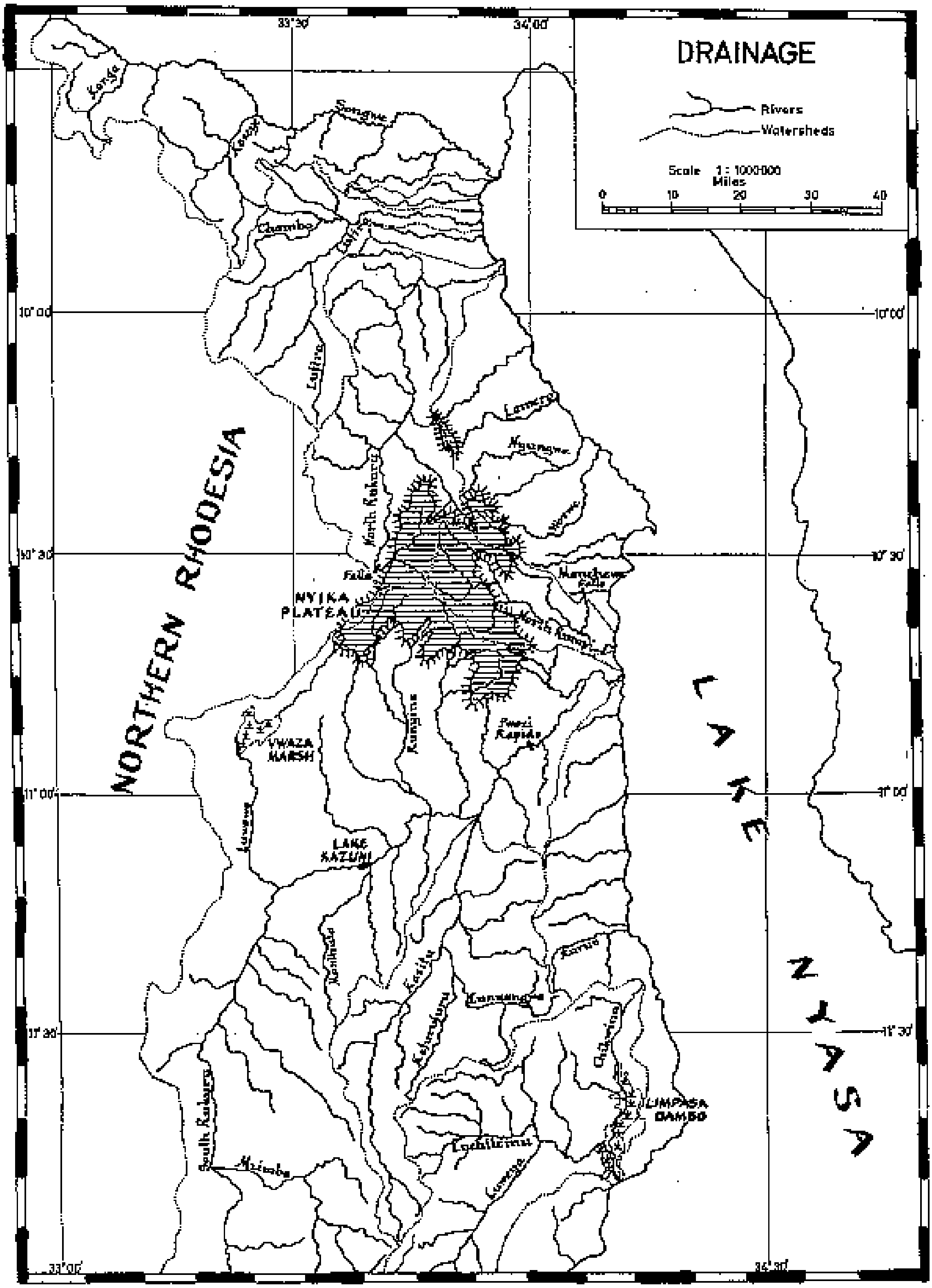

LANDFORMS
Scale 1 : 1000000
Miles
0
10
20
30
40
Lake-shore alluvial plains
Valley flood-plains and terraces
Marshes
Sand beaches, bars, spits
Raised beaches
Almost level plains
Gently sloping plains
" " ", high-altitude
Moderately sloping plains
" " ", high-altitude
Moderate slopes, moderate relief
" ", high relief
Closely-spaced dissection
Pediments
Cuestas
Micro-cuestas
Structurally controlled ridges
Hills, moderate relief
Hills, high relief
Scarps
Gorges
Depositional plains
Erosional plains and plateaus
Dissected areas with moderate slopes
Hill areas with steep slopes
33°00'
34°00'
33°30'
9°30'
10°00'
10°30'
11°00'
11°30'
34°30'
Karonga
Deep Bay
Nkata Bay
NYIKA PLATEAU
PLATEAU
NORTHERN RHODESIA
LAKE NYASA

MAP IV

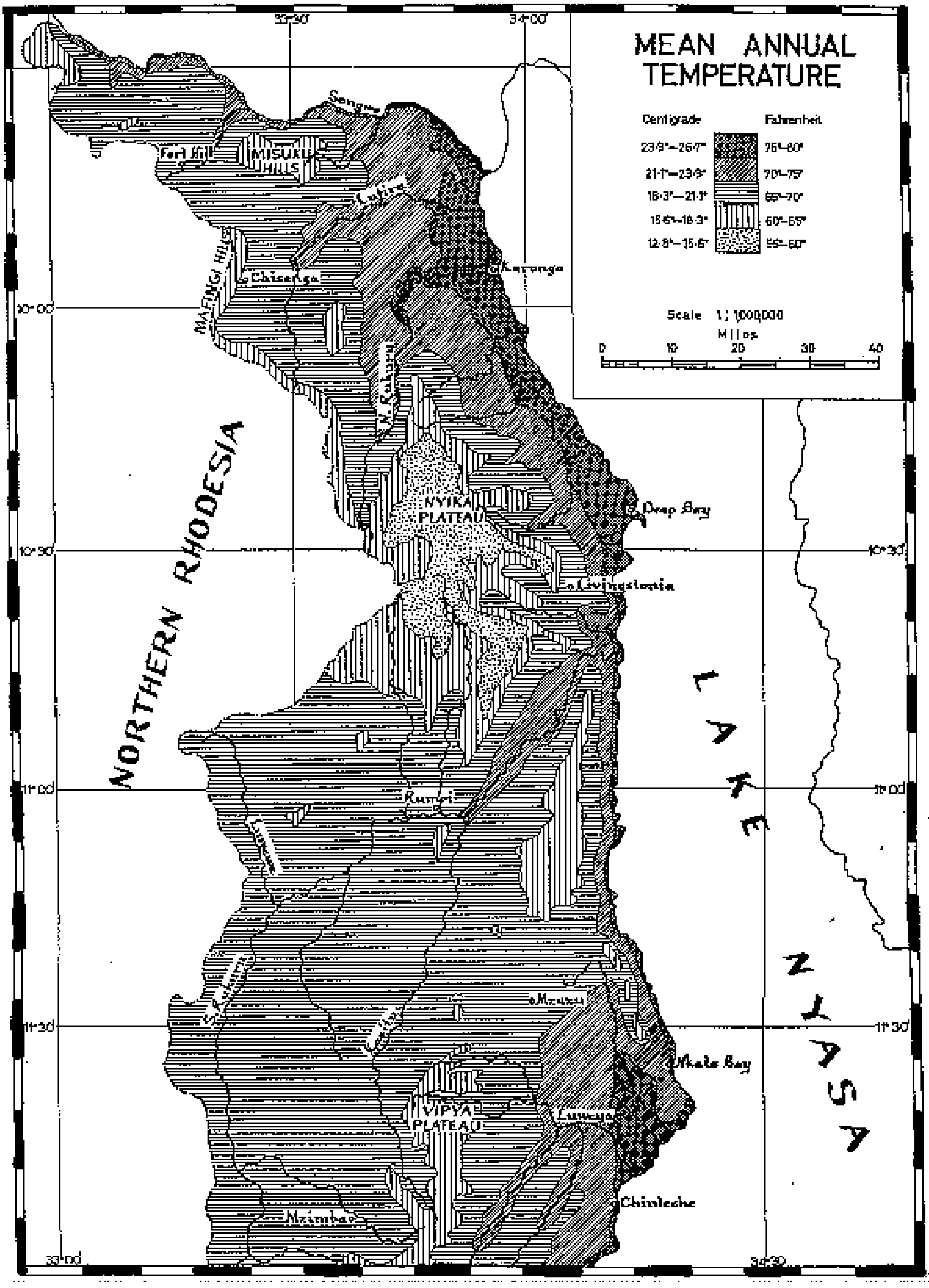


MAJOR RELIEF UNITS
I High Plateaux
II High-altitude Hill Zones
III Mid-Tertiary Surface
IV Rift Valley Scarp Zone
V Lake Shore Plain
Scale 1: 1000000
Miles
0 10 20 30 40
33°30'
34°00'
10°00'
10°30'
11°00'
11°30'
33°00'
34°30'
MISUKU HILLS
Fort Hill
MAFINGI HILLS
Chisenga
Karonga
Deep Bay
NYIKA PLATEAU
Livingstonia
NORTHERN RHODESIA
LAKE NYASA
VIPYA PLATEAU
Nkata Bay
Chinteche

MAP V

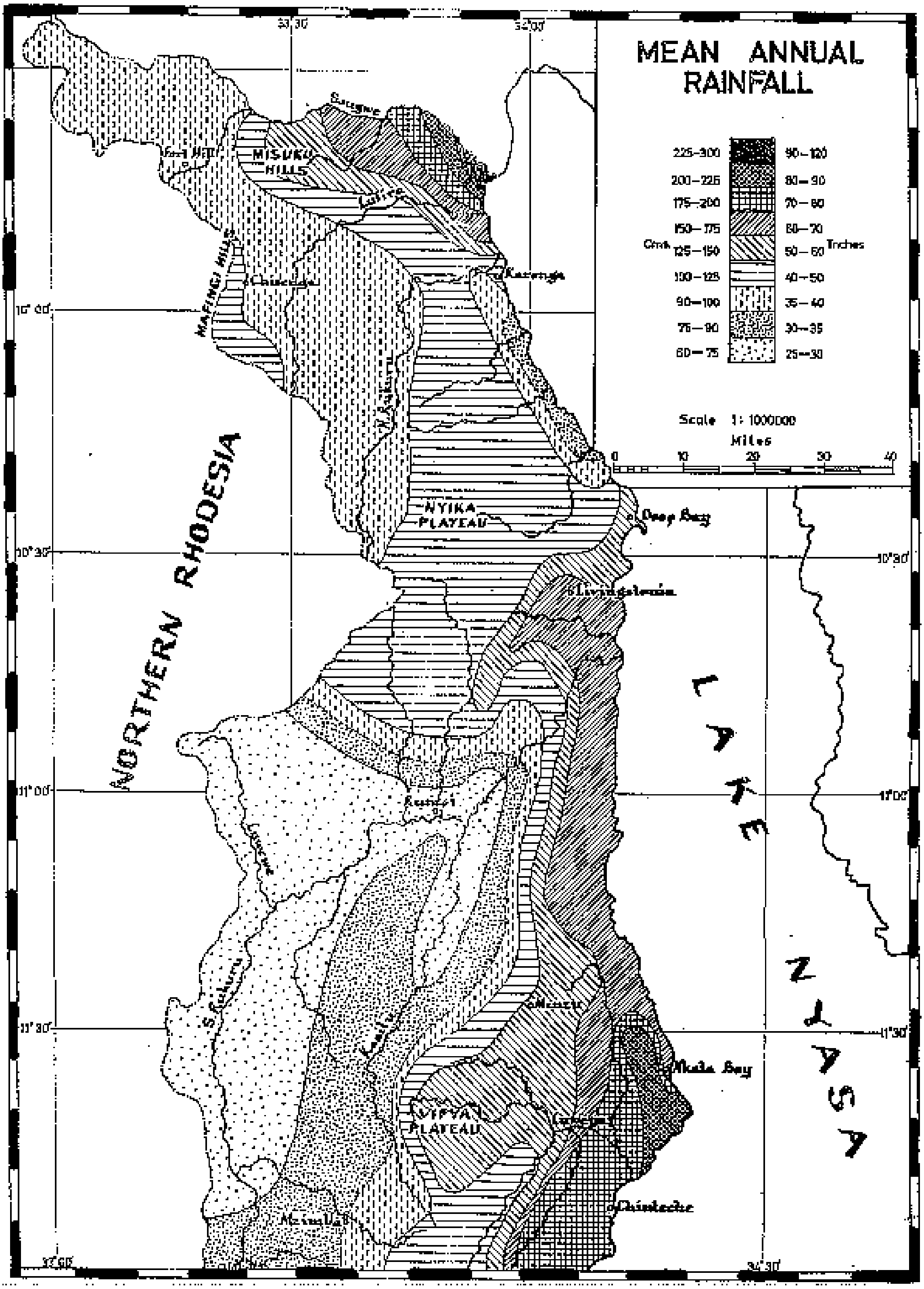

DRAINAGE
Rivers
Watersheds
Scale 1 : 1000000
Miles
0
10
20
30
40
33°30'
34°00'
10°00'
10°30'
11°00'
11°30'
33°00'
34°30'
NORTHERN RHODESIA
LAKE NYASA
NYIKA PLATEAU
VWAZA MARSH
LAKE KAZUNI
LIMPASA DAMBO
Songwe
Chambo
Lufira
North Rukuru
South Rukuru
Falls
Kasitu

MAP VI



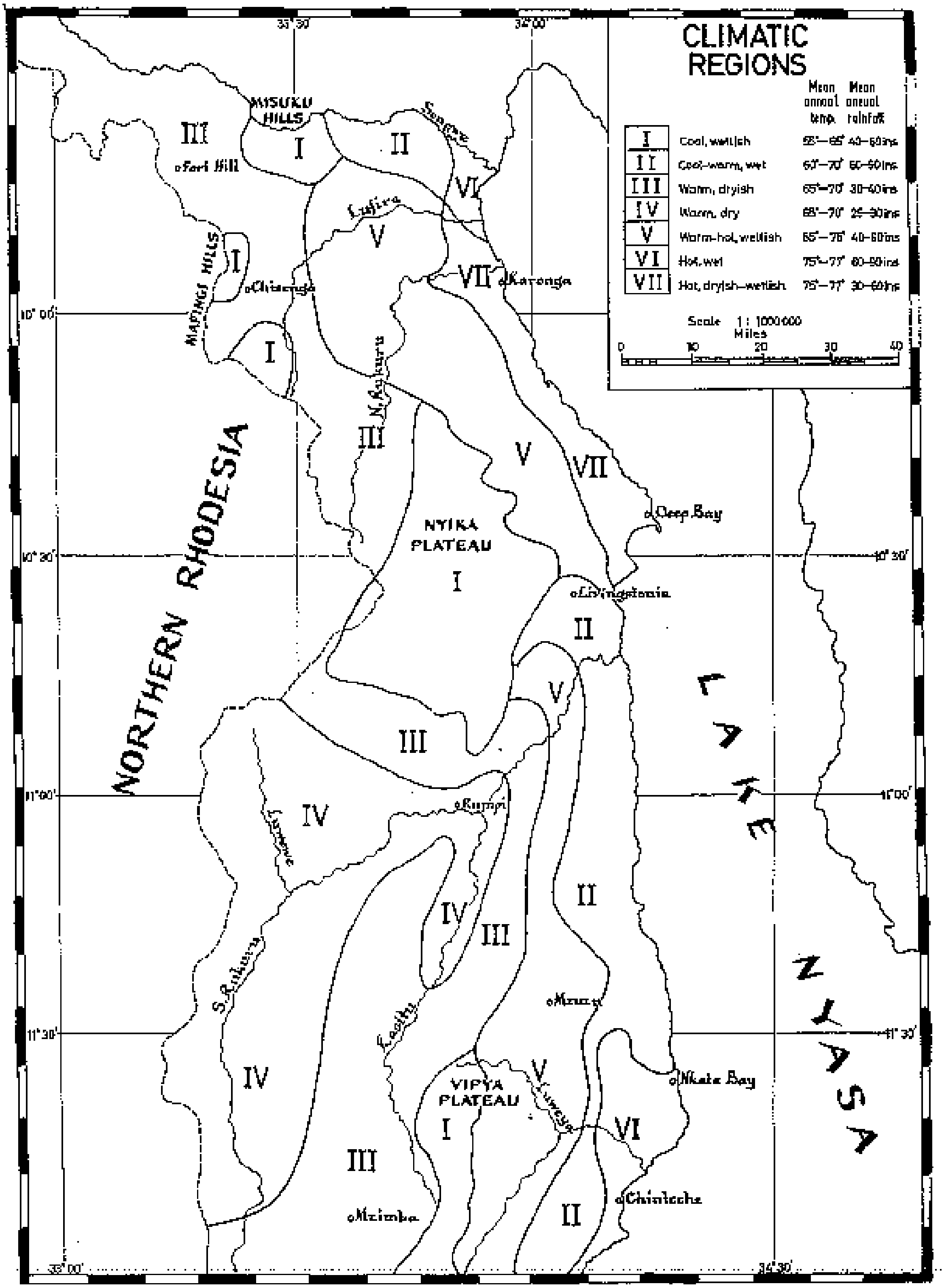
MEAN ANNUAL TEMPERATURE
Centigrade
Fahrenheit
23·9°—26·7°
76°—80°
21·1°—23·9°
70°—75°
18·3°—21·1°
65°—70°
15·6°—18·3°
60°—65°
12·8°—15·6°
55°—60°
Scale 1: 1000,000
Miles
0
10
20
30
40
33°30'
34°00'
10°00'
10°30'
11°00'
11°30'
33°00'
34°30'
NORTHERN RHODESIA
LAKE NYASA
Fort Hill
MISUKU HILLS
Songwe
Lufira
MAFINGI HILLS
Chisenga
Karonga
N. Rukuru
NYIKA PLATEAU
Deep Bay
Livingstonia
Rumpi
Mzuzu
Nkata Bay
VIPYA PLATEAU
Luweya
Chinteche
Mzimba

MAP VII

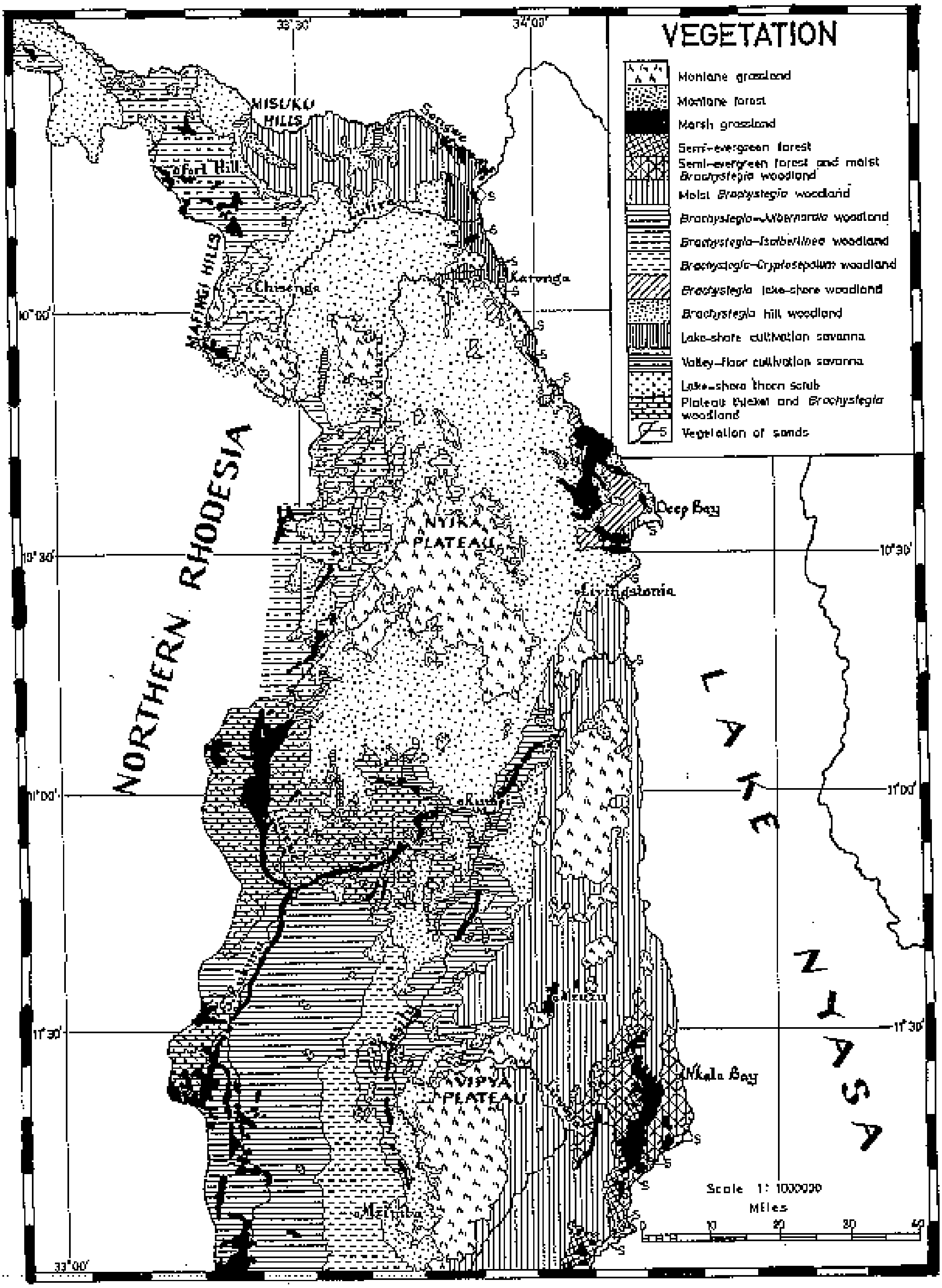


MEAN ANNUAL RAINFALL
Cms.
Inches
225–300
90–120
200–225
80–90
175–200
70–80
150–175
60–70
125–150
50–60
100–125
40–50
90–100
35–40
75–90
30–35
60–75
25–30
Scale 1: 1000000
Miles
0
10
20
30
40
NORTHERN RHODESIA
LAKE NYASA
MISUKU HILLS
MAFINGI HILLS
NYIKA PLATEAU
VIPYA PLATEAU
Chisenga
Karonga
Deep Bay
Livingstonia
Mzuzu
Nkata Bay
Chintechi
10°00'
10°30'
11°00'
11°30'

MAP VIII

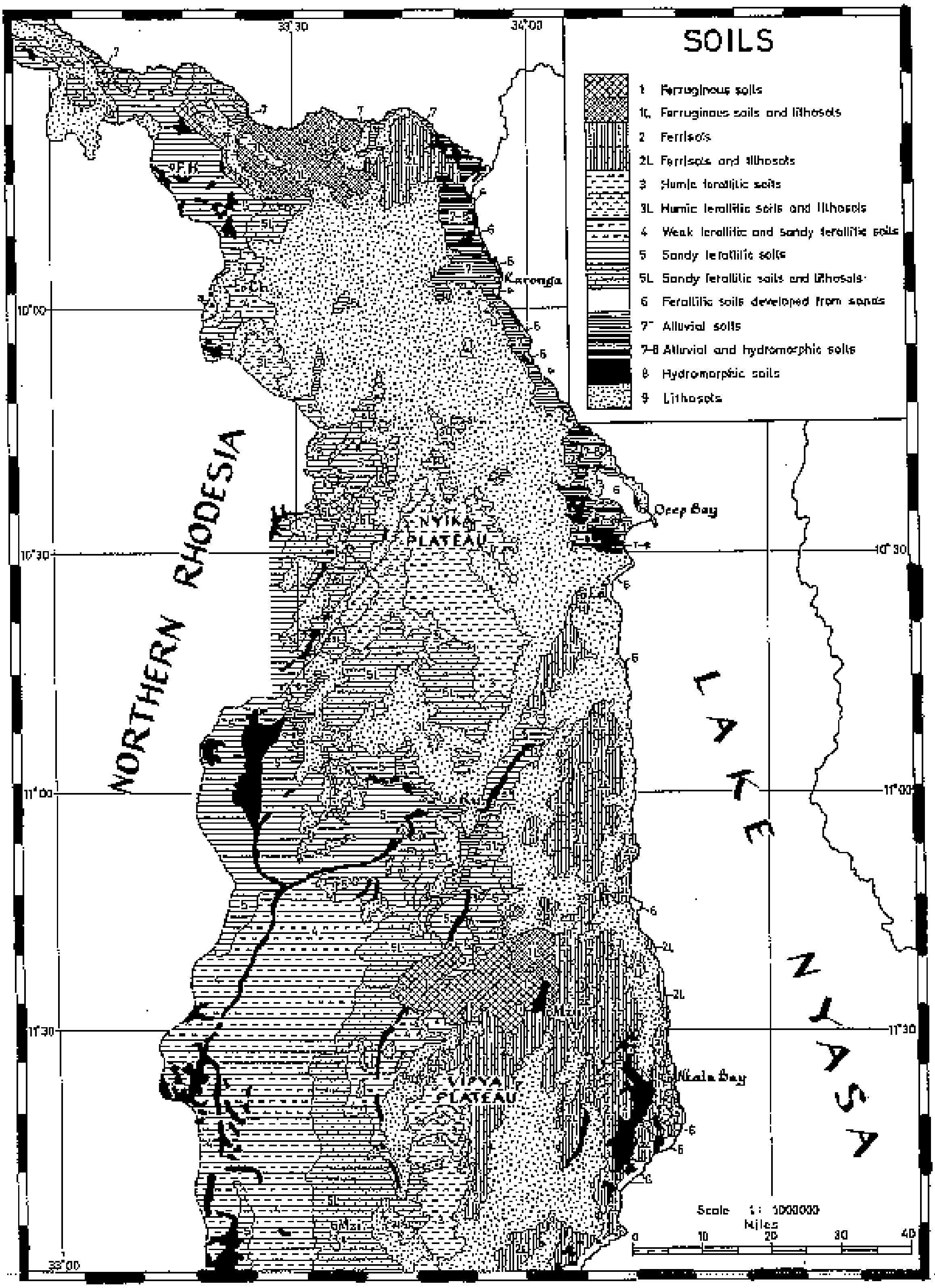

CLIMATIC REGIONS
Mean annual temp.
Mean annual rainfall
I Cool, wettish
II Cool-warm, wet
III Warm, dryish 65°–70° 30–40ins
IV Warm, dry
V Warm-hot, wettish 65°–76° 40–60ins
VI Hot, wet 75°–77°
VII Hot, dryish–wettish 75°–77° 30–60ins
Scale 1: 1000000
Miles
0 10 20 30 40
NORTHERN RHODESIA
LAKE NYASA
MISUKU HILLS
MAFINGI HILLS
NYIKA PLATEAU
VIPYA PLATEAU
Fort Hill
Chisenga
Karonga
Deep Bay
Livingstonia
Rumpi
Mzuzu
Nkata Bay
Chinteche
Mzimba
Songwe
Lufira
N. Rukuru
S. Rukuru
Lasitu
10° 00'
10° 30'
11° 00'
11° 30'
33° 00'
34° 30'

MAP IX



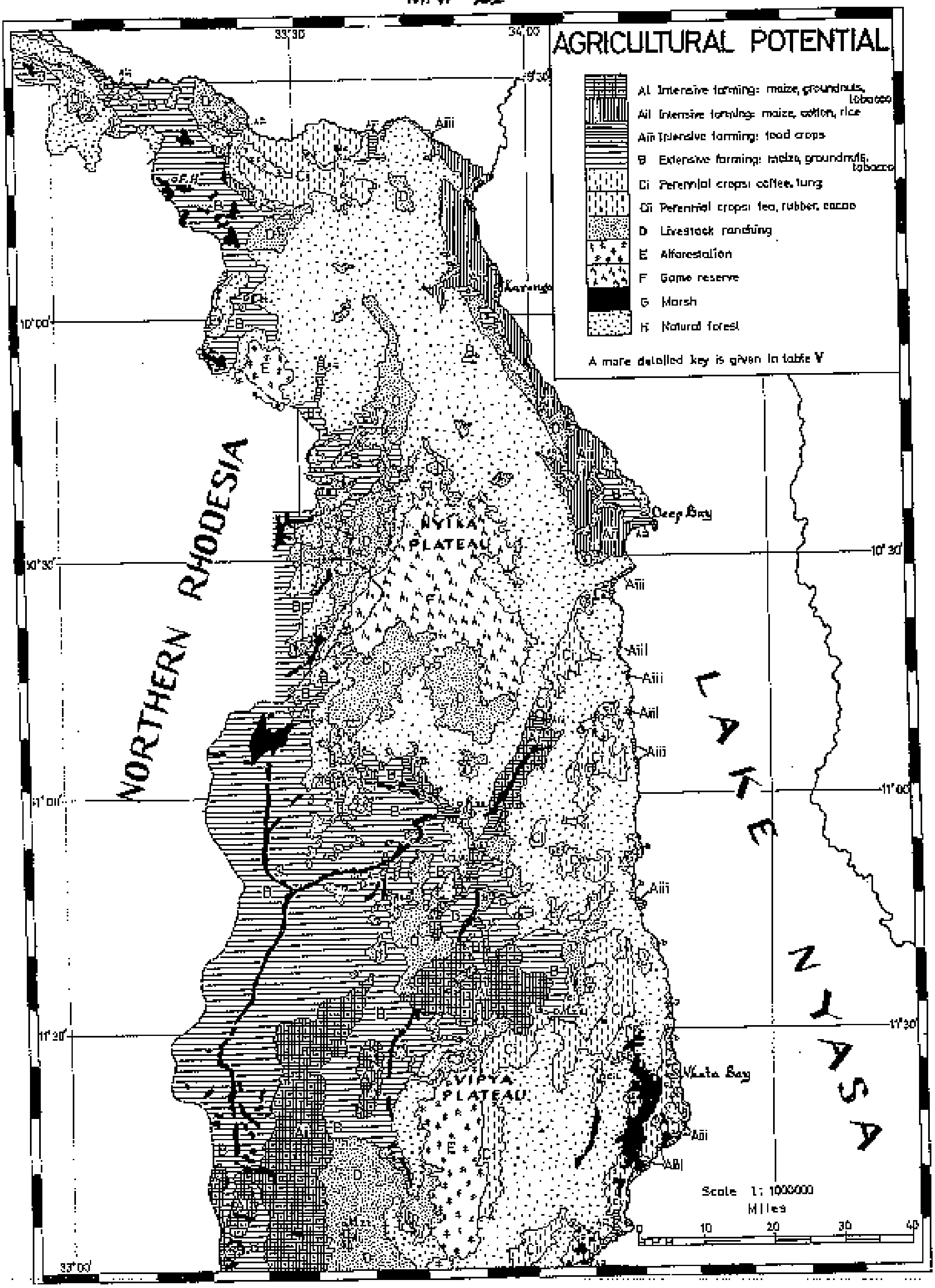
VEGETATION
Montane grassland
Montane forest
Marsh grassland
Semi-evergreen forest
Semi-evergreen forest and moist Brachystegia woodland
Moist Brachystegia woodland
Brachystegia–Julbernardia woodland
Brachystegia–Isoberlinia woodland
Brachystegia–Cryptosepalum woodland
Brachystegia lake-shore woodland
Brachystegia hill woodland
Lake-shore cultivation savanna
Valley-floor cultivation savanna
Lake-shore thorn scrub
Plateau thicket and Brachystegia woodland
Vegetation of sands
33°30′
34°00′
10°00′
10°30′
11°00′
11°30′
33°00′
MISUKU HILLS
MAFINGI HILLS
Chisenga
Karonga
Deep Bay
NYIKA PLATEAU
Livingstonia
NORTHERN RHODESIA
LAKE NYASA
VIPYA PLATEAU
Nkata Bay
Scale 1: 1000000
Miles
0
10
20
30
40

MAP X



SOILS
1 Ferruginous soils
1L Ferruginous soils and lithosols
2 Ferrisols
2L Ferrisols and lithosols
3 Humic ferallitic soils
3L Humic ferallitic soils and lithosols
4 Weak ferallitic and sandy ferallitic soils
5 Sandy ferallitic soils
5L Sandy ferallitic soils and lithosols
6 Ferallitic soils developed from sands
7 Alluvial soils
7-8 Alluvial and hydromorphic soils
8 Hydromorphic soils
9 Lithosols
NORTHERN RHODESIA
LAKE NYASA
NYIKA PLATEAU
VIPYA PLATEAU
Karonga
Deep Bay
Nkata Bay
10°00
10°30
11°00
11°30
33°30
34°00
33°00
Scale 1 : 1000000
Miles
0 10 20 30 40

MAP XI



AGRICULTURAL POTENTIAL
Ai Intensive farming: maize, groundnuts, tobacco
Aii Intensive farming: maize, cotton, rice
Aiii Intensive farming: food crops
B Extensive farming: maize, groundnuts, tobacco
Ci Perennial crops: coffee, tung
Cii Perennial crops: tea, rubber, cocoa
D Livestock ranching
E Afforestation
F Game reserve
G Marsh
H Natural forest
A more detailed key is given in table V
NORTHERN RHODESIA
LAKE NYASA
NYIKA PLATEAU
VIPYA PLATEAU
Deep Bay
Nkata Bay
Karonga
Scale 1: 1000000
Miles
0
10
20
30
40
33°30'
34°00'
33°00'
10°00'
10°30'
11°00'
11°30'