Characteristics, Classification, & Adaptation of SOILS in selected areas in SIERRA LEONE WEST AFRICA

Bulletin 748
Agricultural Experiment Station
College of Agriculture
University of Illinois at Urbana-Champaign

Bulletin 4
Njala University College
University of Sierra Leone

This bulletin is published as a cooperative effort between the University of Illinois at Urbana-Champaign and the Njala University College, University of Sierra Leone. It is also included in the University of Illinois International Publication Series I of the Office of International Programs and Studies and is Publication 2 in the Research Series of the University of Illinois Office of International Agricultural Programs.

Urbana, Illinois November, 1974

Characteristics, Classification, & Adaptation of SOILS in selected areas in SIERRA LEONE WEST AFRICA

R. T. Odell, J. C. Dijkerman, W. van Vuure, S. W. Melsted, A. H. Beavers, P. M. Sutton, L. T. Kurtz, and R. Miedema

During the preparation of this bulletin Professor R. T. Odell and Professor S. W. Melsted held joint appointments with the University of Illinois at Urbana-Champaign and the Njala University College, University of Sierra Leone. J. C. Dijkerman, former Senior Lecturer; W. van Vuure, former Lecturer; P. M. Sutton, Assistant Lecturer; and R. Miedema, former Junior Research Fellow, were members of the staff at Njala University College, University of Sierra Leone. Professor A. H. Beavers and Professor L. T. Kurtz are members of the Department of Agronomy, University of Illinois at Urbana-Champaign.

Contents

ACKNOWLEDGMENTS

Most of the cooperative work from which results are reported in this publication was done between 1965 and 1972. It is impossible to mention everyone who has contributed to it, but the authors are deeply grateful to the following organizations and individuals who made special contributions to the soil survey field work, made laboratory analyses, or gave financial support:

Njala University College

Special thanks are due the administration of Njala University College for continuing support of this work. Messrs. T. N. J. Lamboi, J. M. Cawray, and their laborers were indispensable in the soil survey field work and contributed greatly to it. Mr. E. A. Okine kindly drafted the soil map of the Njala area.

University of Illinois at Urbana-Champaign

Messrs. Victor Gabriel, J. M. Parker, and Chusak Chavengsaksongkram did many of the laboratory analyses of the soil samples. Mr. D. R. Phillips drafted all the figures except the soil map of the Njala area.

United States Agency for International Development

Funds for part of the research and for printing this publication were provided through contracts USAID/Afr-293 and /Afr-648.

Food and Agriculture Organization of the United Nations

FAO supported the soil survey field work of Dr. S. Sivarajasingham and Mr. J. Stark in the Kenema area. Dr. Sivarajasingham's work was especially helpful in elucidating the genesis of soils in eastern Sierra Leone.

Agricultural University of Wageningen, The Netherlands

Messrs. H. Breteler, E. R. Jordens, and D. H. Westerveld, former Junior Research Fellows at Njala University College and former students from the Agricultural University of Wageningen, assisted with the soil survey field work in the Njala area and Torma Bum area.

I. Summary

The research results that are reported in this publication have come from cooperative work by many individuals and several institutions. Staff members of Njala University College, University of Sierra Leone, and of the University of Illinois at Urbana-Champaign have done most of the work, but important contributions were also made by other individuals and institutions, recognized in the Acknowledgments.

This publication presents the results of recent research on important soils in six of the 16 recognized soil provinces in Sierra Leone. Soil maps are included for parts of five of the six soil areas that were studied. Major emphasis is given 44 soil profiles, representing 34 soil series, for which detailed field and laboratory data are given.

The genesis of the soils is discussed, and each of them is classified according to three systems: the comprehensive *Soil Taxonomy* system that is used in the United States of America and many other areas, the FAO/UNESCO soil classification system, and the French soil classification system. The soils are grouped according to their suitability for agricultural use, and suggestions are given concerning their management. All this information is presented in a way that will help improve the management of Sierra Leone soils now, provide a framework in which to learn more about Sierra Leone soils and their proper management, and furnish a mechanism for exchanging useful soils information with other countries in the humid tropics.

On the basis of criteria in *Soil Taxonomy,* the soils belong to the following orders in progressively decreasing importance: Ultisols, Inceptisols, Oxisols, Entisols, and Spodosols. Many of the Ultisols and Inceptisols have oxic properties and, therefore, are near the Oxisol border.

In the FAO/UNESCO soil classification system, the predominant soils are Nitosols, Cambisols, Ferralsols, and Gleysols. In the French classification system, many of the well-drained soils are *Sols ferrallitiques* and the poorly drained soils are often *Sols hydromorphes,* with smaller areas of other classes.

The clay fraction of most of these soils is predominantly kaolinite, which typically makes up 45 to 75 percent of this fraction. Other clay minerals in progressively smaller amounts are gibbsite, chlorite, illite, quartz, and goethite. There is also a unique suite of interstratified minerals composed of illite with chlorite or vermiculite in various combinations. These interstratified minerals are important only in soils that developed from sediments of the Rokel River Series in west-central Sierra Leone.

There are marked differences among the soils and areas that were studied intensively. The soils on the beach ridges along the coast are very sandy and have very little agricultural value. They range from nearly pure quartz sand with few or no soil horizons to soils that have distinct horizons.

The clayey soils that occur in tidal swamps along the coast and up adjacent stream estuaries have unique properties and management problems. They contain excess sulfur, which may produce extreme acidity if there is too much drainage and oxidation. Under careful management, including proper water control, these soils can be used effectively for swamp rice production.

The well-drained and moderately well-drained alluvial soils that occur on the floodplains of the larger streams are among the most productive soils in Sierra Leone. They are usually fine textured (clayey) and have favorable physical properties, but they need to be fertilized to produce profitable yields. These soils are subject to occasional brief flooding. Because they are near water that can be used for irrigation during the dry season, they can produce up to three crops annually.

On stream terraces and colluvial footslopes from the uplands, many soils are well drained and many are poorly drained. Some of these soils have hardened plinthite glaebules of gravel size in their subsoils. The well-drained soils are adapted to a wide range of annual and perennial crops if fertilizers and other improved management practices are used. The poorly drained soils are well suited to swamp rice production, especially if water control is practiced.

Gravelly upland soils are the most extensive ones in Sierra Leone; in many inland areas, such as around Kenema, Makeni, and Njala, they compose approximately two-thirds of the landscape. These gravelly soils are low in productivity because they not only are low in fertility but also are droughty during the dry season as a result of low moisture-holding capacity. These soils are used to produce upland rice, cassava, and groundnuts in a traditional slash and burn system of shifting cultivation. Their agricultural potential is low, however, and they are better adapted to tree crops and forestry.

Steep bedrock hills, often of granite, are scattered throughout the upland in the eastern half of Sierra Leone. These areas of Rock Land have no value for agriculture or forestry, but the natural vegetation should be maintained on them for watershed protection, wildlife use, recreation, and esthetic purposes.

2. Introduction

This publication brings together the results of recent research on the soils in five areas in Sierra Leone near Torma Bum, Rokupr, Njala, Makeni, and Kenema (Fig. 1). These represent six of the 16 soil provinces in Sierra Leone (Fig. 8), since the Torma Bum area represents two soil provinces. These areas occur between approximately 7° 20′ N to 9° 0′ N latitude and 10° 16′ W to 13° 0′ W longitude. This cooperative work was done by staff members of the Agronomy Departments of Njala University College and the University of Illinois, except for the soil survey field work in the Kenema area, which was done by Dr. S. Sivarajasingham and Mr. J. Stark and supported by the Food and Agriculture Organization of the United Nations. Detailed soil reports have been prepared for the Torma Bum, Njala, Makeni, and Kenema areas, to which further reference will be made in the appropriate sections of this report. The size of these areas for which soil maps are available is as follows:

Area	Acres	Hectares
Torma Bum	43,400	17,600
Njala	14,400	5,800
Makeni	26,200	10,500
Kenema	1,335,700	540,550

A detailed soil map is included for the Njala area, and soil association maps are included for the other areas. These soil maps are based on detailed field observations of soils along traverses at appropriate intervals, plus interpretations of aerial photographs to extend soil boundaries into areas not seen directly. No soil map or report has been published for the Rokupr area.

Of the soils identified in the areas studied, special emphasis is given 44 soil profiles, for which detailed descriptions and laboratory analyses are given in Appendix B. The genesis of the soils is discussed. On the basis of field and laboratory data, the various soils are classified in Section 4:12 according to the comprehensive soil classification system (*69*)[1] used in the United States of America and in many other areas, the FAO/UNESCO soil classification system (*28*), and the French soil classification system (*2, 3*). Comparisons among these soil classification systems are made to facilitate the international exchange of information concerning tropical soils. The soils are grouped according to their suitability for agricultural use, and suggestions are given concerning their management (Section 5).

The primary objectives of this report are to consolidate information from separate areas into an integrated whole; add data that were not available previously; present information on the characteristics, distribution, classification, and adaptation of soils so that they can be used and managed efficiently; and provide a framework within which soils in other areas of Sierra Leone, West Africa, and the humid tropics can be studied and characterized in order to improve soil management and food and fiber production.

Section 4:11 briefly summarizes the characteristics of soils in the Boliland Region, as reported by Stobbs (*70*). Of special interest are comparisons between these soils, which developed from Rokel River sediments under savanna vegetation and seasonally swampy conditions, and soils in the Njala area, which developed in the same parent material (Rokel River Series) but under forest vegetation and better drainage.

[1] Italicized numbers in parentheses refer to entries in Literature Cited.

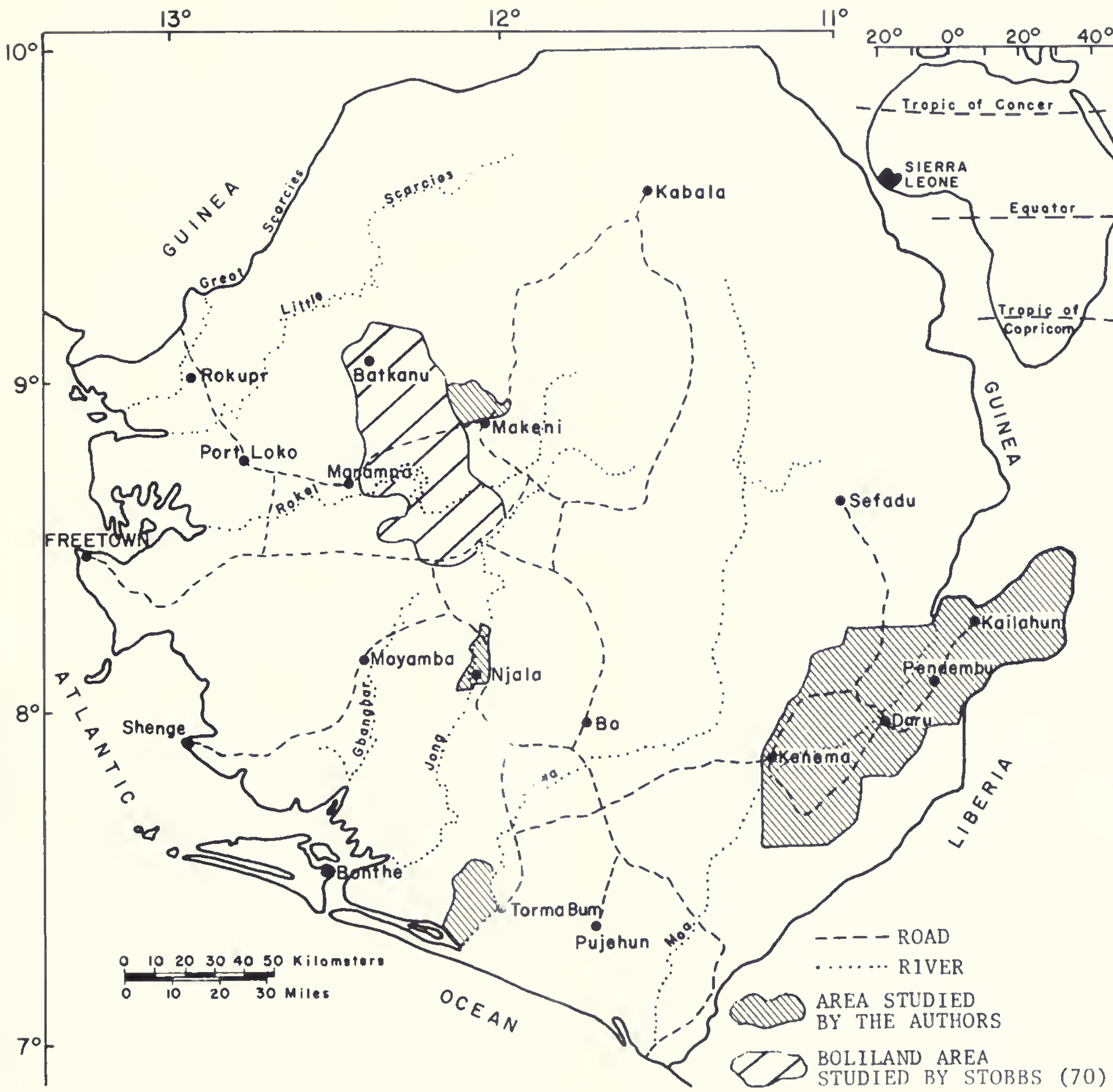


Figure 1. Locotion of areas studied in Sierra Leone, West Africa.

3. Soil Formation Factors

Soils are formed by the alteration of parent material under the influence of climate and living organisms, as conditioned by topography over a period of time. These five soil-forming factors — climate, living organisms, parent material, topography, and time — differ in various parts of Sierra Leone, and so do the soils. These factors also strongly influence the suitability of a soil for agriculture.

3:1. CLIMATE

Sierra Leone has a hot, tropical climate with distinct rainy and dry seasons. **Four main types of weather** may be recognized: thunderstorms and squalls, steady rains, dry weather with high humidity, and dry weather with low humidity. They are distributed through the annual cycle as follows:

Rainy season (May–November)

Thunderstorms and squalls
Steady rains
Thunderstorms and squalls

Dry season (December–April)

Dry weather with high humidity
Short periods of dry weather with low humidity (Harmattan)
Dry weather with high humidity

Thunderstorms and squalls occur from May through June and from October through November; that is, at the beginning and end of the rainy season. Thunderstorms accompanied by heavy rains travel east to west against the general wind direction. They are usually preceded by a squall of easterly wind. These thunderstorms are responsible for most of the rainfall at those times of the year. Their intensity and frequency are highest in June and October. Towards the beginning and the end of the rainy season the thunderstorms decrease in frequency and intensity, and the weather is very changeable. The relative humidity throughout the rainy season is high.

Steady rains occur from July through September; that is, during the middle of the rainy season. Rainfall is frequent and often heavy. Most of the annual rainfall occurs during this period. The wind is southwesterly. The sky is mainly overcast, and sunshine is rare. The relative humidity is between 95 and 100 percent. The temperatures are at their lowest, and the diurnal range of temperature is small. In some years, there is a short pause in the rainy season in July or August, characterized by clear and humid weather with little precipitation. Such a pause is more likely in extreme southeastern Sierra Leone than elsewhere in the country.

Dry weather with high humidity occurs during most of the dry season. Skies are usually clear and, therefore, day temperatures are relatively high. The nights are also warm and very humid. Heavy dew and fog often occur during the night and early morning. Winds predominantly come from the west.

Short periods of dry weather with low humidity (Harmattan) usually occur between late December and early February. The lengths of these periods vary from a few days to a number of weeks. The weather is characterized by a sudden drop in relative humidity from almost 100 percent to sometimes as low as 20 percent. This is caused by dry eastern or northeastern winds from the Sahara. The sky is clear but often obscured by a dust haze. The temperatures are relatively high during the daytime and low at night. The stability of the air prevents precipitation. Evapotranspiration is high because of the low relative humidity and the high temperature.

Although the annual cycle of the various types of weather discussed above applies to all of Sierra Leone, there are distinct differences in **climatic data** of various parts of the country. Details about the climate of Sierra Leone are presented in *Sierra Leone in Maps* (*16*) and the *Atlas of Sierra Leone* (*72*) and by Bartrum (*4*) and Gregory (*35*). Appendix A in this publication contains a collection of rainfall, temperature, relative humidity, sunshine, and evaporation data for selected stations in Sierra Leone.

Differences with respect to **mean annual rainfall** and **wet and dry season rainfall** are illustrated in Figure 2. The wet season is most extreme in the coastal area, with 120 to 200 inches (3,048 to 5,080 mm) or more of rainfall, and least in the north, with rainfall of from less than 80 to 100 inches (2,032 to 2,540 mm). The dry season is most severe in the north, having less than 5 inches (127 mm) of precipitation, and least in the central eastern part, with 10 to 15 inches (254 to 381 mm) or more of rainfall. The intensity of the rainfall is very high. For Bonthe, a maximum daily rainfall of 11.68 inches (297 mm) has been reported; Freetown has had a maximum hourly rainfall of 5.91 inches (150 mm).

Temperature data are illustrated in Figure 3. February, March, and April have the hottest days with mean monthly maximum temperatures of 86° to 93°F (30° to 34°C) near the coast and 93° to 99°F (34° to 37°C) inland. July and August usually have the coolest days with mean monthly maximum temperatures from 81° to

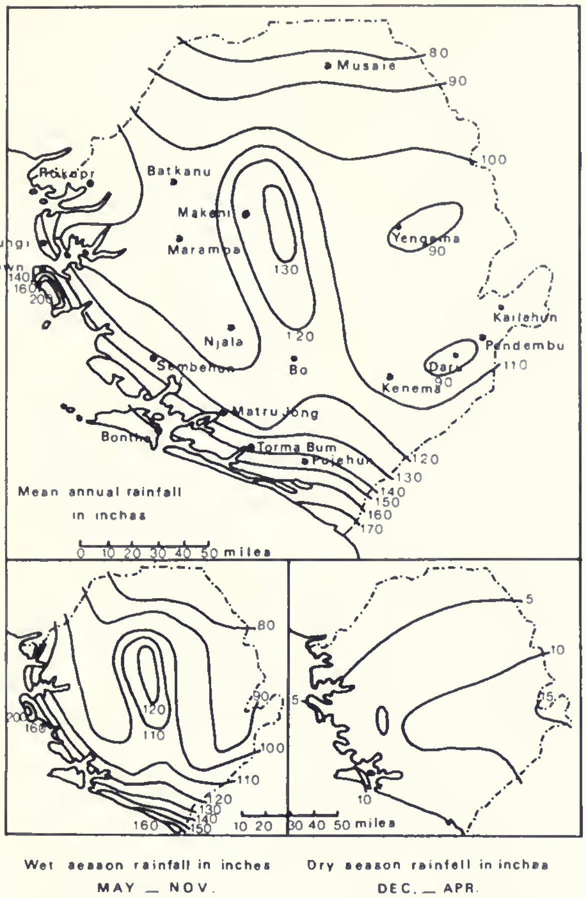


Figure 2. Mean annual, wet season, and dry season rainfall distribution in Sierra Leone (after Gregory, in *16*).

83°F (27° to 28°C). Inland nights are coolest in December, January, and February with mean monthly minimum temperatures as low as 57° to 68°F (14° to 20°C). During the remainder of the year, minimum temperatures vary little from 68° to 74°F (20° to 23°C) but are depressed slightly in June, July, and August. Nights are much warmer along the coast, and reported mean monthly minimum temperatures range from 73° to 78°F (23° to 26°C) with the coolest nights in July and August.

For the Njala station, some **soil temperature** data are available. Soil temperatures at 6 and 12 inches depth show only slight variations. In 1966, 1967, and 1968, the mean annual soil temperatures were 81°F (27°C) at 9 a.m. and 87°F (31°C) at 3 p.m.; corresponding air temperatures were 69°F (21°C) at 9 a.m. and 90°F (32°C) at 3 p.m. Thus, the mean soil temperature is closer to the maximum than to the minimum air temperature, and the daily range in soil temperatures is much smaller than that of the air temperatures.

Relative humidity is very high, often close to 100 percent for the greater part of the day and night, especially during the rainy season. However, during the Harmattan, relative humidity may be as low as 20 percent. Mean monthly relative humidity at 3 p.m. in August ranges from about 90 percent along the coast to 75 percent in the northeast; in January it ranges from about 60 percent along the coast to 30 percent in the northeast.

Evaporation data are scarce. Some open-pan and Piche evaporation data from weather stations at Njala, Torma Bum, and Makeni are given in Appendix A. Although some of these data may not be entirely reliable, the general trend is clear. Evaporation is highest during February and March and lowest in August. The same trend is shown in Figure 4 by the potential evapotranspiration data as calculated according to Papadakis (*60*). These data should be considered as approximations because few parameters are used in the calculations. According to these estimates, mean annual potential evapotranspiration is relatively low at the coast — 37 inches (930 mm) at Freetown, for example — and increases with distance from the coast in a northeasterly direction: 74 inches (1,877 mm) at Musaia is an example of one of the higher values.

The annual **soil moisture** regime depends on the difference between evapotranspiration and precipitation throughout the year (see Fig. 4). During the dry season, potential evapotranspiration greatly exceeds the rainfall so that a distinct water deficit develops in most soils. The length of the period of soil moisture deficiency, which also depends on the available soil moisture-holding capacity, ranges from 5 months to 1 month for well-drained to imperfectly drained soils and from 3 to 0 months for poorly to very poorly drained soils. During the rainy season, precipitation greatly exceeds evapotranspiration. In soils where the excess water cannot be drained away quickly, waterlogging will occur and plant roots may suffer from oxygen deficiency. Soils differ greatly in their ability to discharge excess water rapidly. Some soils are never waterlogged, while others are submerged for four to five months. The soil moisture regimes of various soils in selected areas of Sierra Leone are indicated in Section 4, and some of this information is summarized in Table 2 (pages 16 and 17).

3:2. PARENT MATERIALS, TOPOGRAPHY, AND TIME

The geology and physiography of Sierra Leone have been described by Dixey (*26, 27*), Pollet (*62*), and in *Sierra Leone in Maps* (*16*). A geological map is presented in Figure 5 and a physiographic map in Figure 6.

3:2:1. Physiography

Sierra Leone consists of four broad physiographic regions: the Peninsula Mountains, the coastal plain, the interior plain, and the interior plateau and hill region.

The **Peninsula Mountains**, located near Freetown, are the result of a large basic intrusive body of gabbro, probably of Precambrian age. The present youthful topog-

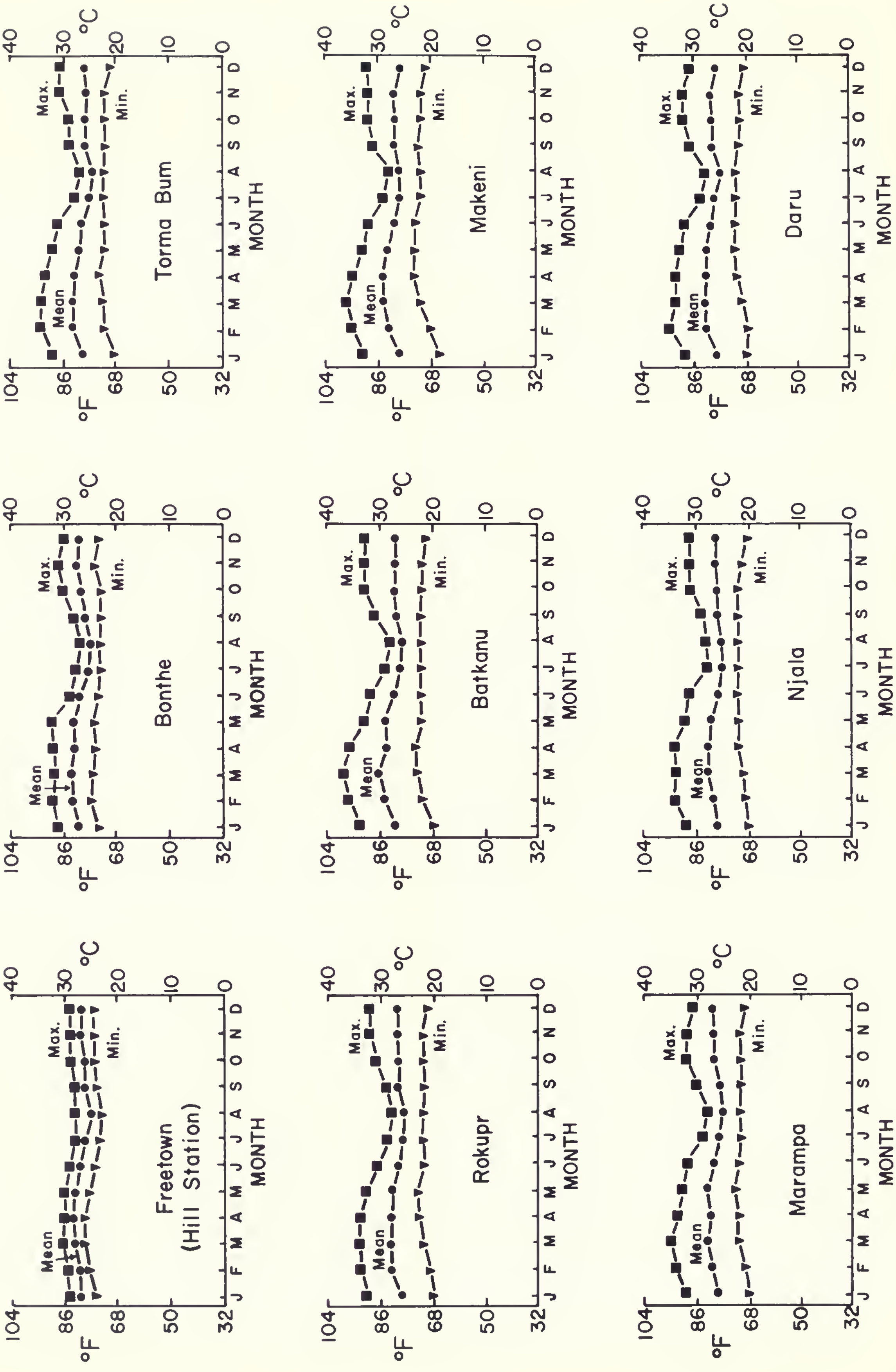


Figure 3. Mean, maximum, and minimum monthly air temperatures at selected stations in Sierra Leone.

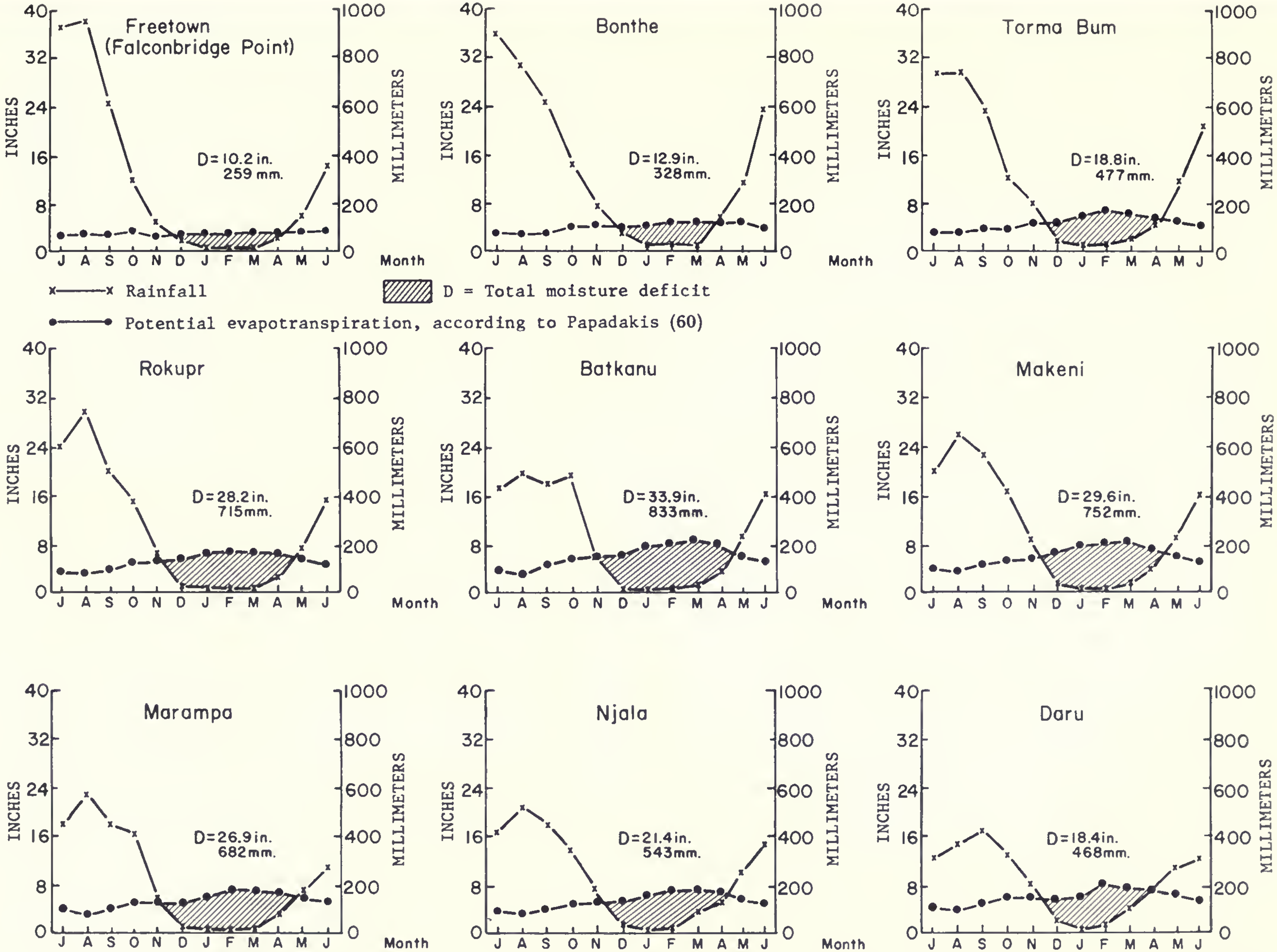


Figure 4. Mean monthly rainfall and potential evapotranspiration (calculated according to Papadakis, 60) and the total moisture deficit (D) during months in which potential evapotranspiration exceeds rainfall for selected stations in Sierra Leone.

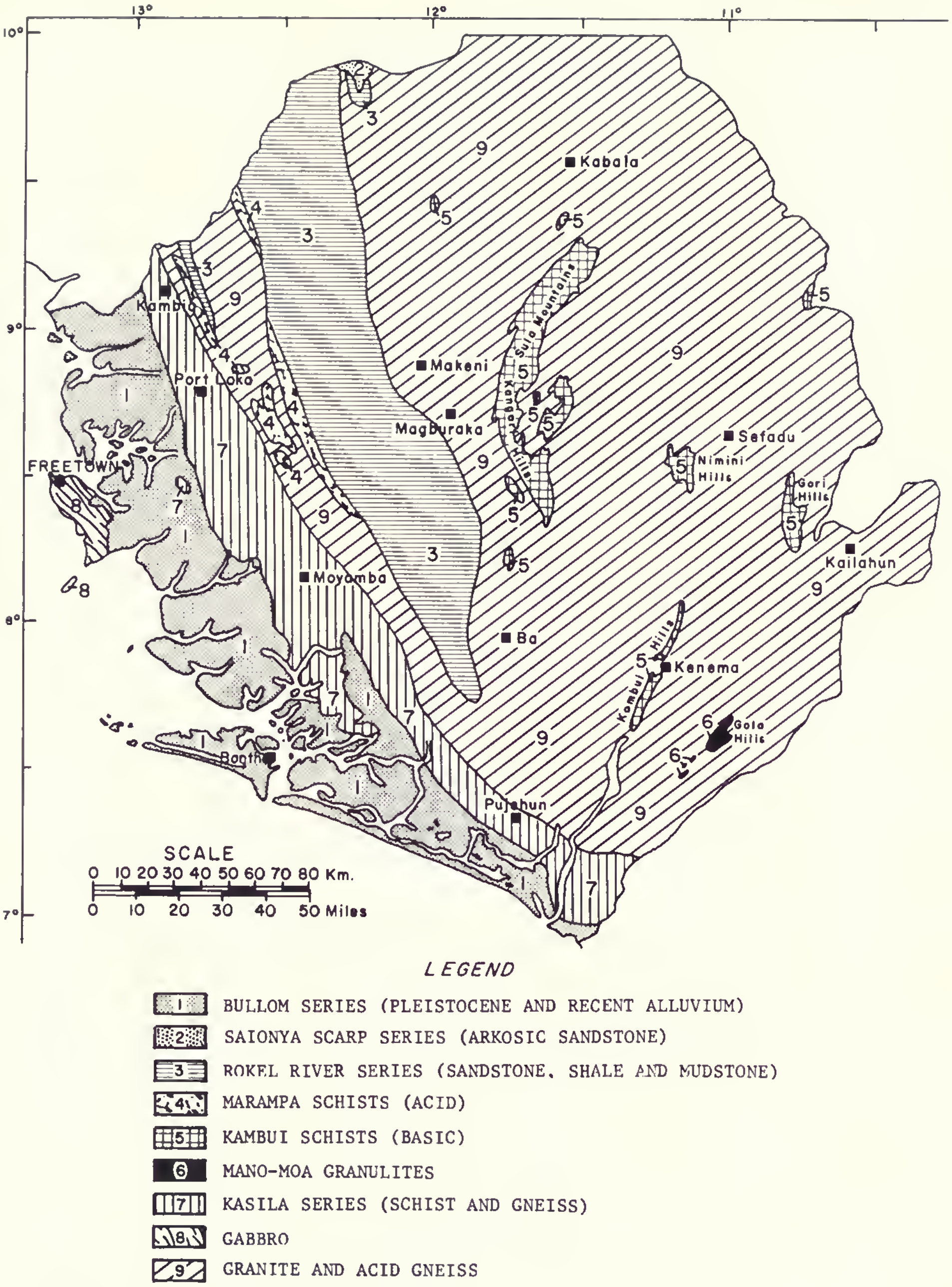


Figure 5. The geology of Sierra Leone (after Anderson, in 16).

raphy, with its strongly dissected mountain range rising to almost 3,000 feet (900 m), is the result of relatively recent uplift, possibly in Tertiary time. A number of platforms have been carved into the mountain mass. Near the base of the mountains, a number of raised beaches are present that are part of the coastal plain.

The **coastal plain** is a strip about 25 miles (40 km) wide adjoining the coast and parallel to it. Most of it is less than 50 feet (15 m) above sea level. It is built up of marine, deltaic, and fluvial deposits of the Bullom Series (Pleistocene or Recent). The topography is nearly flat with many swamps. The coastal plain may be subdivided into sandy beach ridges and lagoons, mangrove swamps, alluvial grassland floodplains, and raised beaches and coastal terraces.

The **interior plain** is a strip about 60 miles (100 km) wide, parallel to and east of the coastal plain. It is an old, gently undulating erosion surface that rises from an elevation of 50 feet (15 m) in the west to about 500 feet (150 m) in the east. It is broken by a number of isolated hills, such as the Kasabere and the Moyamba Hills, which are monadnocks remaining from an earlier plateau. A great variety of rocks underlies the interior plain: crystalline schist and gneiss of the Kasila Series; sand-

Figure 6. The physiography of Sierra Leone.

stone, siltstone, and mudstone of the Rokel River Series; schist and quartzite of the Marampa Series; and granite and acid gneiss. All these rocks are of Precambrian age. The interior plain contains many swamps, especially in the area known as the Boliland Region. This area is underlain by sedimentary rocks of the Rokel River Series and presumably was the site of a delta formed by the merging Mabole, Rokel, and Pampana Rivers during a period of higher sea level. A later drop of the sea level has caused the incision of the rivers into the interior plain. The rivers have poorly developed floodplains at their present level. However, river terraces far above the present river level are quite extensive.

The **interior plateau and hill region** covers the eastern half of Sierra Leone. It is part of the Guinea Highlands, a major West African watershed. It consists mainly of elevated plateau country, primarily between elevations of 1,000 and 2,000 feet (300 and 600 m), but includes numerous steep-sided valleys and dome-shaped granite inselbergs. In the central area and near the Guinea border, the Tingi and Loma Mountains rise far above the main plateau region, with peaks higher than 6,000 feet (1,800 m). In contrast, farther south in the upper Moa River basin, the elevations decrease to only about 500 and 1,000 feet (150 and 300 m). Most of the area is underlain by granite and acid gneiss, although some smaller areas consist of basic schists, amphibolites, and serpentines of the Kambui Series. Both the rocks of the Kambui Series and the granite and acid gneiss are considered to be of Precambrian age. The interior plateaus and hills are separated from the interior plain to the west by a rather sharp escarpment, especially in the north. Farther south, the escarpment is much less clearly defined and more dissected.

3:2:2. Geology and parent materials

Soils are either directly or indirectly derived from rocks by weathering and disintegration. Rocks vary in their resistance to weathering and give different types of soils, depending upon the kind of minerals present. Table 1 gives the mineral content of the major rocks of Sierra Leone. The rocks are grouped into four main classes: basic and ultrabasic igneous and metamorphic rocks, acid and intermediate igneous and metamorphic rocks, consolidated clastic sedimentary rocks, and unconsolidated clastic sedimentary rocks.

Basic and ultrabasic rocks consist of easily weatherable, iron- and aluminum-rich minerals and very little or no quartz. Under humid tropical weathering conditions, bases and combined silica are lost rapidly from this rock, leaving a red clayey soil high in secondary oxides of iron and aluminum. Sand content is low because the parent rock contains few resistant minerals. Plinthite (described in Section 4:12:1) or hardened plinthite, either in gravelly or hardpan form, is common in these soils because the parent rock has a high iron and aluminum content. The weathering of basic and ultrabasic rocks proceeds relatively rapidly. This produces a sharp boundary between the soil and the parent rock because the weathering layer around the parent rock is very thin (*52*). On steep hills, shallow soils and rock outcrops are abundant. The nutrient reserve of basic and ultrabasic rocks is relatively high.

Table 1. Mineral content of the major rocks of Sierra Leone (after data from Pollet, 62)

Major group	Geologic name	Chief rock types	Chief minerals
Basic and ultrabasic igneous and metamorphic rocks	Gabbro	Gabbro	Olivine, pyroxenes, amphiboles, biotite, and calcic plagioclase
	Kambui schists	Amphibolites, serpentines, basic schists	Amphiboles, plagioclases, antigorite, chlorite, talc, biotite
Acid and intermediate igneous and metamorphic rocks	Kasila Series	Feldspathic gneiss, pyroxene gneiss, hornblende schist and gneiss, granulite	Quartz, pyroxenes, amphiboles, alkali feldspars, garnet
	Granite and acid gneiss	Biotite granite and gneiss, hornblende granite and gneiss, muscavite granite and gneiss	Quartz, alkali feldspars, acid plagioclase, biotite, muscovite, hornblende
	Marampa schists	Garnetiferous biotite schists, sericitic quartz schists, quartzites, muscavite-biotite schists, biotite paragneiss, hematite schists	Quartz, muscovite, garnet, biotite, sericite, alkali-feldspars, hematite
Consolidated clastic sedimentary rocks	Rokel River Series	Sandstone, siltstone and mudstone, with dikes of dolerite and quartz veins	Quartz, aluminum and iron hydroxides, kaolinite, mica, chlorite
Unconsolidated clastic sedimentory rocks	Bullom Series	Gravels, sands, and clays of lacustrine, estuarine, deltaic, marine, and fluvial origin	Variable, depending on the source area of the sediment

Acid and intermediate igneous and metamorphic rocks yield soils with a sandy clay texture. The sand present is mainly quartz, which is resistant to weathering. Plinthite formation occurs but is not so abundant as in basic and ultrabasic rocks because the iron and aluminum content of the parent rock is lower. Acid and intermediate igneous and metamorphic rocks contain minerals that are rather resistant to weathering. Weathering, therefore, proceeds more slowly, and a thick layer of weathering rock is usually present between the fresh rock and the soil. On steep slopes, rock outcrops and shallow soils are common but are less abundant than in areas of basic and ultrabasic rocks. The nutrient reserve of acid and intermediate igneous and metamorphic rocks is moderate.

Soils derived from the **sedimentary rocks of the Rokel River Series** are variable in texture. In the swamps, clayey soils that have developed from clayey shales and mudstones usually are present. On the upland, the predominant soils are sandy clay and sandy clay loam textures, derived from sandstones and sandy shales. The iron oxides and hydrated oxides abundantly present in this sedimentary rock can, upon redistribution, contribute directly to the formation of plinthite, which is rather extensive. The rocks of the Rokel River Series are soft so that physical disintegration occurs relatively rapidly. As a result, rock outcrops and shallow soils on steep slopes are rare. The nutrient reserve of rocks of the Rokel River Series is low.

Soils derived from the **unconsolidated sediments of the Bullom Series** vary in texture and composition. These sediments may be gravel, sand, or clay of lacustrine, estuarine, deltaic, marine, or fluvial origin. Consequently, the mineral content and the nutrient reserve of these materials are variable and depend upon the source area of the sediment and the mode of deposition.

3:2:3. Topography

A close relationship exists between topography, parent material, and kind of soil. Steep slopes have rather shallow residual soils that developed from the weathering bedrock. On plateaus of old erosion surfaces in areas with basic or ultrabasic parent rock, soils are usually shallow over a hardened plinthite sheet. In areas where rocks are not basic or ultrabasic, the plateaus of old erosion surfaces are usually covered by a thick mantle of locally transported, highly weathered material that contains large quantities of gravel-size hardened plinthite glaebules (*13*).[1] In the same area on gentle concave slopes, colluvial and termite activity (see also Section 3:3:2) is mainly responsible for creating a gravel-free layer of varying thickness that overlies the gravelly subsoil. A thick layer of gravel-free material is usually also present on the colluvial footslopes and upper river terraces. The middle and lower river terraces typically consist of gravel-free alluvium, the characteristics of which depend upon the source area.

3:2:4. Time

Time is an important factor of soil formation since it indicates the duration of processes that have been active in the development of a soil. Compared with the age of the bedrock (mainly Precambrian), the soils in Sierra Leone are relatively young. From a pedological point of view, however, many are rather old. The erosion surface that covers most of the interior plain probably dates from the late Tertiary (*70*). The age of the plateaus of the eastern part of Sierra Leone is unknown. The coastal terraces and river terraces may be of Pleistocene or Holocene age. Recent alluvium is present both along the coast and along the major rivers.

It should be realized that for a soil to register the full impact of time, the land surface on which it occurs should be free from disturbances by erosion or deposition. Such situations are not common. Surface erosion and mass movement of surficial material will cause some removal and disturbance, even on gentle slopes. It should also be kept in mind that many soils of Sierra Leone have formed from highly weathered parent materials that have undergone several previous cycles of weathering and soil formation. Upon erosion these materials have been removed and transported by colluvial or alluvial processes and redeposited at another place, where they are the parent materials for a new cycle of soils until erosion again removes them. Thus, although a soil may be relatively young in terms of years of soil formation at a particular site, it may be very old in terms of number of years of weathering of the original material.

3:3. LIVING ORGANISMS

3:3:1. Plants

Living organisms, both plants and animals, cause differences in soil. Vegetation causes, among other things, large differences in the organic matter content of soils. With respect to the major vegetation types in Sierra Leone — forest, farm bush, savanna, grassland, and mangrove — soils under forest and grassland have higher organic matter content than soils under farm bush, while soils under savanna have the lowest organic matter content. In grassland, different types of vegetation are correlated with the class of soil drainage, and in mangrove swamps the type of mangrove species is indicative of the possible presence or absence of potential acid sulfate soils. The vegetation of Sierra Leone has been described by Martin (*49*), Waldock *et al.* (*77*), the *Atlas of Sierra Leone* (*72*), Clarke (*16*), and Cole (*17*). Each of the five major types of vegetation will be discussed below. Their distribution, alone and in various combinations, is indicated in Figure 7.

Much of the country was formerly covered by **forest.** This has been greatly reduced by clearing. The forest that is still present is mainly secondary forest, which means that the original growth has been cleared at some time. Typical species present are: *Elaeis guineensis* (oil palm), *Chlorophora regia, Funtumia latifolia, Musanga smithii, Bombax buonopozense, Anisophyllea meniandi* (east of Bo), *Anisophyllea laurina* (west of Bo), *Pycnanthus kombo, Homalium* spp., *Millettia* spp., *Daniellia thurifera,* and *Macrolobium dawei.*

As a consequence of a shifting cultivation type of agriculture, most of the forest has been converted by man to **farm bush.** This dense evergreen woodland vegetation is farmed periodically. In general, the period of bush fallow in Sierra Leone is less than 15 years and is becoming progressively shorter because of the increasing population pressure. Typical farm bush species are *Dichrostachys glomerata, Albizzia gummifera, Albizzia zygia, Elaeis guineensis* (oil palm), *Nauclea latifolia* (*Sarcocephalus esculentus*), *Phyllantus discoideus, Macaranga* spp., *Morinda germinata, Cathormion dinklagei, Anisophyllea laurina, Mussaenda elegans, Combretum* spp., *Alchornea cordifolia, Anthocleista* spp., *Terminalia ivorensis, Holarrhena africana, Xylopia aethiopica, Hugonia planchonii, Hugonia platysepala, Ochthoscosmus africanus, Caloncoba echinata,* and *Macrolobium macrophyllum.*

Savanna vegetation prevails in northern Sierra Leone. It consists of three types: savanna woodland, open savanna, and *Lophira* savanna. Savanna woodland is present mainly in the southern part of the savanna zone. It consists of typical fire-tolerant tree species with almost closed canopy. The dominant grasses are usually *Andropogon* spp. In open savanna, the trees are more widely spaced and *Andropogon* spp. are replaced by *Chasmopodium caudatum* or by *Hyparrhenia* spp., *Anadelphia* spp., and similar grasses. *Lophira* savanna is a type of open savanna in which *Lophira alata* is the dominant tree and *Hyparrhenia* or sometimes *Chasmopodium* is the dominant grass; it occurs in the northwestern part of Sierra Leone where the bedrock consists of mudstones of the Rokel River Series.

Grassland is present in the Boliland Region and on some alluvial floodplains. The Boliland Region is a swampy area in the interior plain where the major rivers

[1] The hardened plinthite glaebules in Sierra Leone soils include concentrations of sesquioxides that occur as nodules, a few concretions, glaebular haloes, and possibly some of the other subgroups of glaebules as defined by Brewer and Sleeman (*13*). The term "hardened plinthite glaebules" is used in this publication instead of general terms such as "laterite gravel" and "ironstone gravel" or restrictive terms such as "laterite concretions" and "plinthite concretions." Only a few of the glaebules have the concentric fabric around a center that is characteristic of concretions.

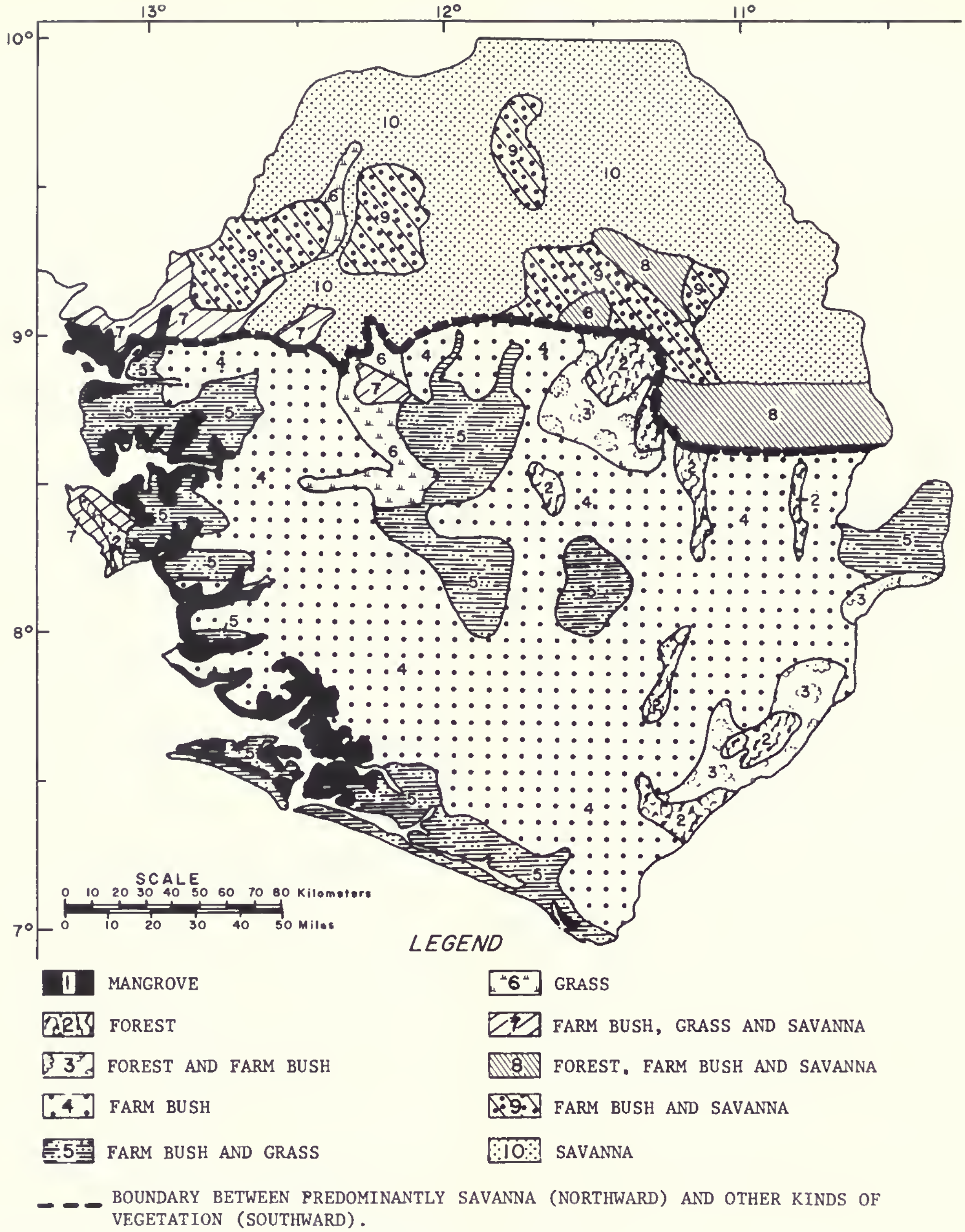


Figure 7. The vegetation of Sierra Leone (after Clarke, 16).

cross the sedimentary rocks of the Rokel River Series. The swamps, which are seasonally flooded during the rainy season, support short and medium grasses, especially *Anadelphia* and *Rhytachne* species (Fig. 44). The slightly higher areas adjacent to the swamps, which are wet but not flooded in the rainy season, have a tall grass vegetation with *Chasmopodium caudatum* as one of its main species. The other major grassland area occurs in southern Sierra Leone on the alluvial floodplains of the Waanje and Sewa Rivers as they cross the coastal plain. It, too, has short and medium grasses in the wettest areas, which are deeply flooded during the rainy season, and tall grasses on the adjacent, slightly higher areas that are not flooded. Typical grasses and sedges found in the wetter parts are *Saccharum spontaneum, Paspalum scrobiculatum, Eleocharis* spp., *Oryza barthii, Anadelphia* spp., and *Fuirena umbellata.* On the drier areas, typical species are *Panicum repens, Imperata cylindrica,* and *Chasmopodium caudatum.*

Mangrove swamps occur along the coast and in the mouth of creeks and rivers where a saline tidal environment is present. Two main types of mangrove trees are present: *Rhizophora racemosa* and *Avicennia nitida*. *Rhizophora racemosa* occurs on soft fibrous muds that are waterlogged throughout the year (Fig. 14). Upon empoldering, these muds may develop into very acid sulfate soils (see Section 4:6). *Avicennia nitida* occurs on firmer nonfibrous soils that are more sandy or somewhat better drained; such soils are not potential acid sulfate soils.

3:3:2. Animals

Soil fauna also influence soil formation. This is especially true of termites and earthworms. **Termites** are very abundant in Sierra Leone soils and, where present, make the soil very porous. Termite activity, in combination with colluvial action, is probably responsible for the gravel-free surface layer in many upland soils, especially on gentle concave slopes where this layer often overlies a stone line or a subsoil rich in hardened plinthite gravel. Abundant in Sierra Leone are the *Macrotermes* species, which build large termite mounds. From a study of *Macrotermes natalensis* mounds near Makeni (*51*), the following conclusions can be drawn:

a. The material of the mound is of subsoil origin from depths of about 12 to 51 inches (30 to 130 cm).

b. The mounds show higher values for most chemical characteristics, especially pH, base saturation, cation-exchange capacity, and exchangeable Ca, Mg, K, and Mn. Although *Macrotermes natalensis* mounds form isolated patches of more fertile soils compared to the surrounding sites, the termite mound materials are still low in fertility.

c. Termites do not use specific size fractions of material to build their mound, but they tend to prefer clay, silt, and finer sand fractions; they do not carry particles larger than 2 mm.

d. The vertical influence area is mainly between 12 and 51 inches (30 to 130 cm); the horizontal influence area extends to about 33 feet (10 meters) from the center of the mound.

e. The above differences between termite mounds and surrounding soils are most clearly expressed in the young, inhabited mounds.

Little is known about **earthworm** activity in Sierra Leone soils. One of the authors has observed earthworms to be very active in the alluvial floodplain near Torma Bum and near the base of the Kaswe Hills. In both cases, the soils are somewhat poorly drained and are nearly flooded in the wet season. The worms form a micro relief — a very uneven surface resembling that formed by cows when they walk in a wet pasture. The higher islands, which are full of earthworm excretions, are a few feet in diameter and one-half to one foot high. Apparently, the worms concentrate in the higher islands and build them up during the wet season when the water table comes very close to the surface. These are similar to kawfoetoes (cowfeet) in Suriname, which are also caused by worm activity (*63*).

Man, too, has influenced soil formation, primarily by clearing the forest and using the land for agriculture in a shifting cultivation system. This has caused soil erosion, especially on the steep slopes. Because the increasing population requires an expanding area for agriculture, the fallow period has become shorter and shorter. Without the use of fertilizers, this has caused a serious decline in soil organic-matter content and thus in soil fertility.

4. Soil Characteristics, Genesis, and Classification

4:1. SOIL PROVINCES IN SIERRA LEONE AND RELATIONSHIPS AMONG SOILS IN THE AREAS STUDIED

The broad soil regions in Sierra Leone have been outlined previously by Dijkerman and Odell (*23, 59*). Dijkerman's soil province map is used here as Figure 8, with shadings added to highlight the six soil provinces (B*, C*, D*, G*, J*, and L*) for which detailed data are presented in this publication. Earlier work in the Boliland Region (soil province I*) by Stobbs (*70*) is also briefly discussed, especially because of its close relationship with soil province G*. An asterisk has been added to the soil province symbols (A* through P*) on Figure 8 to distinguish them from the letter symbols used later on the soil association maps of the areas near Torma Bum (Fig. 12), Makeni (Fig. 31), and Kenema (Fig. 43).

The relationships among the soil series that have been recognized in seven soil provinces (B*, C*, D*, G*, I*, J*, and L*) are shown in Table 2. An alphabetical list of these soil series, their area of occurrence, and a few key characteristics of each are given in Appendix D. Major attention is given to 44 soil profiles for which detailed data are presented in this publication; these profiles represent the 34 soil series set in heavy type in Table 2. Table 2 is especially helpful in comparing soils in different areas. Information concerning moisture regimes is important in relation to soil properties, as described in Section 4, and to soil use, management, and other soil moisture parameters discussed in Section 5.

In Sections 4:2 through 4:4 some special characteristics of soils in Sierra Leone are explained. Then, in Sections 4:5 through 4:10, detailed data are presented and discussed for the six soil provinces highlighted in this publication. The soils in these six provinces are characterized on the basis of detailed field descriptions and laboratory analyses of the 44 soil profiles, which are reported in Appendix B. Section 4:11 relates Stobbs' work (*70*) in the Boliland Region (soil province I*) to our work. In Section 4:12 the soils we studied are classified according to three different taxonomic soil classification systems (*69, 28, 2,* and *3*).

4:2. MAJOR PROCESSES ACTIVE IN SOIL FORMATION

Soil develops from its parent material as a result of several physical, chemical, and biological processes. Differences in soils are caused both by different kinds of parent materials and by differences in the rate and direction of these soil-forming processes. Some important soil characteristics resulting from soil-forming processes in Sierra Leone are as follows:

a. Epipedons develop by the accumulation of organic matter in the surface soils.

b. Cambic and oxic horizons (see *69* and Section 4:12:1) develop by mineral weathering, leaching of soluble substances, and formation of secondary minerals.

c. Argillic and spodic horizons form by illuviation of clay, iron, and organic matter.

d. Gley features and plinthite form in seasonally wet soils by segregation of iron and the subsequent formation of hardened plinthite on repeated wetting and drying.

e. A gravel-free surface layer forms in some soils by termite activity and colluviation.

4:2:1. Accumulation of Organic Matter in the Surface Soil

The formation of a dark-colored surface horizon or epipedon, as a result of the accumulation of organic matter, is one of the first soil-forming processes in most soils. It depends upon the difference between additions and losses of organic matter. Additions come from dead leaves that fall on the surface of the soil and from roots that die and decompose within the soil. Losses are caused by oxidation and, to a lesser extent, by leaching of organic matter. In the beginning stage of soil development, additions usually greatly exceed losses; but as the organic matter content builds up, the losses also increase until finally the losses and additions of organic matter balance each other, and an equilibrium state is reached in which there is a nearly constant level of organic matter in the surface soil. The amount of organic matter at the equilibrium state depends upon the environmental conditions. Under natural conditions, it increases with available moisture and nutrients and decreases with temperature. When the soil is used for agriculture, considerably less organic matter is normally added than in the case of natural vegetation, and organic matter content will decrease. On the other hand, a "bush" fallow, as practiced under shifting agriculture, will lead to an increase of organic matter. The longer the fallow period, the greater the amount of organic matter. Forest fallow adds more organic matter to the soil than savanna fallow (*58*).

In Sierra Leone, two kinds of epipedons (*69*) have been recognized: an **umbric epipedon,** which is a thick, dark-colored, acid surface horizon with at least 1-percent organic matter; and an **ochric epipedon,** which is thinner, or lighter colored, and usually lower in organic mat-

A*– SOILS OF THE PENINSULA MOUNTAINS FROM NORITE AND GABBRO

B*– SOILS OF THE SANDY BEACH RIDGES AND LAGOONS

C*– SOILS OF THE COASTAL SWAMPS

D*– SOILS OF THE ALLUVIAL GRASSLAND FLOODPLAINS

E*– SOILS OF THE RAISED BEACHES AND COASTAL TERRACES

F*– SOILS OF THE INTERIOR PLAIN FROM ACID IGNEOUS AND METAMORPHIC ROCKS

G*– SOILS FROM THE ROKEL RIVER SERIES UNDER SECONDARY BUSH

H*– SOILS FROM THE ROKEL RIVER SERIES UNDER SAVANNA

I*– SOILS OF THE BOLILANDS

J*– SOILS OF THE ESCARPMENT REGION FROM GRANITE AND ACID GNEISS UNDER SECONDARY BUSH AND FOREST

K*– SOILS OF THE ESCARPMENT REGION FROM GRANITE AND ACID GNEISS UNDER SAVANNA

L*– SOILS OF THE UPPER MOA BASIN

M*– SOILS OF THE PLATEAUS FROM GRANITE AND ACID GNEISS UNDER SECONDARY BUSH AND FOREST

N*– SOILS OF THE PLATEAUS FROM GRANITE AND ACID GNEISS UNDER SAVANNA

O*– SOILS OF THE HILLS AND MOUNTAINS FROM GRANITE AND ACID GNEISS

P*– SOILS OF THE HILLS AND MOUNTAINS FROM THE KAMBUI SCHISTS

Figure 8. Soil province map of Sierra Leone, Africa.

Table 2. Important soils in selected areas of Sierra Leone grouped by physiography, parent material, and moisture regime[a]

Physiography and parent material	Soil province (Fig. 8)	Moisture regime[b] Well drained	Moderately well drained	Imperfectly drained	Poorly drained	Very poorly drained
Steep hills						
Predominantly hard granite, or sometimes granodiorite or gneiss	G*,J*,L*	Rock Land (5,0)				
Residuum from quartz-rich granite with bedrock <36 inches (<91 cm) below the surface	L*	**Vaahun** (3,½)				
Residuum from granodiorite low in quartz and high in dark minerals	L*	**Segbwema** (3,0)	Mandu (3,½)			
Gravelly colluvium over clayey residuum from siltstone, sandstone, or shale	G*	**Momenga** (4,0)				
	I*	Belia (4,0)				
Upland erosion surfaces of highly weathered material						
0-24 inches (0-60 cm) of gravelly or gravel-free colluvium over hard granite	J*	Mabanta (5,0)				
24-48 inches (60-122 cm) of gravelly, fine-loamy colluvium over residuum from granite	J*	**Timbo** (4,0)				
10-24 inches (25-60 cm) of gravel-free, fine-loamy colluvium over residuum from sandstone	I*	Diabama (4,0)				
10-24 inches (25-60 cm) of gravelly fine-loamy colluvium over vermicular ironpan	I*	Wari (4,0)				
10-24 inches (25-60 cm) of gravel-free, fine-loamy colluvium over vermicular ironpan	I*		Makoima (4,1)			
Very gravelly and usually clayey reworked material	G*	**Njala** (5,0)				
	I*	Batkanu (5,0)	Mayanki (4,1)			
	J*	**Makeni** (5,0)				
	L*		Fanima (4,0)			
	L*		**Manowa** (4,0)			
	L*	Waima (4,0)	Giema (3,0)			
0-10 inches (0-25 cm) of gravel-free topsoil over gravelly subsurface over gravel-free subsoil	G*		Belebu (4,0)			
24-48 inches (60-122 cm) or more of gravel-free colluvium over gravelly material	J*	**Mabassia** (4,0)				
	L*	**Baomo** (4,0)				
	L*		Ngelehun (3,0)	Panderu (2,1)		
Calluvial footslopes and upper river tributary terraces and inland swamps						
10-24 inches (25-60 cm) of gravel-free, fine-loamy colluvium over gravelly material	G*		**Mokonde** (4,0)		Batiema (3,3)	
	I*		Malinka (4,0)	Matutu (4,2)		
	J*	Rosinth (5,0)				
24-48 inches (60-122 cm) of gravel-free, fine-loamy colluvium over gravelly material	G*		**Bonjema** (4,½)		**Pelewahun** (2,3)	
	I*		Mankahun (4,0)	Masuri (4,1)		
	J*	**Bosor** (4,0) **Tubum** (4,0)				
	L*		Tisso (3,0)			
24-48 inches (60-122 cm) of gravel-free, fine-loamy alluvium over groundwater laterite	I*			Masebra (3,3)	Massimo (2,4)	
	I*			Modina (3,3)		
Coarse-loamy alluvium and colluvium > 48 inches (>122 cm) thick over groundwater laterite	I*				Romankne (2,4)	
Coarse-loamy alluvium and colluvium	J*			**Panlap** (2,3)	**Mankane** (0,4)	
	L*					**Keya** (0,4)
Fine-loamy colluvium and alluvium	J*	**Masheka** (4,0)	**Masuba** (3,0)			
	L*		Yumbuma (3,0)	**Pendembu** (2,2)	**Kparva** (0,3)	
Fine-loamy alluvium and colluvium	I*			Makonte (3,3)	Kontobe (2,4)	
	I*			Babaibunda (2,3)		
Stream terraces and swamps						
10-24 inches (25-60 cm) of gravel-free, fine-loamy alluvium over gravelly material or groundwater laterite or both	I*		Makoli (4,1)	Mamalia (3,3)	Malop (3,4)	
	I*		Matamba (3,2)			
Sandy alluvium	I*	Maroki (5,0)				
Fine-loamy alluvium	G*			Moyambaworo (3,2)		
	I*	Mabang (4,0)				
	I*	Mara (4,0)				
Fine-loamy and clayey alluvium with a thick, dark surface	D*	Bali (4,0)		Tolia (3,1)	Naba (2,3)	Mamu (0,4)
	G*		**Nyawama** (4,0)	**Kania** (3,2)	**Taiama** (2,3)	
Clayey sediments	G*					Bonganema (0,4)

(Footnotes given at end of table.)

Table 2 (continued).

Physiography and parent material	Soil province (Fig. 8)	Moisture regime[b] Well drained	Moderately well drained	Imperfectly drained	Poorly drained	Very poorly drained
Alluvial floodplains						
24-48 inches (60-122 cm) or more of gravel-free, clayey alluvium over gravelly material	G*	Mogbondo (3,1f)				
	I*			Tabai (3,2)		
Fine-loamy alluvium	G*	**Pujehun** (3,½f)			Masungo (2,4)	
	I*	Magbunga(3,½f)				
	I*	Bom (3,1)				
Fine-loamy and clayey alluvium	D*			Sewa (2,4f)		
	I*			Rochin (2,3)		
Clayey alluvium	D*	**Taso** (2,½f)		Torma Bum(1,2f)	**Gbehan** (0,3)	Senehun (0,4)
	D*		Koyema (2,1f)	Sangama (1,3f)		
	G*	**Gbesebu** (2,1f)		**Mokoli** (1,3f)		
	I*			Malansa (2,3)	Rokel (2,4)	
	I*				Mabole (2,4)	
	I*	Mateboi (2,1)		Seli (2,2)		
	J*	**Makundu** (2,½f)				
	L*				Blama (0,3)	Dowjo (0,4)
	L*	**Moa** (1,½f)				
Sandy beach ridges and lagoons						
Sandy material with little profile development	B*	**Sahama** (5,0)			Hahun (2,3)	Mani (0,4)
Sandy material with distinct profile development	B*	**Gbamani** (5,0)				
Tidal swamps						
Clayey sediments	C*					**Rokupr** (0,5)

[a] Detailed data and discussion are given in the text for the soil series names set in **heavy type**.
[b] First number in parentheses after each soil series name indicates duration of soil moisture deficiency in months.
Second number in parentheses indicates duration of waterlogging at the surface as follows:
0 = none
½ = 1 to 15 days
1 = 10 to 30 days, including occasional brief submergence
2 = 1 to 2 months
3 = 2 to 4 months, including submergence about 1 month
4 = 3 to 5 months, including submergence > 1 month
5 = floods daily at high tide unless protected by levees
The letter "f" indicates soils flooded by river water with high oxygen content.

ter content (see also Section 4:12:1). In the field, however, it is difficult to distinguish between the kinds of epipedons because of the poor correlation between soil color and organic matter content in Sierra Leone. For instance, a young alluvial Gbesebu soil, N13, with 4.47-percent organic carbon in the A_1 horizon, has a color of 10YR 4/3 (ochric epipedon); by contrast, Nyawama, N100, a river terrace soil with 1.26-percent organic carbon, has a color of 10YR 3/2 (umbric epipedon). The latter is darker colored because the organic matter more fully coats the smaller specific surface area of the Nyawama A_1 horizon, which is 23-percent clay, than the Gbesebu A_1 horizon, which is 46-percent clay.

Soils of the young alluvial floodplains have the highest organic matter contents. Both umbric and ochric epipedons occur in these areas. The organic carbon contents of the A_1 horizons range from 2.71 percent in the well-drained, sandy Pujehun soil under secondary farm bush to 13.48 percent in the poorly drained, clayey Gbehan soil under grass vegetation. The reasons for the high organic matter content in these floodplain soils are a relatively good moisture and nutrient supply and the low-intensity agricultural use thus far because of flooding hazards. In contrast, the surface horizons of soils of stream terraces and the colluvial footslopes have the lowest organic matter contents, ranging from 1.12-percent to 3.34-percent organic carbon. They may also have either ochric or umbric epipedons. Their low organic matter content is probably related to their frequent use for primitive agriculture in a shifting cultivation system with rather short fallow periods. The soils of the upland old erosion surfaces and steep hills have intermediate organic matter contents, ranging from 2.01-percent organic carbon in the steep Segbwema soil to 4.19 percent in the more level Makeni soil. Although organic matter content here also depends upon the duration of the fallow period, erosion is an additional factor on steep slopes. This is probably why soils on steep hills have ochric epipedons, while soils of the gently sloping upland erosion surfaces have ochric or umbric epipedons.

Charcoal from partially burned vegetation occurs in variable amounts in many soil profiles, causing organic matter content to be somewhat erratic.

4:2:2. Mineral weathering, leaching of soluble substances, and formation of secondary minerals

Weathering of primary minerals is the result of instability under atmospheric conditions, especially those minerals that have been formed at much higher temperatures and pressures. The rate of weathering in Sierra Leone is rapid because of the high temperature and abundant rainfall. Most minerals in the soil are silicates. Weathering breaks down the crystalline structure of silicates, releasing silica, aluminum, iron, and bases. Bases, such as calcium and magnesium, and part of the silica are in soluble form and are leached away by the abundant rainfall. The remaining silica combines with aluminum and forms 1:1 clays. The surplus aluminum and iron may form gibbsite and goethite. Thus, the clay fraction of many soils in Sierra Leone consists mainly of 1:1 clays, gibbsite, and goethite and has a low cation-exchange capacity. The remaining primary minerals, especially quartz, are resistant to weathering and are concentrated in the sand fraction.

Two kinds of weathering horizons are common in the subsoils of Sierra Leone soils: a **cambic horizon,** which is slightly weathered, and an **oxic horizon,** which is strongly weathered and has a low cation-exchange capacity and very few or no weatherable minerals (see *69* and Section 4:12:1). Well-drained cambic horizons occur in soils on steep hills (Vaahun, Momenga). Erosion constantly exposes fresh weatherable minerals to the surface so that these minerals, and sometimes weathering bedrock, are present in the subsoil. The Segbwema soil, which also occurs on steep hills, presents a boundary case between a cambic and an oxic horizon. Cambic horizons also occur in some poorly drained soils such as Panlap, Mankane, etc. Strong weathering is prevented in these soils, probably because flooding during the rainy season prevents leaching. In soils of the young alluvial floodplains, cambic or oxic horizons are present, depending upon whether or not the catchment area of the river contains a source of weatherable minerals. Soils such as Gbesebu and Pujehun, which have high amounts of mica in the sand and silt fractions but a low cation-exchange capacity, have cambic horizons. Oxic horizons, which occur in Gbehan, Makundu, and Moa soils, contain few weatherable minerals and have a low cation-exchange capacity. The presence of oxic horizons in young alluvial floodplain soils is a good example of the importance of preweathering of the parent material.

4:2:3. Illuviation of clay, iron, or organic matter

Illuvial horizons may be formed when clay, iron, or organic matter is transported from the surface horizon and accumulates in the subsoil. In Sierra Leone the great surplus of rainfall over evapotranspiration in the rainy season promotes the mobilization and transportation of these materials through the soil profile. The pronounced dry season may be one of the essential factors for the subsequent deposition of the migrating materials.

Two kinds of illuvial horizons, a spodic horizon and an argillic horizon (see *69* and Section 4:12:1), occur in Sierra Leone soils. A **spodic horizon** is a horizon of accumulation of illuvial amorphous humus and aluminum, with or without iron. Soils with a spodic horizon (Gbamani series) occur on the oldest sandy beach ridges along the coast in soil province B*. They have developed in very permeable, almost pure quartz sands.

The **argillic horizon** is an illuvial horizon in which fine silicate clays, often with iron, have accumulated to a significant extent. Clay coatings are a characteristic feature of argillic horizons. They are formed when, upon drying, water is drawn from the noncapillary pores and the clay is filtered out and deposited on the ped surfaces and on the walls of pores as clay coatings. During the field work in Sierra Leone, clay coatings were not detected except in the Pendembu and Pelewahun (N47) soils. Later, however, a micromorphological study[1] on thin sections of nine soil profiles belonging to six different soil series indicated the presence of clay skins in Njala, Pelewahun, Makeni, and Taiama soils and their absence in Momenga and Gbesebu soils. As a consequence, several soils that formerly were considered to have a cambic or oxic horizon (*23*) were found to have an argillic horizon. Unfortunately, micromorphological data are available for only a few soils. By extrapolating the available thin-section data to other similar soils and utilizing data about the clay distribution in soil profiles, the presence or absence of argillic horizons in the other soil series has been inferred. Apparently, argillic horizons are widespread in Sierra Leone. They occur in many upland soils of the old erosion surfaces (Njala, Makeni, Manowa, and Mabassia series) and in several of the soils of colluvial footslopes and stream terraces (Mokonde, Bonjema, Pelewahun, Masheka, Bosor, Pendembu, Nyawama, Kania, and Taiama series).

4:2:4. Formation of gley, plinthite, and hardened plinthite glaebules

In seasonally wet soils in the presence of organic matter, iron is mobilized by reduction because of low redox potentials. It is transported over relatively short distances in the soil profile and oxidized in the form of reddish mottles along the biggest pores, where higher redox potentials prevail. Manganese, if present, undergoes similar changes but at different levels of redox potential. Thus a gleyed horizon develops that is characterized by reddish mottles in which iron has been concentrated and by grayish spots from which iron has been removed.

Plinthite (*69*) is similar to gley but more strongly developed and more highly weathered. It is a sesquioxide-rich, humus-poor, highly weathered mixture of clay with quartz and other diluents, and it occurs as a red mottled material that irreversibly hardens on exposure to repeated wetting and drying. The high rainfall and distinct dry season of Sierra Leone are optimum for the formation of plinthite. Saturated or nearly saturated water conditions in the soil during the rainy season cause segregation of iron, so that it crystallizes to goethite or similar minerals during the dry season (*65*). In many places, additions of iron from overlying horizons or from higher adjacent areas probably occur. The reddish parts of the plinthite, which contain much iron, harden irreversibly when exposed to repeated wetting and drying. The hardening process involves segregation and crystal-

[1] Personal communication from Dr. E. B. A. Bisdom and Ir. R. Miedema of the Netherlands Soil Survey Institute and the Agricultural University, respectively, at Wageningen, The Netherlands.

lization of iron into a continuous assemblage that acts as a skeleton, thus ensuring induration (*48*). The hardening process is accelerated by the removal of the forest cover and by erosion, thus resulting in more intense wetting and drying cycles (*1*). If much iron is present in the parent material, the plinthite mottles may be so abundant that they become connected with each other and form a continuous phase that, upon hardening, develops into a massive ironstone hardpan. With less iron present in the parent material, the individual plinthite mottles are not connected with each other; upon hardening, therefore, these mottles develop into gravel-sized, indurated plinthite glaebules.

Gley is present in poorly drained soils that are immature or that do not have enough iron for plinthite development (such as the Keya and Kparva series). Plinthite is present in many soils in Sierra Leone, especially in the imperfectly or poorly drained soils that are waterlogged during the wet season but dry out completely during the dry season (Panlap, Mankane, and Mokoli series). Abundant plinthite is also present in soils of the colluvial footslopes and stream terraces (Mokonde, Bonjema, Pelewahun, Masuba, Nyawama, Kania, and Taiama series); in these soils, plinthite is most abundant on poorly drained sites that are waterlogged during the wet season. Waterlogging, however, is not absolutely necessary: plinthite mottles have also been observed, although only to a limited extent, in the subsoils of some well-drained upland soils that are never waterlogged (Njala and Momenga series). In the soils of the young alluvial floodplain, few plinthite mottles have been reported in the moderately well-drained Taso and Makundu soils, whereas abundant plinthite is present in the poorly drained Gbehan soils. Hardened plinthite glaebules of gravel size are abundant in the well-drained upland soils such as the Momenga, Njala, Manowa, Makeni, Mabassia, and Baoma series; in these soils, as much as 80 percent of the total soil mass may be composed of gravels that are mainly hardened plinthite glaebules. Some of the soils of the colluvial footslopes and a few of the stream terraces (Mokonde, Bonjema, Pelewahun, Bosor, and Tubum series) have a very high gravel content in the subsoil, but the surface layer is gravel-free. Hardened plinthite in the form of a massive ironstone hardpan is especially abundant in areas with basic rocks high in iron, such as on the footslopes of the Peninsula Mountains near Freetown.

4:2:5. Formation of a gravel-free surface layer

On the gravelly upland soils such as the Njala, Makeni, and Manowa series, a gravel-free layer up to 10 inches (25 cm) thick may be formed by termite activity, especially by the *Macrotermes* species. These termites build numerous mounds as high as 10 feet (3 m). The mounds consist entirely of material less than 2 mm in diameter, brought up by the termites from the gravelly subsoil. Since the termites leave the gravels in the subsoil, the gravel content of the gravelly layer progressively increases. The same kind of process has been reported in Nigeria (*56, 57*) and in Zaire (*71*). Evidences for the termite activity are the numerous termite mounds and the relatively small percentage of very coarse sand in the gravel-free surface layers as compared to the gravelly layers, because in fact most termites usually do not carry particles larger than 1 mm in diameter. As soon as the mounds are abandoned by the termites, erosion during the rainy season spreads the gravel-free material over the surface, resulting in a gravel-free surface layer. The transition between this layer and the underlying gravelly soil is very sharp. On some relatively low places on the upland and on the colluvial footslopes, a thicker gravel-free layer may be present. This is the result of erosion of the gravel-free layer on higher ground and subsequent deposition on the lower sites. This explains why, on most upland soils, the gravel-free layer is very thin or absent and why this layer becomes progressively thicker downslope. Consequently, a gravel-free colluvium up to more than 48 inches (122 cm) thick may be formed. In a toposequence from the summit of a hill to the valley bottom, the gravel-free topsoil gradually increases in thickness, so that the gravelly subsoil is found at progressively greater depths. The gravelly subsoil gradually decreases in thickness and finally becomes a stone line that separates the colluvium from the residual material. This process of termite activity and subsequent colluviation of the gravel-free topsoil, resulting in the formation of soils with a thick gravel-free surface layer overlying a gravelly subsoil, is widespread on the colluvial footslopes and upper river terraces (for example, Mokonde, Bonjema, Pelewahun, Bosor, and Tubum series). The streams also contribute to this process, especially on the upper river terraces, which are the result of both colluvial and alluvial action.

4:3. AMOUNT AND CHARACTERIZATION OF THE CLAY FRACTION

Clay is the most important fraction of many of the soils in Sierra Leone. In 44 soil profiles studied in detail, 18 to 69 percent of the fine earth (< 2.0 mm) is in the clay fraction in all except five soil series (Sahama and Gbamani on the sandy coastal beach ridges, Panlap and Mankane in the Makeni area, and Keya in the Kenema area) and in the surface horizons of a few other soils. Therefore, detailed analyses were made of the < 0.002 mm clay fraction to help understand the genesis of these soils and guide their use and management.

4:3:1. Mineralogy of the clay fraction

The mineralogy of the clay fraction of soils in the areas that were studied is discussed briefly here; more detail will be given later for individual soil profiles. Detailed clay mineralogy values from Appendix C are presented as averages in Table 3 for areas and subareas. The soil areas discussed are shown in Figure 8.

The kinds of clay minerals in the clay fraction of Sierra Leone soils vary widely. For the most part, these

Table 3. Average composition of the clay fraction (< 0.002 mm) of selected soil profiles in Sierra Leone, grouped according to parent material and moisture regime

Soil province (Fig. 8)	Well and moderately well drained: Soil profile	Quartz (%)	Goethite (%)	Gibbsite (%)	Kaolinite (%)	Illite (%)	Chlorite (%)	Interstratified Kind[a]	Interstratified (%)	Imperfectly, poorly, and very poorly drained: Soil profile	Quartz (%)	Goethite (%)	Gibbsite (%)	Kaolinite (%)	Illite (%)	Chlorite (%)	Interstratified Kind[a]	Interstratified (%)
B*	**Sandy beach ridges**																	
	Sahama T149	7	3	15	66	1	8											
	Gbamani T165	23		11	57	5	2	C	2									
	Average	15	1	13	62	3	5		1									
C*	**Tidal swamps**																	
										Rokupr R1	6		4	77	3	6	C	4
										Rokupr R2	4	1	5	76	3	6	C	5
										Average	5		5	76	3	6		5
D*	**Alluvial floodplain grasslands**																	
	Toso T183	6	2	13	65	4	5	C	5	Gbehan T187	5		14	64	4	9	C	4
G*	**Rokel River Series, Njala area**																	
	Upland and colluvial footslopes																	
	Momenga N123	7		4	57	18	3	V	11	Bonjema N39	6	1	10	47	3	10	C,V	23
	Momenga N86	11	2	5	46	5	6	V	25	Bonjema N105	3	1	6	58	2	17	C,V	13
	Momenga N44	9	2	7	48	6	6	V,C	22	Pelewahun N47	9		9	43	5	14	C,V	20
	Njala N109	1	2	5	68	2	10	C	12	Pelewahun N106	5		7	52		26	C	10
	Njala N108	3	1	6	62	2	12	C,V	14									
	Mokonde N42	3	2	9	52	3	11	C,V	20									
	Average	6	1	6	56	6	8		17	Average	6		8	50	3	17		16
	Stream terraces																	
	Nyawama N100	2		12	72	1	10	C	3	Kania N70	4		13	70	2	9	C	2
	Nyawama N71	5		11	74	2	7	C	1	Taiama N101	4		6	63	2	17	C	8
	Nyawama N15	6		9	74	4	4	C	3									
	Average	5		11	73	2	7		2	Average	4		10	66	2	13		5
	Alluvial floodplains																	
	Pujehun N80	5	1	14	69	2	6	C	4	Mokoli N14	5		12	71	2	7	C	3
	Gbesebu N125	3		13	74	3	4	C	3									
	Gbesebu N13	4	3	12	70	3	5	C	3									
	Average	4	1	13	71	3	5		3									

[a] C represents 10-14C (illite interstratified with chlorite) and V represents 10-14V (illite interstratified with vermiculite); the predominant one is listed first when both are given. Both are described in the introduction to Appendix C.

Table 3 (continued).

Soil province (Fig. 8)	Soil profile	Well and moderately well drained: Quartz (%)	Goethite (%)	Gibbsite (%)	Koolinite (%)	Illite (%)	Chlorite (%)	Interstratified Kind[a]	Interstratified (%)	Imperfectly, poorly, and very poorly drained: Soil profile	Quartz (%)	Goethite (%)	Gibbsite (%)	Koolinite (%)	Illite (%)	Chlarite (%)	Interstratified Kind[a]	Interstratified (%)
J*	**Granite and acid gneiss, Makeni area**																	
	Upland and colluvial footslopes																	
	Timbo P19	1	9	31	52	3	3	C	1	Ponlap P1	3		11	77	4	4	C	1
	Makeni P2	2	3	13	75	2	4	C	1	Mankone P8	4		12	74	5	5		
	Mabassia P71	5	2	20	63	3	4	C	3									
	Mabassia P108	4	5	20	62	4	4	C	1									
	Bosor P60	2	4	21	67	2	2	C	2									
	Tubum P13	6		14	70	6	3	C	1									
	Masheka P49	3		17	71	4	3	C	2									
	Masuba P9	6		10	73	5	3	C	3									
	Average	4	3	18	67	3	3		2	Average	4		12	75	4	5		
	Alluvial floodplains																	
	Makundu P104	4	1	11	75	3	3	C	3									
L*	**Granite and acid gneiss in the upper Moa Basin, Kenema area**																	
	Upland and colluvial footslopes																	
	Vaahun 145010	2	1	7	69	4	17			Pendembu,								
	Segbwema 145005	4	4	4	81	4	1	C	2	Kpuabu 2	1		15	74	5	5		
	Manowo Kpuabu 1	2	6	24	55	5	8			Keya 145041	4	1	15	73	6		V	1
	Baoma 144801A	3	6	9	71	3	8			Kporvo 145042	4	2	18	65	5	4	C	2
	Averoge	3	4	11	69	4	8		1	Average	3	1	16	71	5	3		1
	Alluvial floodplains																	
	Moa Kpuabu 3	4		11	75	4	6											

[a] C represents 10-14C (illite interstratified with chlorite) ond V represents 10-14V (illite interstratified with vermiculite); the predaminont one is listed first when both ore given. Both are described in the introduction to Appendix C.

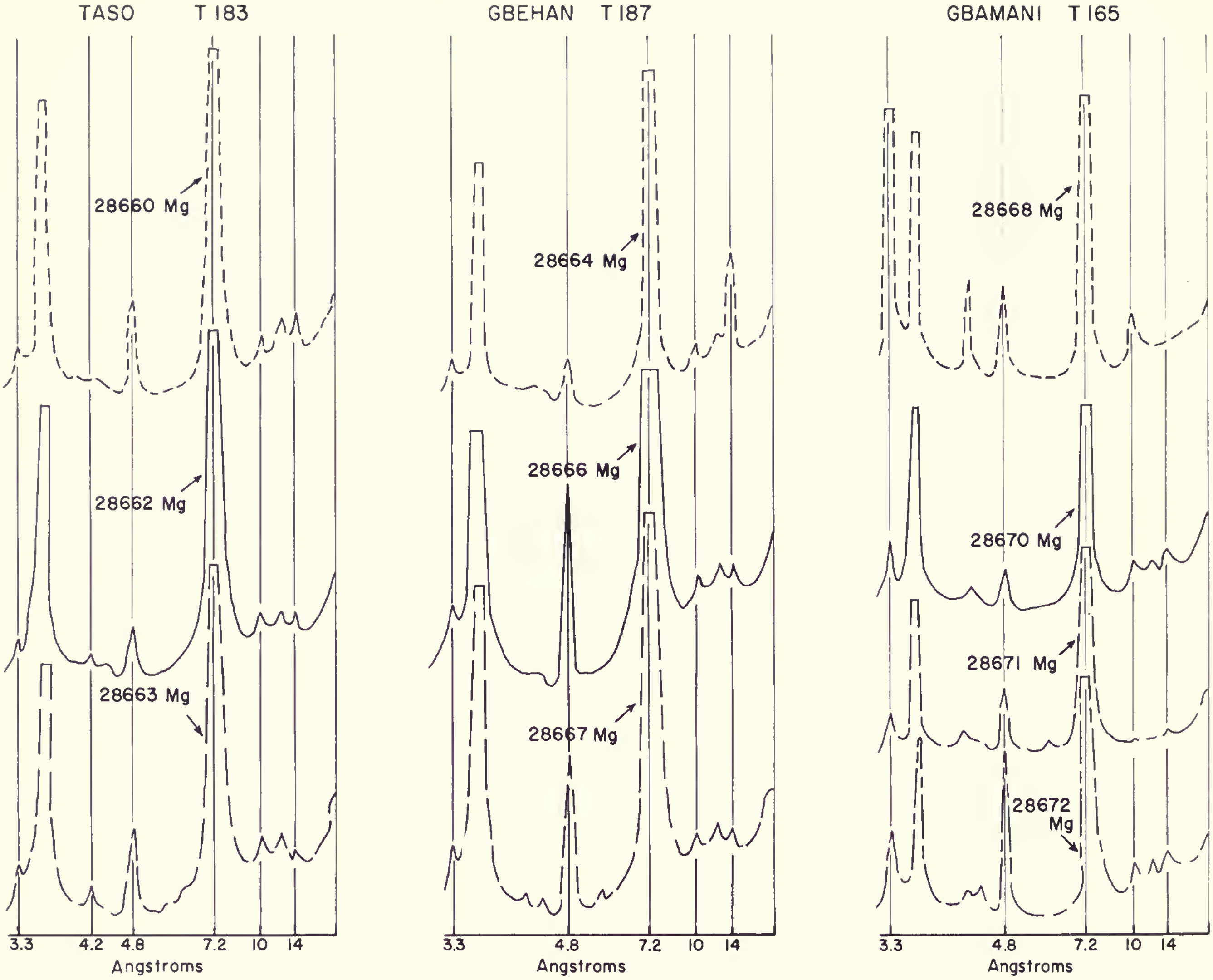


Figure 9. X-ray diffractograms of the $< 2\mu$ clay fraction (glycolated) of selected horizons of some soils in the Torma Bum area.

differences in clay mineralogy are directly related to the kind of minerals in the parent rocks within a physiographic region (Fig. 8) or, in the case of river alluvium, from upstream regions.

Area B* — Sandy Beach Ridges. The small amounts of clay in these sandy soils have been transported by water. The clay fraction is predominantly kaolinite, with a considerable amount of gibbsite, some chlorite, and, in the upper horizons of Gbamani, T165, a large amount of quartz (Fig. 9). Except for the high content of quartz in a few horizons, and the corresponding decrease in kaolinite, the mineralogy of the clay fraction of these sandy soils is similar to that of the alluvial soils (Taso and Gbehan) in the adjacent Area D* (Fig. 8).

Area C* — Tidal Swamps. The high content of kaolinite with only small amounts of chlorite, gibbsite, illite, and an interstratified mineral (10-14C) indicates that these minerals were transported primarily from highly weathered upland granitic materials, such as those in Area J* (Fig. 8); there is also a small admixture of interstratified materials, such as those in the Rokel River Series in Areas G*, H*, and I*.

Area D* — Alluvial Floodplain Grasslands. X-ray diffractograms of the clay fraction of soils in the Torma Bum area are given in Figure 9. Taso, T183, is moderately well drained, whereas Gbehan, T187, is poorly drained. The clay minerals in these two associated soils are similar, except that Gbehan contains slightly more chlorite, but no goethite. Kaolinite is the dominant mineral, accompanied by some gibbsite and small amounts of chlorite, illite, quartz, and an interstratified mineral (10-14C).

Area G* — Rokel River Series in the Njala Area. Most of the soils in this area, especially those on the upland

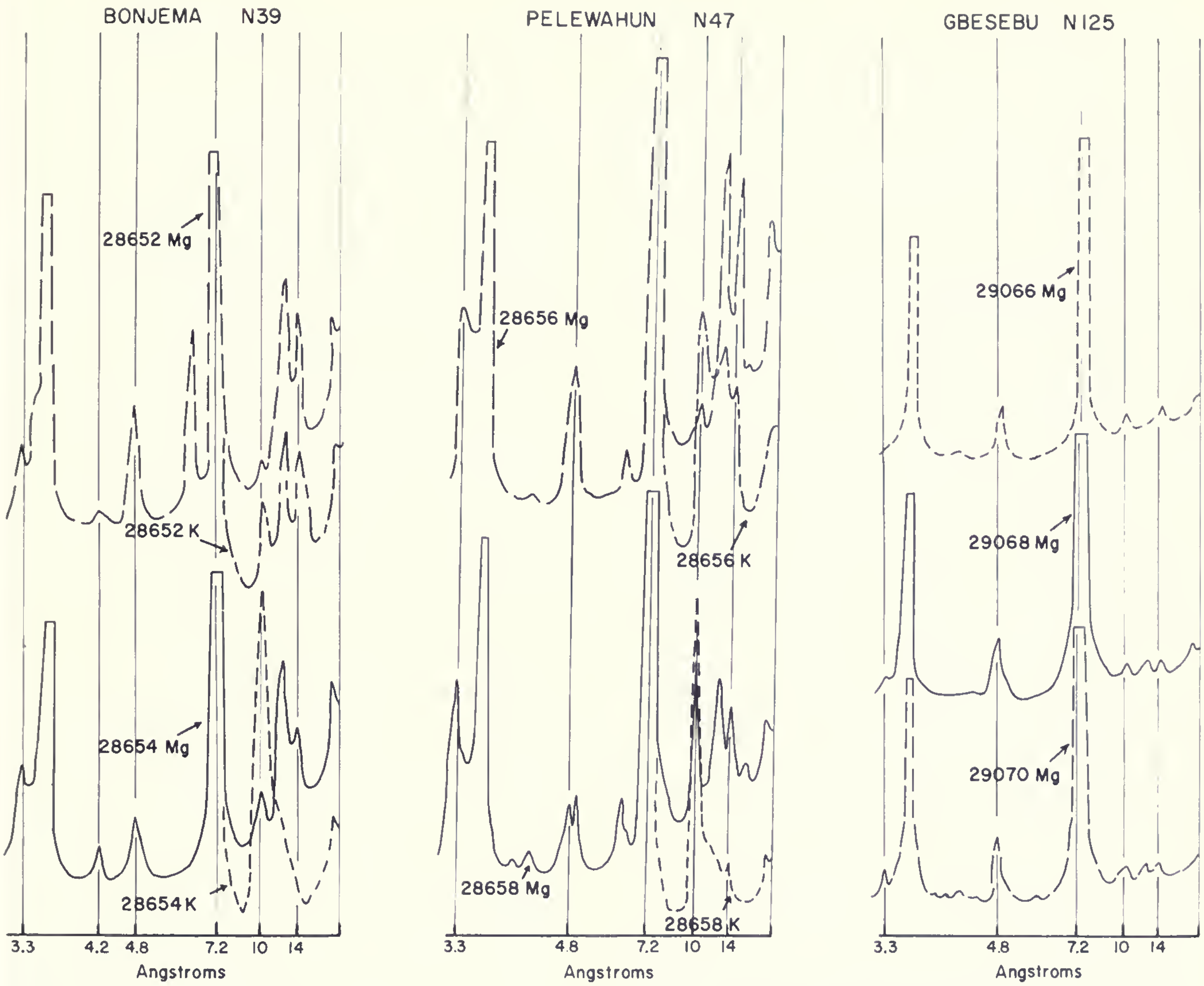


Figure 10. X-ray diffractograms of the $< 2\mu$ clay fraction (glycolated) of selected horizons of some soils in the Njola area.

and **colluvial footslopes,** have developed from sedimentary rocks such as sandstone, siltstone, and mudstone. The mineralogy of the clay fraction of these soils is varied and presents a combination of rare interstratified minerals. X-ray diffractograms of the glycolated, Mg- and K-saturated clay fraction of Bonjema, N39, and Pelewahun, N47, are given in Figure 10. These diffractograms show excellent examples of interstratification of 10 Å illite with 14 Å chlorite, vermiculite, or both, to give 10-14C and 10-14V minerals. In 10 soil profiles studied on the upland and colluvial footslopes in Area G*, the average content of interstratified minerals 10-14C and 10-14V is from 10 to 25 percent of the clay fraction (Table 3), with more in individual horizons (Appendix C).

Kaolinite is the dominant mineral, averaging approximately 45 to 65 percent; the better-drained soils contain slightly more kaolinite than their more poorly drained associates. These values for kaolinite content are distinctly lower than those found for other soils studied in Sierra Leone, which average approximately 70-percent kaolinite. The chlorite content in the better-drained soils (six profiles) averages 8 percent, contrasting with 17-percent chlorite in the more poorly drained soils (four profiles).

The illite content is relatively small (< 6 percent) in these soils, except in the Momenga profiles, which occur on steep slopes, and in the lower horizons of a few other soils (such as Pelewahun, N47) that extend nearly to the bedrock from which the illite comes. The most striking sample (Lab. No. S29065) is from the IIC horizon of Momenga, N123, in which the clay fraction is 46-percent illite and 54-percent kaolinite (Appendix C). Among the soils studied in Sierra Leone so far, this sample is also unique in other properties, such as very high available water-holding capacity (Appendix B).

Gibbsite and quartz are present in small amounts; goethite, if present, is found only in trace amounts. The diffractogram in Figure 10 for the Bonjema B_{1t} horizon, sample S28652 Mg, shows a 6.8 Å line for boehmite present in significant amounts, up to 10 percent. There are also less intense 6.8 Å lines, indicating about 3-percent boehmite, in the two samples of Pelewahun, N47. Since boehmite was present in more than trace amounts only in these three samples, this mineral is not listed in Table 3 or Appendix C.

Compared with soils on the upland and colluvial footslopes in Area G*, the soils on **stream terraces** contain very little interstratified minerals and less chlorite but significantly more kaolinite and gibbsite. In these respects the clay fraction of the soils on the Taia (or Jong) River terraces resembles the clay fraction of soils in upstream Area J*, which indicates that most of the material came from there rather than from the adjacent upland in Area G* (Table 3). The clay fraction of the well-drained Nyawama soils contains more kaolinite but less chlorite than their more poorly drained associates (Kania and Taiama); this is similar to the effect of drainage found in the clay composition of soils on the adjacent upland and colluvial footslopes in Area G*.

The clay fraction of Pujehun, Gbesebu, and Mokoli soils in the **alluvial floodplains** of Area G* is unlike that in soils on the adjacent upland and colluvial footslopes (the alluvial soils contain very little interstratified minerals and chlorite, but more kaolinite and gibbsite), but similar to that in soils in upstream Area J*, from which most of the materials probably came (see Fig. 8 and Table 3). The low content of illite in the clay fraction of these alluvial soils in Area G* is interesting, since there are many mica flakes in the silt fraction of the soils and probably in the sand fraction of Pujehun, N80 (see Appendix B).

Area J* — Granite and Acid Gneiss, Makeni Area. The soils on the **upland and colluvial footslopes** (10 profiles reported) have developed from granite and acid gneiss. The mineralogy of the clay fraction of these soils reflects their advanced age. Kaolinite, the predominant mineral, averages around 70 percent, except in Timbo, P19, which averages 52-percent kaolinite (Table 3). Gibbsite, the content of which is higher in these soils than in any other area studied, varies from 10 to 31 percent, with an average of 17 percent for the 10 profiles. All other clay minerals are present in amounts of less than 6 percent. Very small amounts of the interstratified mineral 10-14C are present in most of the profiles. The well-drained soils studied in the Makeni Area contain slightly less kaolinite and more gibbsite than their more poorly drained associates.

The clay fraction of the Makundu soil, P104, on the **alluvial floodplain** of the Mabole River in this area merely reflects the same mineralogy as the soils on the adjacent upland and colluvial footslopes.

Area L* — Granite and Acid Gneiss in the Upper Moa Basin, Kenema Area. The mineralogy of soil clays from seven soil profiles on the upland and colluvial footslopes and one profile on the alluvial floodplain in this area differs only slightly from the soil clays in Area J* from similar bedrock. The kaolinite content is almost the same, but the gibbsite content is slightly greater on the poorly drained soils in Area L* (see Table 3 and Fig. 11).

Mineralogy of the Clay Fraction in Soils on Alluvial Floodplains. In Areas D*, G*, J*, and L*, the clay mineralogy of the alluvial soils is strikingly similar (see Table 3 and the diffractograms for Taso, Gbesebu, and Moa in Figures 9, 10, and 11, respectively). These soils developed in alluvium from the Sewa, Taia, Mabole, and Moa Rivers, respectively, all of which flow primarily from areas in which granite and acid gneiss predominate.

With the exception of Pujehun, N80, all of these alluvial soils are clayey (41 percent to 67 percent), with considerable silt and relatively low sand contents (Appendix B). Taso, T183, in Area D* and Makundu, P104, in Area J* are especially similar in that they have thick, dark surface horizons (umbric) and oxic subsoils (see Section 4:12).

4:3:2. Total analyses and cation-exchange capacity of the clay fraction

Total K_2O, Fe_2O_3, Al_2O_3, and TiO_2 analyses of the clay fraction of selected soils are given in Appendix C. Total K_2O content of the clay fraction is related to the content of illite as a clay mineral and as a constituent in the interstratified minerals. Total Fe_2O_3 content of the clay fraction is closely related to the natural drainage of the various soils. Total Fe_2O_3 in the well- and moderately well-drained soils ranged from 7 to 20 percent, whereas the poorly and very poorly drained soils contained 1 to 8 percent. In comparison with the < 0.002 mm clay fraction, total analyses of the < 2.0 mm fine earth (Appendix B) of the same soil profiles indicate that the percent of total K_2O tends to be similar, but total Fe_2O_3 content is usually smaller in the < 2.0 mm fine earth fraction than in the < 0.002 mm clay fraction.

The cation-exchange capacity of the clay fraction ranges primarily from 15 to 25 milliequivalents (me) per 100 grams of clay, with the higher values more common among those samples which contain more illite, chlorite, and interstratified clay minerals. The cation-exchange capacity per gram of < 0.002 mm clay (Appendix C) is usually about 2 to 3 times greater than in the < 2.0 mm fine earth (Appendix B).

4:3:3. Amount of water-dispersible clay

Clays that are not dispersible in water are relatively stable and inactive. When less than 5 percent of the total clay in a subsurface horizon is dispersible in water, the horizon may be an oxic horizon, unless it lacks some other essential features or is part of an argillic horizon (see the definition of oxic horizon in Section 4:12:1).

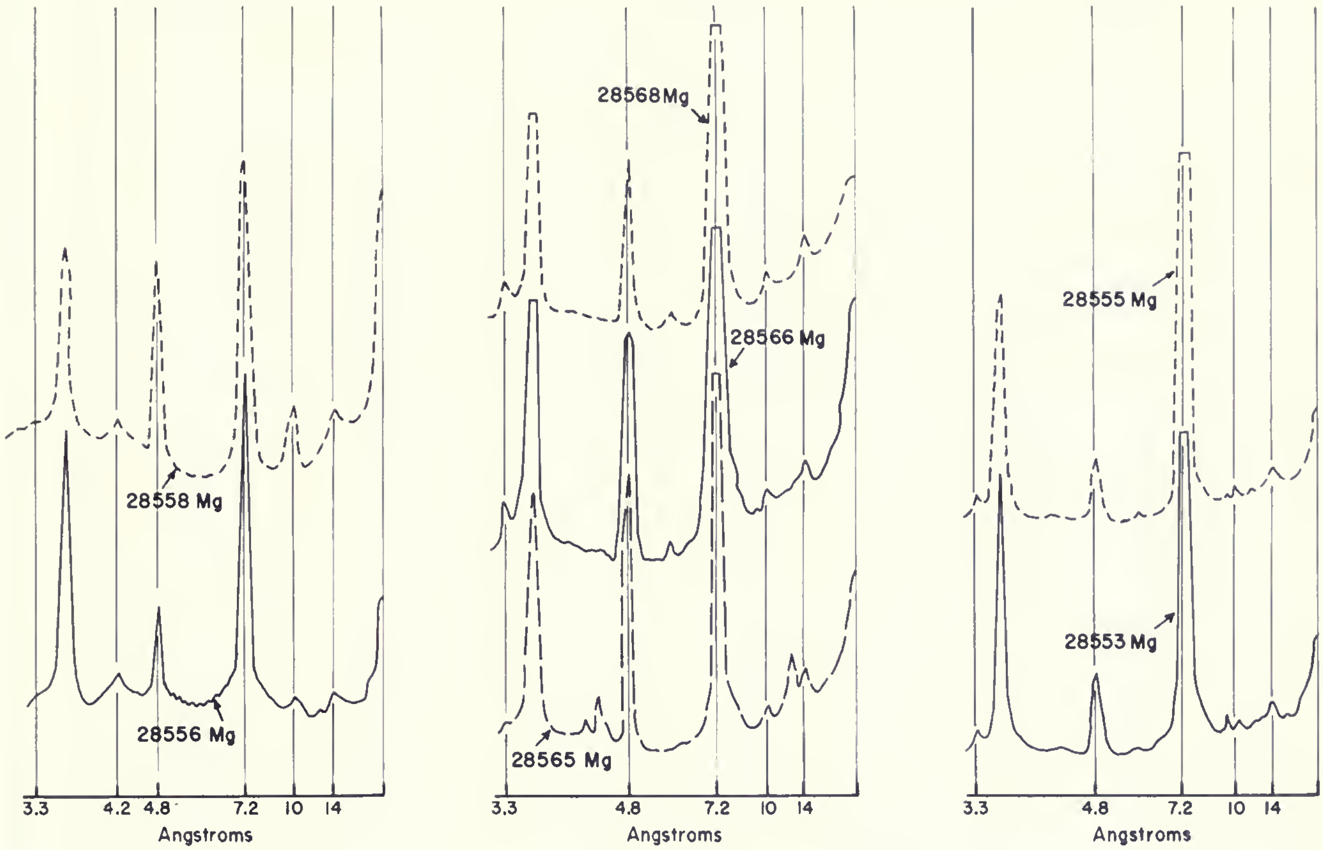


Figure 11. X-ray diffractograms of the $< 2\mu$ clay fraction (glycolated) of selected horizons of some soils in the Kenema area.

The lower horizons of Oxisols such as the Gbehan, Taso, and Makundu soils contain very little water-dispersible clay, as is indicated in Appendix C, even though their total clay content is high.

4:4. AMOUNT AND SIGNIFICANCE OF EXCHANGEABLE ALUMINUM

The parent rocks from which most Sierra Leone soils developed include granite, schist, and gneiss. Common alumino-silicate minerals such as feldspars, hornblendes, chlorites, and micas (both muscovite and biotite) that make up these rocks weather and liberate large quantities of aluminum. Exchangeable aluminum, as determined with 1N KCl, will usually exceed 1 me/100 g of soil in some or all horizons, with the highest values usually in the lower portion of the profile. Soils with surface horizons having 2 to 6 me of exchangeable aluminum per 100 g of soil are not uncommon, and, in general, this contributes to the low productivity capacity of such soils. Soils that developed in Rokel River Series materials on the upland and colluvial footslopes in Area G* contain the largest amounts of exchangeable aluminum, typically in the range of 2 to 4 me/100 g, but Momenga soils contain up to nearly 13 me/100 g in their lower subsoils (Appendix B). The soils in Area J* contain the least exchangeable aluminum, usually less than 1 me/100 g of soil, and soils in Area L* are nearly as low — typically about 1 to 2 me/100 g. Soils in both Areas J* and L* developed from granite and acid gneiss.

The presence of large amounts of exchangeable aluminum in soils usually increases their "unavailable" water content — water that is held against 15 atmospheres of tension. Clayey soils with 3 me/100 g, or more, of exchangeable aluminum in the surface are difficult to cultivate when wet; when they undergo severe drying, as happens during the dry season, they become quite hard. These soils are the least desirable for plantation crops.

Aluminum toxicity to crops is a potential threat on all unlimed soils in Sierra Leone. Toxicity may be suspected on almost all soils if the pH is below 4.8 or if the ratio of exchangeable Ca + Mg to Ca + Mg + Al drops below 0.100. For a crop like sugar cane, the critical ratio may be as high as 0.250, while for a tolerant crop such as cassava it may be as low as 0.050 before serious damage occurs. For other crops such as rice, groundnuts, corn, cocoa, oil palm, etc., the critical ratios probably fall somewhere between 0.100 and 0.200. Therefore, liming has two objectives: to raise the soil pH to at least

Table 4. Toxicity levels of aluminum in soils as determined by the ratio of exchangeable Ca + Mg to Ca + Mg + Al

Soil province, Fig. 8	Soil series, profile no.	Depth, inches	$\frac{Ca + Mg}{Ca + Mg + Al}$
B*	**Sandy beach ridges**		
	Sahama T149	0–6	.223
		6–11	.178
		11–20	.153
		20–31	.151
		31–40	.506
		40–55	.231
	Gbamani T165	0–16	.018
		16–41	.006
		41–48	.086
		48–80	.231
		80–120	.088
	Average		.170
C*	**Tidal swamps**		
	Rokupr oxidized, R1	0–5	.810
		5–22	.494
		22–57	.571
	Rokupr reduced, R2	0–3	.747
		3–26	.684
	Average		.661
D*	**Alluvial floodplain grasslands**		
	Taso T183	0–6	.293
		6–12	.074
		12–22	.138
		35–50	.158
	Gbehan T187	0–5	.082
		5–11	.061
		11–14	.258
		23–52	.518
	Average		.198
G*	**Rokel River Series, Njala area**		
	Upland and colluvial footslopes		
	Momenga N123	0–3	.209
		3–9	.094
		9–33	.030
		33–40	.004
		40–62	.085
	Momenga N86	0–6	.343
		6–16	.107
		16–24	.108
		24–38	.058
		38–50	.050
		50–63	.037
	Momenga N44	0–7	.867
		7–15	.143
		15–33	.039
		33–42	.035
		42–57	.021
		57–69	.021
	Njala N109	0–14	.176
		14–21	.096
		21–49	.229
		49–62	.221
	Njala N108	0–4	.145
		4–14	.113
		14–24	.101
		24–35	.083
		35–57	.131
	Mokonde N42	0–5	.267
		5–15	.167
		15–30	.050
		30–39	.115
		39–60	.064
		60–67	.058
G*	Upland and colluvial footslopes (cont.)		
	Bonjema N39	0–4	.620
		4–16	.233
		16–25	.072
		25–33	.062
		33–57	.065
		57–70	.029
	Bonjema N105	0–20	.158
		20–32	.114
		32–40	.087
		40–50	.173
		50–60	.075
	Pelewahun N47	0–11	.103
		11–17	.074
		17–25	.054
	channel	25–41	.121
	matrix	25–41	.080
		41–72	.082
	Pelewahun N106	0–15	.095
		15–26	.074
		26–41	.036
		41–58	.060
	Average		.127
G*	Stream terraces		
	Nyawama N100	0–21	.083
		21–31	.090
		31–42	.080
		42–60	.148
	Nyawama N71	0–11	.101
		11–17	.107
		17–26	.086
		26–50	.140
	Nyawama N15	0–5	.886
		5–14	.396
		14–33	.192
		33–50	.228
	Kania N70	0–12	.070
		12–16	.080
		16–24	.104
		24–39	.092
		39–56	.085
	Taiama N101	0–13	.085
		13–31	.072
		31–42	.081
		42–63	.065
	Average		.156
G*	Alluvial floodplains		
	Pujehun N80	0–4	.101
		4–12	.128
		12–31	.198
		31–55	.173
	Gbesebu N125	0–4	.141
		4–7	.134
		7–19	.115
		19–25	.182
		25–63	.249
	Gbesebu N13	0–7	.536
		7–42	.117
		42–50	.242
	Mokoli N14	0–6	.181
		6–15	.065
		15–27	.139
		27–60	.268
	Average		.186

Table 4 (continued).

Soil province, Fig. 8	Soil series, profile no.	Depth, inches	$\frac{Ca + Mg}{Ca + Mg + Al}$
J*	**Granite and acid gneiss, Makeni area**		
	Timbo	0–12	.473
	P19	12–19	.278
		19–28	.463
		28–43	.509
		43–70	.688
	Makeni	0–10	.946
	P2	10–20	.500
		20–67	.903
	Mabassia, shallow	0–7	.873
		7–25	.338
	P71	25–39	.308
		39–65	.344
	Mabassia, deep	0–6	.791
		6–13	.428
	P108	13–26	.267
		26–35	.272
		35–59	.750
	Bosor	0–9	.428
	P60	9–18	.114
		18–26	.187
		24–43	.321
		43–51	.203
	Tubum	0–4	.644
	P13	4–13	.321
		13–25	.290
		25–33	.168
		33–54	.246
	Masheka	0–16	.878
	P49	16–26	.268
		26–38	.194
		54–68	.219
	Masuba	0–7	.458
	P9	7–22	.227
		22–67	.261
	Panlap	0–11	.553
	P1	11–23	.618
		23–37	.693
		37–60	.725
J*	**Granite and acid gneiss, Makeni area** (cont.)		
	Mankane	0–6	.452
	P8	6–21	.512
		21–25	.528
	Makundu	0–8	.916
	P104	8–16	.384
		16–21	.178
		21–28	.160
		28–43	.368
		43–74	.236
	Average		.444
L*	**Granite and acid gneiss in the upper Moa Basin, Kenema area**		
	Vaohun	0–6	.965
	145010	6–20	.432
		20–28	.462
	Segbwema	0–13	.601
	145005	28–60	.123
		60–94	.126
	Manowa	0–10	.038
	Kpuabu 1	10–21	.067
		35–70	.106
	Baoma	0–5	.249
	144801A	5–23	.330
		23–43	.800
		43–67	.814
	Keya	5–11	.298
	145041	21–33	.488
	Pendembu	0–7	.022
	Kpuabu 2	7–18	.036
		37–54	.069
	Kparva	0–9	.178
	145042	9–39	.048
		39–66	.178
		68–80	.158
	Moa	0–6	.232
	Kpuabu 3	6–21	.073
		31–59	.188
	Average		.283

5.4 so that exchangeable Al^{+++} is changed to hydrated aluminum oxide, $Al_2O_3 \cdot 3H_2O$; and to increase the Ca + Mg to Ca + Mg + Al ratio to above 0.300, where aluminum toxicity usually does not occur. The Ca + Mg to Ca + Mg + Al ratios for unlimed soils are given in Table 4.

The ratio of exchangeable Ca + Mg to Ca + Mg + Al is lowest (average 0.127) in soils on the upland and colluvial footslopes in Area G* (Table 4), indicating that aluminum toxicity to crops is most likely in this area unless corrective liming is practiced for sensitive crops. On upland soils, the highest ratios are in Area J* (average 0.444), followed by Area L* (average 0.283), so that aluminum toxicity is less likely in these areas. The high ratios of the Rokupr soils in Area C* are associated with much higher exchangeable Ca and Mg levels in these tidal swamps than in the upland soils, even though Rokupr soils contain 1 to 5 me/100 g of exchangeable aluminum.

4:5. AREA B* — SANDY BEACH RIDGES AND LAGOONS

Sandy beach ridges are present in the southern coastal part of Sierra Leone in a strip about 5 to 10 miles (8 to 16 km) wide adjacent and parallel to the Atlantic Ocean shore and including part of Sherbro Island, Turner's Peninsula, and a small coastal strip south of Shenge (Fig. 8). The ridges, ½ to 1 mile (about 1 km) wide, are separated from each other by sandy lagoons. The beach ridges and lagoons consist of Pleistocene and Recent beach sand that is more than 90 percent quartz. Geologically, it belongs to the Bullom Series. The annual rainfall in this area is between 140 and 160 inches (356 to 407 cm), 90 to 95 percent of which falls in the wet season. The vegetation is primarily coastal park savanna (3-feet tall grass and herbs with scattered trees) and farm bush; coastal scrub occurs near the ocean (*17*).

Three landscape units are present: young beach ridges, old beach ridges, and lagoons (*25*). The ridges closest

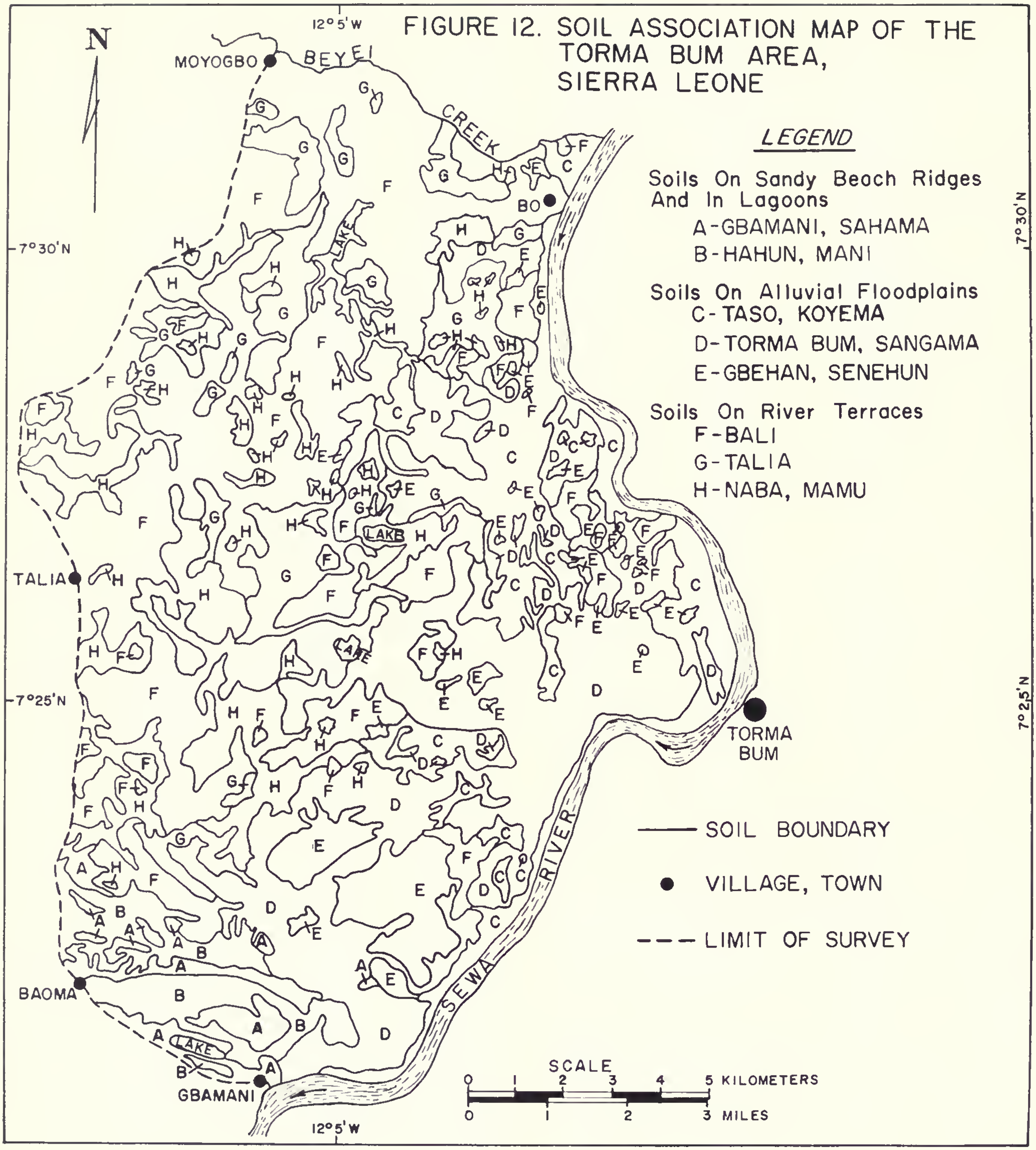


FIGURE 12. SOIL ASSOCIATION MAP OF THE TORMA BUM AREA, SIERRA LEONE

to the sea are the youngest and have soils that show little profile development. On the older beach ridges, there are two kinds of well-drained soils, Sahama and Gbamani, described below. In the lagoons, which are flooded during much of the year, Mani soils occur (Table 2). The soils in Area B* have sand or loamy sand textures. They are infertile and have extremely low water-holding capacities. They are unsuitable for most agricultural crops, although coconuts and cassava grow reasonably well on the ridges.

A small area of soils on sandy beach ridges and in lagoons was mapped by Dijkerman and Westerveld (*25*) near the Atlantic coast, along the Sewa River southwest of Torma Bum (see Fig. 12 and Table 5).

Table 5. Area of different soil associations in the Torma Bum area, as shown in Figure 12

Symbol on map	Major soil series	Area		Percent of total area
		Acres	Hectares	
	Soils on sandy beach ridges and in lagoons			
A	Gbamani, Sahama	1,700	690	3.9
B	Hahun, Mani	1,700	690	3.9
	Soils on alluvial floodplains			
C	Taso, Koyema	6,500	2,640	15.0
D	Torma Bum, Sangama	10,800	4,380	24.9
E	Gbehan, Senehun	2,100	850	4.9
	Soils on river terraces			
F	Bali	14,200	5,750	32.7
G	Talia	3,000	1,220	6.9
H	Naba, Mamu	3,400	1,380	7.8
	Total	43,400	17,600	100.0

Sahama Series. The Sahama soils are well drained and occur on the convex higher parts of sandy beach ridges. The vegetation is usually either secondary bush with many oil palms or tall and medium-height grasses. These soils are approximately 90- to 95-percent sand throughout their profiles.

Sahama soils have three principal horizons with gradual boundaries between them. The very dark grayish-brown to dark brown surface soil is approximately 20 inches (51 cm) thick. It is usually dark enough and deep enough to be umbric, but the organic carbon content of the lower part of this horizon is often less than is specified for an umbric epipedon. The brown to dark yellowish-brown upper subsoil extends from about 20 to 40 inches (51 to 102 cm). The strong brown lower subsoil extends below 40 inches (102 cm).

Sahama soils are very strongly acid, low in available nutrients, and rapidly permeable, with no waterlogging during the wet season. They are very droughty with a very low moisture-holding capacity and low soil moisture content during about five months of the dry season (Table 2). In comparison with Gbamani soils (described below), Sahama soils are slightly better because of their somewhat finer sand and darker surface layer, which contains more organic matter. Despite such qualities, however, Sahama soils are still very poorly adapted to any kind of productive agriculture.

A detailed description and analytical data for a representative profile, T149, of the Sahama series are given in Appendix B.

Gbamani Series. These are well-drained, coarse sandy soils that occur on the convex higher parts of beach ridges. Vegetation is similar to that on the Sahama soils.

Gbamani soils typically have five horizons, of which the illuvial humus (B_{2h}) and iron (B_{2ir}) subsoil horizons are quite distinctive. There is usually a thin, very dark gray surface horizon (ochric epipedon) of coarse sand, unless it has been obliterated by mixing or removed by wind erosion. The dark gray, coarse sand A_2 horizon is very thick — about 40 inches (102 cm). The dark reddish-brown illuvial humus B_{2h} horizon occurs at approximately 40 to 50 inches (102 to 127 cm) below the surface. It contains much more organic matter and has a higher cation-exchange capacity than any other horizon in the profile, but this organic matter is amorphous and does not decompose readily to release plant nutrients. Sometimes this horizon is slightly cemented and hence restricts root growth. The yellowish-red illuvial iron B_{2ir} subsoil horizon (1.85-percent total Fe_2O_3) extends from about 50 to 80 inches (127 to 203 cm) below the surface. The loamy coarse sand C horizon below approximately 80 inches (203 cm) is yellowish brown with distinct strong brown mottles, which indicates that it is saturated with water for short periods of the wet season.

Gbamani soils are very strongly acid, very low in available nutrients in the solum, and rapidly permeable. They are distinctly droughty with a very low moisture-holding capacity and have a low soil moisture content during about five months of the dry season (Table 2). Gbamani soils, among the poorest soils in this area, are unsuitable for most agricultural crops; however, coconuts grow reasonably well on these soils, although they suffer from inadequate moisture during the dry season. Oil palms are numerous on the sandy beach ridges, but their yields are very poor.

A detailed description and analytical data for a representative profile, T165, of the Gbamani series are given in Appendix B.

The poorly drained Hahun and very poorly drained Mani soils (Table 2), which occur in lagoons adjacent to the beach ridges, are described by Dijkerman and Westerveld (*25*). Laboratory data for these two soils are not available, however.

4:6. AREA C* — TIDAL SWAMPS

Tidal swamps are present in Sierra Leone in a strip about 2 to 5 miles (3 to 8 km) wide along most of the coast from Mattru in the south to Rokupr in the northwest. Along the mouth of creeks and rivers they are present up to about 15 to 20 miles (24 to 32 km) inland. Soils in these swamps have formed in a salt- or brackish-water environment from recent marine and estuarine mud. Geologically, these sediments belong to the Bullom Series. The annual rainfall in this area ranges from 150 inches (381 cm) in the south to 110 inches (280 cm) in the northwest. Over most of the area, 90 to 95 percent of the rain falls between May and November; however, in the extreme northwestern part near Rokupr, more than 95 percent of the precipitation falls in that period. On the basis of vegetation, the coastal swamps can be divided into *Rhizophora racemosa* mangrove swamps, *Avicennia nitida* mangrove swamps, and sedge (*Eleocharis dulcis*) swamps (*77*, p. 9). The two types of mangrove swamps are present near the coast and along tidal creeks; the sedge swamps occur between the mangrove swamps and the upland.

Figure 13. Profile of Rokupr clay at the Rice Research Station, Rokupr.

Figure 14. Mangrove (*Rhizophora racemosa*) vegetation at low tide. Rokupr clay soils often develop in coastal mangrove swamps.

In the *Rhizophora racemosa* swamps, very poorly drained Rokupr soils occur, which are described next (see Fig. 13 and 14). These soils are waterlogged throughout the year and never dry out unless they are empoldered to exclude some water. They usually have a fibrous clay or silty clay surface soil over a very dark gray, soft-clay or silty clay mud. Upon empoldering and drying in a noncalcareous environment, they develop distinct yellow jarosite mottles [$KFe_3(SO_4)_2(OH)_6$] and become extremely acid ($pH < 4$) because of the oxidation of sulfur compounds to sulfuric acid (*36, 37, 39, 74*). These soils are known as acid sulfate soils or cat clays. Reclamation is possible by leaching the excess acid with sea water (*37*).

The *Avicennia nitida* swamps have firmer, nonfibrous soils that are sandier or somewhat better drained than those of the *Rhizophora racemosa* swamps. Upon empoldering and drying, these soils do not develop low pH (*73,* p. 46).

Sedge swamps occur between the upland and the marginal mangrove swamps of many rivers. They are flooded during the rains and remain more or less wet during the dry season. Stagnant fresh water conditions occur throughout most of the year because of a lack of creeks and small drainageways. Some of the sedge swamps were apparently once mangrove swamps, for large tree trunks identified as *Rhizophora racemosa* have been found beneath the swamps. Soils of the sedge swamps have a dark surface horizon high in organic matter over a gray silty or clayey subsoil with red mottles.

Most of the soils of the coastal swamps are fertile and can be used for swamp rice. The suitability of the land for rice is determined by the length of time that the swamp is covered by fresh water. The period during which the tidal water is harmfully saline decreases with distance from the sea. Areas for which the fresh water period is too short can be reclaimed by empoldering to exclude saline water so that rice can be grown as a rain-fed crop. A soil survey before empoldering is essential to determine whether any potential cat clays, which become very acid upon drying, are present. Such soils can be reclaimed but need special treatment (*37*). Sedge swamps have stagnant, fresh water throughout the year, but rice cannot be grown there because of excessive flooding. These soils can be reclaimed for rice growing by providing drainage channels large enough to allow the tidal water to flood and drain from the land freely.

A detailed description and analytical data are given in Appendix B for both an oxidized phase of Rokupr soils (profile R1), which has been empoldered, and a reduced phase (profile R2), which floods daily at high tide. Both of these soil profiles were sampled on the Rice Research Station, Rokupr, where there has been much research concerning the characteristics and proper management of these soils. A detailed soil map delineating the distribution of these and other kinds of soils in the Rokupr area is not available, but their general occurrence along the Atlantic coast is shown in Figure 8.

The **Rokupr** soils occur on nearly level tidal swamps and up adjacent stream estuaries. The parent material is recent marine and estuarine mud that is high in sulfur and usually high in organic matter. Textures are typically clay or silty clay — approximately 40- to 60-percent clay, 45- to 30-percent silt, and a relatively low sand content

(Appendix B). The surface horizon is very dark gray to very dark grayish brown (10YR 3/1-3/2). In the subsoil, the color is very dark gray (10YR 3/1-N 3/) under reduced conditions (profile R2); upon oxidation, prominent jarosite mottles develop, which become pale yellow (2.5Y 8/4) when dry (profile R1). This yellowish mud and the smell of H_2S when the soil is disturbed give rise to the term "cat clay." Under natural conditions, the Rokupr soils are very poorly drained and flood daily at high tide. Water control is necessary in order to use these soils for crops such as rice, but it must be done carefully so that excess drainage, oxidation of sulfur compounds, and the development of extreme acidity are avoided.

Moisture relations, sulfur, organic matter, and iron are key factors in characterizing Rokupr soils and chemical changes that occur in them. The total sulfur content is greater than 1 percent in all horizons of the two Rokupr soil profiles that were analyzed (Appendix B), reaching a maximum of 11.5 percent in the B_{21g} horizon of profile R1. This is the highest total sulfur content encountered by Chavengsaksongkram (*15*) in 22 acid sulfate soil profiles from Southeast Asia, South America, southeastern United States, and Sierra Leone. Some typical changes in sulfur that occur in these and related soils are outlined below.

a. Soluble sulfates from sea water, in the presence of organic matter, are reduced to sulfides by sulfate-reducing bacteria. $SO_4 \longrightarrow S$

b. With time and available iron and sulfur, iron sulfide recrystallizes to pyrite.

$$FeS + S \longrightarrow FeS_2$$

c. With drainage and aeration, pyrite oxidizes and yields sulfuric acid, which causes extreme acidity down to pH 2.0 or even lower.

$$4FeS_2 + 15O_2 + 2H_2O = 2Fe_2(SO_4)_3 + 2H_2SO_4$$

Reactions *a* and *b* occur at neutral to alkaline reactions under waterlogged or reducing conditions. The B_{21g} horizon of Rokupr profile R1 has the yellow jarosite mottles, high sulfur content, and very low pH that are characteristic of a sulfuric horizon in which reaction *c* occurs as a result of too much drainage and oxidation.

Rokupr soils contain more exchangeable calcium than most other Sierra Leone soils because the calcium is replenished by sea water. Exchangeable Mg is nearly as high as Ca, except in the sulfuric B_{21g} horizon of profile R1 (Appendix B). Cation-exchange capacity ranges from 20 to 26 me/100 g in the various horizons. At the time of measurement, pH ranged from 4.5 to 2.1; it is markedly influenced, however, by the status of reactions such as those described above.

4:7. AREA D* — ALLUVIAL FLOODPLAIN GRASSLANDS

This area occurs in the Southern Province, along the lower reaches of the Sewa and Waanje Rivers (Fig. 8). The predominant grasses are *Saccharum spontaneum* and *Chasmopodium caudatum* (*17*). The annual rainfall is approximately 140 inches (356 cm), of which 90 to 95 percent falls between May and November (see Appendix A data for Torma Bum). The soils are formed from Pleistocene and Recent river alluvium of the Bullom Series. Unlike the tidal swamps in Area C*, there is no influence of marine or brackish water, because connection with the sea is blocked by the sandy beach ridges (Area B*) that make up Turner's Peninsula. These sandy beach ridges force the Waanje and Sewa Rivers to run parallel to the coast for 30 to 60 miles before reaching the sea. Because these rivers lack an easy outlet to the sea, the alluvial floodplain grasslands are flooded every year as deep as 20 feet (6 m).

The soils on approximately 40,000 acres (16,220 hectares) were mapped by Dijkerman and Westerveld (*25*) west of Torma Bum and the Sewa River (Fig. 12 and Table 5). Distinctly different soils were found on the recent alluvial floodplain near the Sewa River and the older terrace farther away from the river. The recent alluvium, which occurs as a strip 2 to 4 miles (3 to 6 km) wide adjacent to the Sewa River, can be divided into a moderately well-drained natural levee (Appendix B, Taso profile T183) and poorly drained basins (Appendix B, Gbehan profile T187). The soils have clay or silty clay textures, a thick dark humus layer, and high water-holding capacities; however, they are low in nutrients and are so acid (pH 3.6 to 4.2) that aluminum toxicity is a serious problem.

The older terrace is located farther away from the river, between the recent alluvium and the upland (Fig. 12). The soils are less productive than those that developed in recent alluvium. They range from well to very poorly drained and have moderate humus content, low water-holding capacities, and sandy clay loam, sandy clay, and clay textures. They are very low in nutrients and very acid (pH 4). Aluminum toxicity is a serious problem. Detailed information concerning the Bali, Talia, Naba, and Mamu soils that occur on this older river terrace is not presented here but is available elsewhere (*6, 25*).

The recent alluvial floodplain soils, especially those in the basins, can produce excellent rice crops. There are two main obstacles to the agricultural development of this area: the presence of coarse grass, which makes the preparation of a native farm a difficult job, and excessive flooding. Although the first obstacle has been solved by the introduction of a mechanical cultivation scheme, excessive flooding remains a problem. Generally, floating rice is grown; however, if after the flood begins to subside the waters suddenly rise again, the rice is greatly damaged (*77*, p. 42). Local water control by bunding is not possible because of the great height of the flooding. Digging a channel through Turner's Peninsula to provide an outlet for the excess water has been suggested. When the floodwater rises to a predetermined level, the sluices would be opened and the surplus water would flow to the sea by the shortest possible route. If these flood-control and drainage improvements proved feasible and were installed, the soils on the recent alluvial floodplain not only would be more suitable for rice but also would have possibilities for other crops such as bananas, sugar cane, and pineapples. The soils on the older river terrace may well be used for rubber or oil palm, except in the poorly drained areas, which are more suitable for rice or dry season vegetables. Because of the low nutrient status of all soils of the alluvial floodplain grasslands, fertilization is essential. Lime, especially, is needed to correct the low pH and aluminum toxicity.

Taso Series. Taso soils occur on gentle convex slopes on natural levees adjacent to the Sewa River (Fig. 12). They are moderately extensive (Table 5), and they are important because they are better than most soils in the area. The parent material is recent clayey alluvium, containing approximately 45- to 60-percent clay, 45- to 30-percent silt, and small amounts of sand (*25*, and Appendix B).

Textures are typically clay in the A horizon and silty clay in the B horizon, but this is not always true because of variable stratification. The A_1 horizon is about 6 inches (15 cm) thick, black (10YR 2/1), and is high in organic carbon (6 to 8 percent). The A_3 horizon is approximately the same thickness, very dark grayish brown (10YR 3/2), and contains about 4-percent organic carbon. These two A horizons make up the umbric epipedon. Colors of the upper subsoil, about 11 to 33 inches (28 to 84 cm), are yellowish brown (10YR 5/6 to 6/4) with strong brown (7.5YR 5/8) and yellowish-red (5YR 4/6) mottles. The lower subsoil is pale yellow (2.5Y 7/4), with mottles similar to those in the upper subsoil. Taso soils are well to moderately well drained, but they may be flooded from 1 to 15 days each year when the river level is very high (Table 2).

Available phosphorus and potassium and cation-exchange capacity are favorable in the A_1 horizon because of the high content of organic matter; they are fair in the A_3 horizon but low at greater depths. Exchangeable Ca and Mg are low, about 1 me/100 g in the A_1 horizon and much less in the deeper horizons. Exchangeable aluminum decreases with depth from approximately 4 to 1.5 milliequivalents per 100 grams of soil. Base saturation is low, ranging from 2 to 7 percent. The pH increases with depth in the profile (from 4.8 to 5.4 in H_2O, and from 3.8 to 4.0 in KCl). Total K_2O and Fe_2O_3 contents are greater in Taso soils than in corresponding horizons of the poorly drained Gbehan soils associated with them (see next soils discussed).

Taso soils receive deposition periodically, and erosion is not a problem except along stream banks. These soils are permeable because they have many to common macropores. The available water-holding capacity is high because they contain more silt than most soils in Sierra Leone. The soil moisture content is low during only about two months of the dry season.

Taso soils are among the most productive soils in this area. They have favorable physical properties and need only modest fertilization to produce satisfactory yields of the common agricultural crops.

A detailed description and analytical data for a representative profile, T183, of the Taso series are given in Appendix B.

Gbehan Series. Gbehan soils occur in concave basins and in old channels of the Sewa River floodplain (Fig. 12). The vegetation is water-loving grasses and sedges. These soils are of limited extent (Table 5). The parent material is recent clayey alluvium, containing approximately 55- to 70-percent clay; most of the remainder is silt with very little sand (Appendix B).

Textures are typically clay throughout the profile except in the A_1 horizon, which is often silty clay. The black (10YR 2/1) A_1 horizon is usually 5 to 10 inches (13 to 25 cm) thick and very high in organic carbon (13.5 percent). In Gbehan profile T187, however, the dark color does not extend deep enough to qualify as an umbric epipedon and, therefore, the epipedon is ochric (Appendix B). The dark gray (10YR 4/1) subsurface horizon extends from depths of about 7 to 13 inches (18 to 33 cm) and contains nearly 6-percent organic carbon. It has strong angular blocky structure. The subsoil is light gray (2.5Y 7/2) with distinct yellowish-red (5YR 5/6) and strong brown (7.5YR 5/6) mottles. The structure is strong prismatic in the upper part and angular blocky in the lower part.

Gbehan soils are poorly drained. They are waterlogged two to four months annually, including about one month of submergence (Table 2).

Available phosphorus and cation-exchange capacity are favorable in the highly organic A horizon, but they are relatively low in the subsoil. Available and total potassium and total iron contents are lower in poorly drained Gbehan soils than in the better-drained Taso soils. Exhangeable Ca and Mg are low except in the lower subsoil, where they increase to more than 1 me/100 g of soil. Exchangeable aluminum ranges from approximately 6 me/100 g of soil in the A horizon to 3 me/100 g of soil in the B horizon. Base saturation is low except in the lower subsoil, where it increases to 37 percent. The pH also increases (4.8 to 5.5 in H_2O, and 3.6 to 4.2 in KCl) with depth in the profile.

Gbehan soils receive deposition periodically, but they are not subject to erosion. They are moderately permeable due to common macropores. Because of their high available water-holding capacity and low topographic position, these soils are not droughty.

Gbehan soils are suitable for swamp rice production. With adequate drainage and fertilization they can be made moderately productive for other crops, but they would still be less productive than Taso soils under similar management.

A detailed description and analytical data for a representative profile, T187, of the Gbehan series are given in Appendix B.

Detailed information concerning the Koyema, Torma Bum, Sangama, and Senehun soils, which also occur on this recent alluvial floodplain of the Sewa River, is not presented here but is available elsewhere (*6, 25*).

4:8. AREA G* — ROKEL RIVER SERIES IN THE NJALA AREA

This area occurs in the center of Sierra Leone in a belt about 20 miles (32 km) wide stretching from Bumpe to Yonibana (Fig. 8). Mean annual rainfall is about 108 inches (275 cm) in the Njala area (see Appendix A), 90 to 95 percent of which falls between May and November. The vegetation consists of secondary bush, but *Lophira* savanna or *Chasmopodium* grasses are present in some areas where secondary bush has been eliminated by too intensive farming (*17*). This area is part of the interior plain, a vast, gently undulating erosion surface with a few remnant hills (monadnocks) of earlier plateaus. The soils have developed from sandstones, mudstones, and shales of the Rokel River Series (see Section 3:2). Because these rocks are poor in weatherable minerals, the soils developed from them have low nutrient status. The monadnocks, such as the Kasabere Hills of the Kasewe Forest Reserve, consist of more resistant acid-volcanic rocks, which give rise to more fertile soils (*62,* p. 10). Because of the low resistance of the local bedrock, extensive floodplains have developed, especially along the Taia (or Jong) River. More recent changes in base level have made this meandering river cut down again, leaving the older terraces well above the modern floodplain (*26,* p. 48). The presence of three deposition levels along the Taia River indicates that at least three changes in base level have taken place (*24*).

Four major landscape units in the area are the upland erosion surface, colluvial footslopes and upper terraces and swamps, stream terraces, and current alluvial floodplains. The major soil series that occur on these landscapes (see Table 2) are discussed in the remainder of Section 4:8, and additional information is published elsewhere (*76*). The distribution of various soils is shown on the soil map of the Njala area (Fig. 15), and the extent of each soil mapping unit is given in Table 6.

4:8:1. Soils on upland erosion surfaces and steep hills

Upland soils on old erosion surfaces include the Njala and Momenga series. They are 35- to 75-percent hardened plinthite gravel, and the fine earth fraction (< 2.0 mm) is usually sandy clay loam or sandy clay. The gravelly Njala soils are low in available water-holding capacity and low in plant nutrients. Momenga soils are better in these properties but occur on steep slopes and contain harmful amounts of exchangeable aluminum, especially in the subsoil. Njala and Momenga soils are used for shifting cultivation, with upland rice and cassava as the main crops. A long fallow period is advisable. The strongly sloping areas are best adapted to tree crops and forestry.

Momenga Series. The soils of the Momenga series usually occur on steep escarpment slopes of the uplands, with slopes commonly ranging from 15 to 50 percent. These soils are of limited extent in the surveyed area (Table 6).

Table 6. Area of different soil mapping units in the Njala area, as shown in Figure 15

Soil mapping unit: No. on map	Soil mapping unit: Name	Area: Acres	Area: Hectares	Percent of total area
1	Momenga	108	44	0.7
2	Njala, nearly level	1,895	767	13.1
3	Njala, sloping	5,432	2,199	37.7
4	Belebu	56	23	0.4
5	Makande	1,605	650	11.1
6	Bonjema	695	281	4.9
7	Pelewohun	724	293	5.0
8	Nyawama	855	346	5.9
9	Kania	200	81	1.4
10	Taiama	857	347	5.9
11	Pujehun	194	79	1.3
12	Gbesebu	1,032	418	7.2
13	Mokoli	96	39	0.7
14	Gullied Land	18	7	0.1
15	Mosungo Complex	51	21	0.4
16	Rock Land	6	2	0.1
17	Batiema	140	57	1.0
18	Banganema	15	6	0.1
19	Mogbondo	42	17	0.3
20	Moyambaworo	108	44	0.7
	Barrow Pit	7	3	0.1
	Swamp	11	4	0.1
	Water	260	105	1.8
	Total	14,407	5,833	100.0

The parent material is a gravelly colluvium, usually overlying gravelly residual material, over weathered bedrock (saprolite), usually within a depth of 48 inches (122 cm). Hard bedrock may also be present. The colluvial plinthite gravels are rounded, hard, and dense and amount to approximately 50 percent by volume. The residual plinthite gravels, which formed *in situ,* are more irregular, relatively porous, and soft. Quartz veins may occur in the residual material. Quartz gravels may be present in the whole profile, being rounded in the topsoil and more angular in the subsoil. A gravel-free surface layer is only a few inches thick or absent. Textures vary from gravelly sandy loam to gravelly clay in the upper few inches and are gravelly clay in the subsoil. The silt content of the subsoil often increases because of the presence of weathered bedrock pieces (Rokel River Series).

The A_1 horizon is only a few inches thick (ochric epipedon). The subsoil colors vary from very pale brown to strong brown and yellowish red (10YR 7/4, 7.5YR to 5YR 5/6-6/8) with red and brown to white (saprolite) mottles. Topsoil colors range from dark grayish brown to dark yellowish brown (10YR 4/2 to 4/4). The soils are well drained; however, profiles on the lower slopes close to the Taia River may occasionally be flooded during part of the rainy season, as is indicated in the water-table graph for profile N123 in Figure 16.

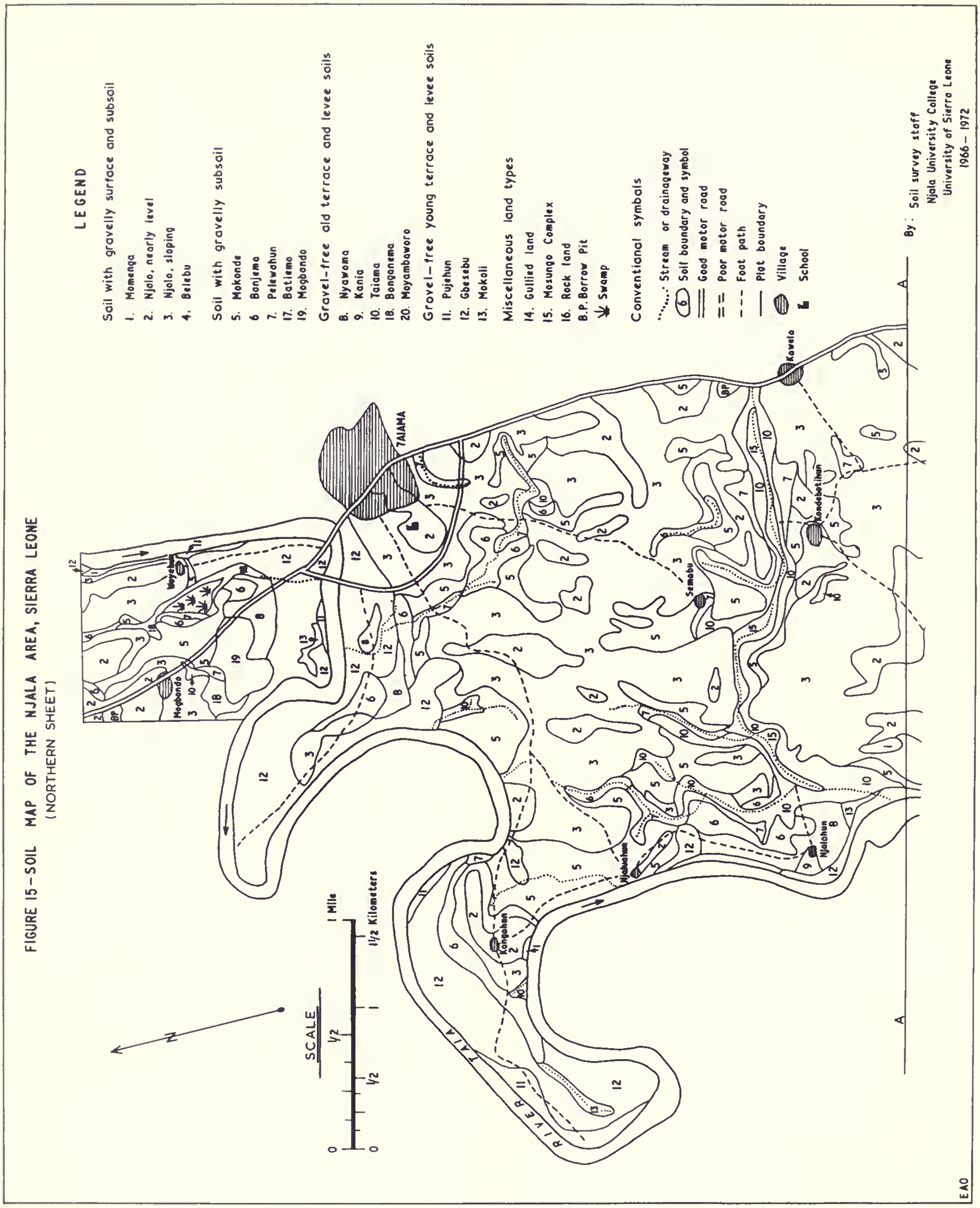


FIGURE 15 – SOIL MAP OF THE NJALA AREA, SIERRA LEONE
(NORTHERN SHEET)

Figure 15 is in three sheets, on pages 34, 35, and 37.

FIGURE 15-SOIL MAP OF THE NJALA AREA, SIERRA LEONE
(MIDDLE SHEET)

Momenga soils are chemically poor, with a low nutrient content. The cation-exchange capacity is fairly high (varying from 10 to 20 me/100 grams of soil), often increasing in the subsoil. Contents of exchangeable Ca, Mg, K, and Na are low, and base saturation is very low except for the topsoil in a few occasions. In comparison with other upland soils (for example, the Njala series), exchangeable aluminum is high. The pH (KCl) is lower, and available water-holding capacity is higher. Organic carbon content is high (up to 4 percent) in the surface few inches but decreases sharply with depth. Total K_2O is reasonably high and increases with depth. Total Fe_2O_3 is highest in the B horizon, lowest in the C horizon (profile N123), and intermediate in the A horizon.

Because of the usually steep slopes, runoff is rapid and erosion is a serious hazard. Permeability is moderate. The soil moisture content is low during about four months of the dry season (Table 2).

Detailed descriptions and analytical data for three profiles of the Momenga series, N123, N86, and N44, are given in Appendix B.

Njala Series. Njala soils are the most extensive ones in the surveyed area (Fig. 15 and Table 6). They occur on nearly level ridgetops (map unit 2, on 0 to 3-percent slopes) and on moderate slopes (map unit 3, usually 3- to 15-percent gradient) downward toward the drainageways (Fig. 17).

The parent material is a gravelly colluvium overlying gravelly residual material over weathered bedrock, which is always found at a depth of more than 48 inches (122 cm). The colluvial plinthite gravels are rounded, hard and dense, and dusky red to reddish black. The gravel content of the colluvial surface layer is usually 40 to 70 percent by volume; the thickness of the layer varies from 30 to 60 inches (76 to 153 cm). The residual plinthite gravels are more irregular, relatively more porous and soft, and are formed *in situ*. Colors are brighter red (10R 4/6). The gravel content varies from 35 to 45 percent, gradually declining with depth, and is replaced at about 8 feet (2.4 m) or more by red plinthite mottles in a light gray to white matrix. The total thickness of both colluvial and residual gravelly layers may be 10 feet (3 m) or more. Quartz veins may be present in the residual material. Quartz gravels may be present in the whole profile, being relatively rounded in the colluvial layers and relatively angular in the residual layers.

A gravel-free surface layer is thin or absent (0 to 10 inches, or 0 to 25 cm), its thickness often depending upon topography. Textures are usually gravelly clay loam in the surface soil and gravelly clay loam to gravelly clay in the subsoil (Fig. 18). Topsoil colors are very dark grayish brown to dark yellowish brown (10YR 3/2-4/4). Subsoil colors are usually yellowish brown to yellow, but strong brown and yellowish-red colors also occur (10YR-7.5YR-5YR 5/8-7/6). Red mottles may or may not be present. The soils are well to moderately well drained and are never waterlogged, as is indicated in the water-table graphs of profiles N109 and N108 (Fig. 19).

The A_1 horizon is usually less than 10 inches (25 cm) thick (ochric epipedon), as it is in Njala profile N108, rather than more than 10 inches, as in N109 (Appendix B). Njala soils have a very low nutrient status for plants. Except for the A_1 horizon, the cation-exchange capacity is less than 10 me/100 g of soil. Exchangeable contents of Ca, Mg, K, and Na are low. In comparison with the Momenga soils, the exchangeable aluminum content is lower, pH (KCl) is higher, and the available water-holding capacity is much lower in Njala soils. The base saturation is very low. The organic carbon content of the A_1 horizon is moderate (about 3 percent) but declines sharply with depth to about 0.5 percent. Total K_2O and Fe_2O_3 increase with depth in the soil profile.

The erosion hazard is slight on nearly level areas (map unit 2) and moderate on sloping areas (map unit 3). Runoff is little to moderate; permeability is rapid. Njala soils are very low in moisture content during approximately five months of the severe dry season (Table 2).

Detailed descriptions and analytical data for two profiles, N109 and N108, of the Njala series are given in Appendix B.

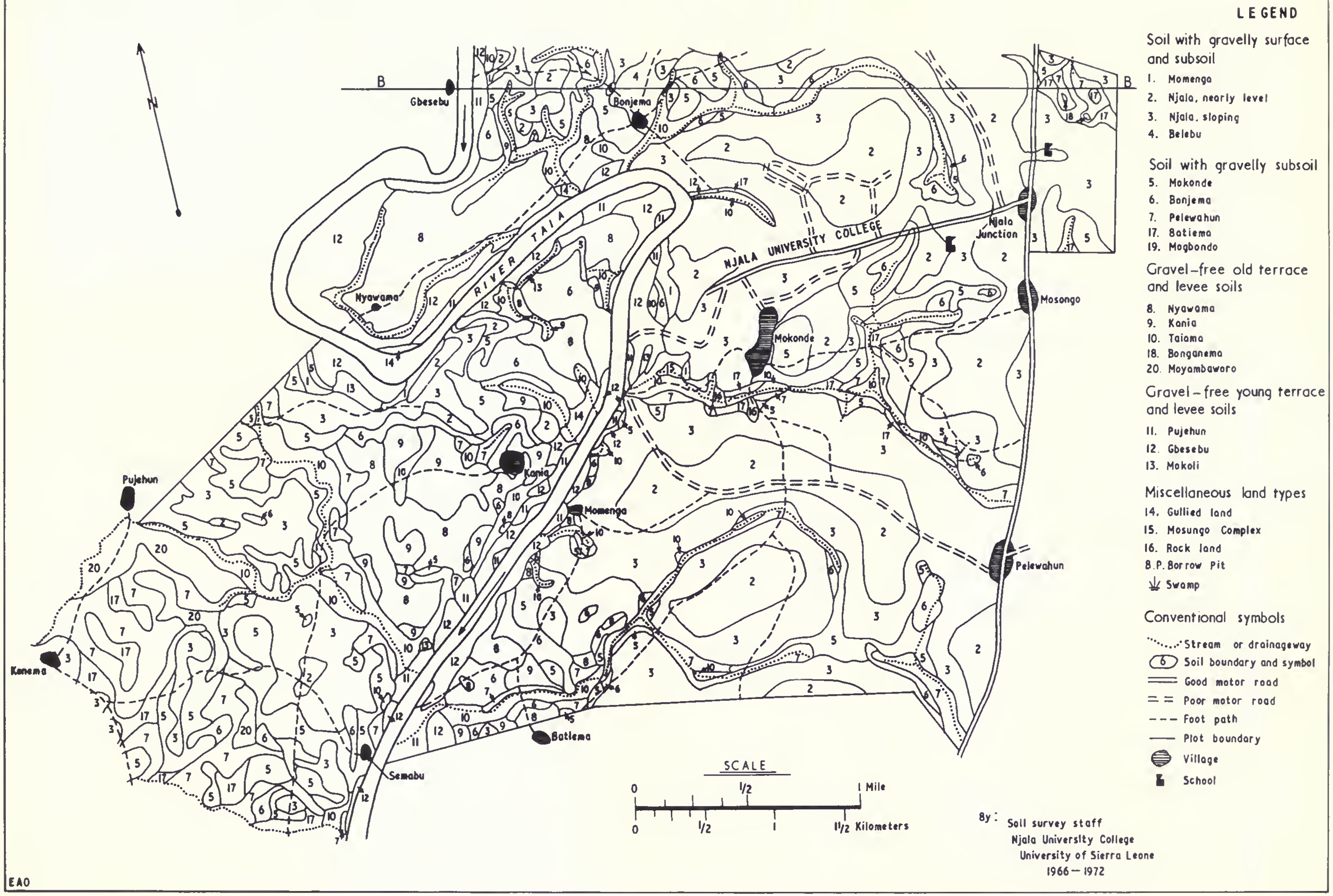
4:8:2. Soils on colluvial footslopes and upper terraces and in swamps

On the colluvial footslopes and upper tributary terraces and in swamps, soils such as Mokonde, Bonjema, and Pelewahun occur (Table 2). Downslope from the upland, the upper gravel-free layer becomes progressively thicker. On the upland footslope and highest terrace are the Mokonde soils, which have 10 to 24 inches (25 to 61 cm) of gravel-free material over a gravelly subsoil. At lower elevations are Bonjema soils, which have 2 to 4 feet (61 to 122 cm) of gravel-free material over a gravelly lower subsoil. In similar parent material, poorly drained Pelewahun soils develop in inland swamps.

Mokonde Series. Soils of the Mokonde series occur on concave colluvial footslopes (2- to 8-percent gradient) and the upper river and tributary terraces. Mokonde soils are scattered throughout the mapped areas (Fig. 15 and Table 6).

The parent material is a gravel-free colluvium, overlying gravelly colluvium, over gravelly residual material, over weathered bedrock. The gravel-free colluvial top layer is 10 to 24 inches (25 to 61 cm) thick. The colluvial plinthite glaebules are rounded, hard and dense, and dusky red to reddish black. The gravel content is usually 40 to 60 percent by volume; the thickness of this colluvial layer varies from 10 to 30 inches (25 to 76 cm). The residual plinthite glaebules, formed *in situ*, are more irregular and relatively more porous and soft. Hard laterite sheets are locally present at depths from 30 to 60 inches (76 to 153 cm) below the surface. The gravel content is high (40 to 80 percent by volume), gradually declining with depth and fading into the weathered bedrock material (Rokel River Series). Quartz veins may be present in the residual material, and quartz gravels may be present in the whole profile.

FIGURE 15 - SOIL MAP OF THE NJALA AREA, SIERRA LEONE
(SOUTHERN SHEET)



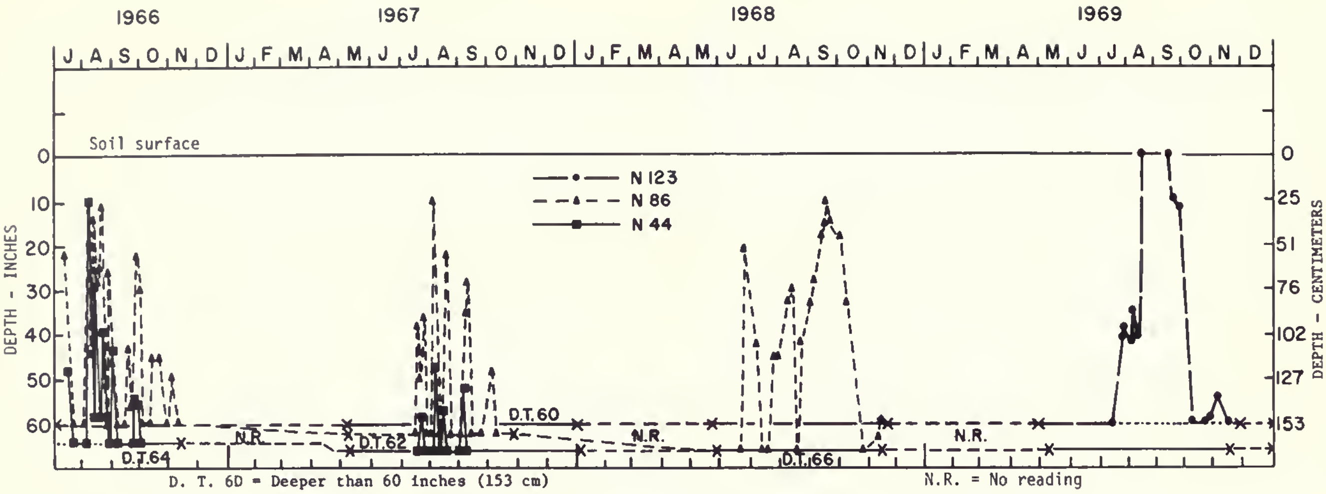


Figure 16. Water levels in Momenga profiles N123, N86, and N44.

Textures are sandy loam in the topsoil, changing into gravelly clay loam or gravelly sandy clay loam in the subsoil. The A_1 horizon is thin, usually less than 10 inches (25 cm) thick (ochric epipedon). Surface soil colors are dark brown to dark yellowish brown (10YR 3/3-4/3-4/4); subsoil colors are yellowish brown to yellow (10YR 5/6-7/6, sometimes 2.5Y 7/6). Prominent reddish (2.5YR 4/8) mottles are usually present in the subsoil.

The soils are moderately well drained and are seldom waterlogged, as is indicated in the water-table graph of profile N42 (Fig. 20).

The chemical and physical properties of Mokonde soils can be compared with the Njala soils. The cation-exchange capacity is less than 10 me/100 g of soil. Exchangeable contents of Ca, Mg, K, and Na are low. Exchangeable aluminum is about 1 to 2 me/100 g, increasing in the subsoil. Base saturation is very low (ap-

Figure 17. Njala soils on the upland in the background, and rice growing on Taiama soils in the valley in the foreground.

Figure 18. Njala gravelly clay loam contains many hardened plinthite glaebules (gravels) throughout the profile.

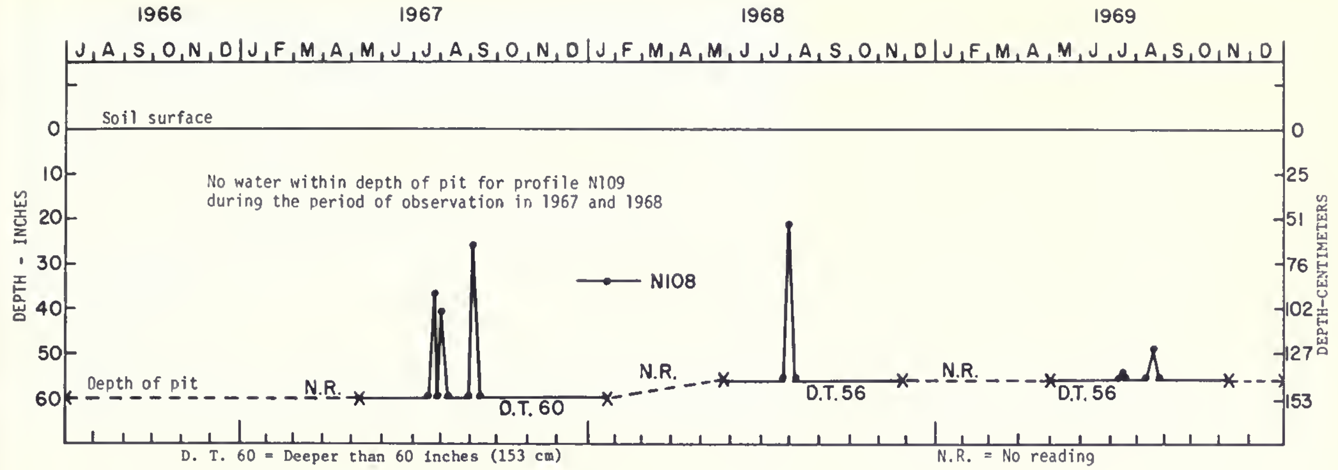


Figure 19. Water levels in Njola profiles N109 and N108.

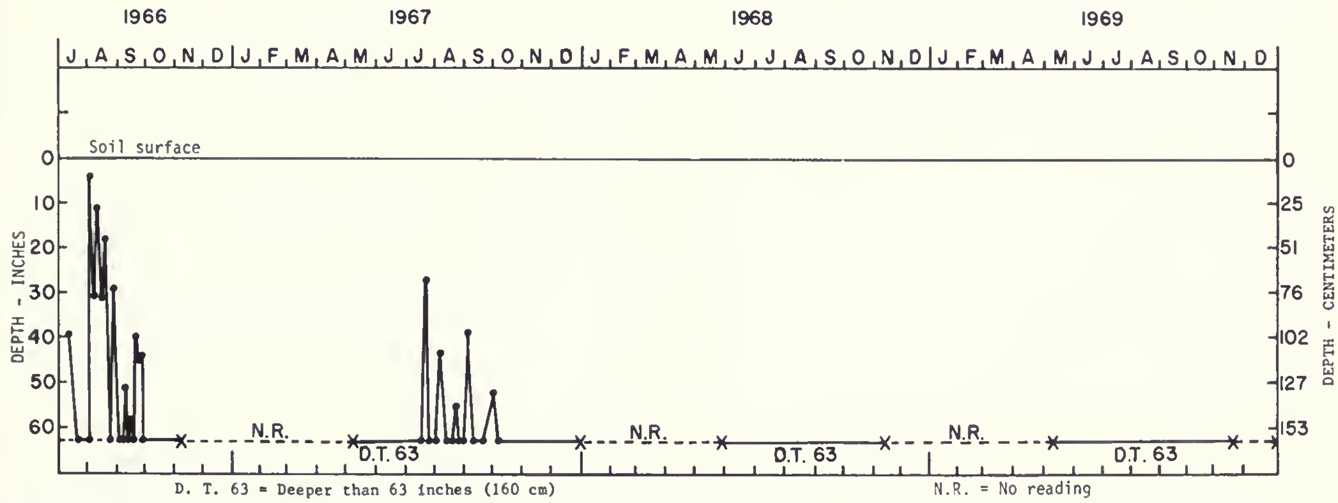


Figure 20. Water levels in Mokonde profile N42.

proximately 5 percent, except for the A_1 horizon); pH is very low (pH KCl = 3.6; pH H_2O increases with depth from 4.4 to 4.9). Organic carbon content of the A_1 horizon is about 2 percent, sharply decreasing with depth to 0.5 percent and lower. Total contents of Fe_2O_3, K_2O, and P increase with greater depth.

Erosion danger is slight on the sloping Mokonde soils, runoff is little, and permeability is moderately rapid. The water-holding capacity is low. The soil moisture content is very low during four months because of the severe dry season (Table 2).

A detailed description and analytical data for a representative profile, N42, of the Mokonde series are given in Appendix B.

Bonjema Series. The soils of the Bonjema series are part of the concave colluvial footslopes (2- to 4-percent gradient) and the upper terraces. Bonjema soils occupy a modest part of the surveyed area (Table 6). They occur near Njala and Mokonde soils on footslopes (Fig. 21) and on terraces of the Taia River.

The parent material is a gravel-free colluvium or alluvium, over gravelly colluvium, over residual material weathered from the local bedrock (Rokel River Series). The gravel-free upper layer is 24 to 48 inches (61 to 122 cm) thick. The gravelly colluvial layer is thinner than the corresponding layer in Njala and Mokonde soils and often has the character of a stone line less than 10 inches (25 cm) thick. The plinthite glaebules are rounded, hard, and dense; the gravel content varies from 30 to 60 percent by volume. The residual material has soft, more irregular, and relatively more porous glaebules, the number of which gradually decreases with depth. Quartz may be present in varying amounts.

Textures are sandy loam to loam in the topsoil, changing into sandy clay loam in the upper subsoil and gravelly clay loam in the lower subsoil. The A_1 horizon is thin, usually less than 10 inches (25 cm) thick (ochric epipedon). The colors of the surface soil are very dark grayish brown to dark brown (10YR 3/2-3/3-4/3), changing with depth into yellowish brown (10YR 5/4-

Figure 21. Boundary between Njala soils (left), which contain many hardened plinthite glaebules (gravels) throughout the profile, and Bonjema soils (right), which developed in gravel-free colluvium 24 to 48 inches (61 to 122 cm) thick over gravelly material.

5/6-5/8); by about 48 inches (122 cm) deep, the color usually changes into light brownish gray (10YR 6/2). Prominent red mottles (2.5YR 4/8) are usually present at depths of 20 inches (51 cm) or more.

Bonjema soils are moderately well to imperfectly drained. They can be waterlogged at the surface and even submerged for a few weeks, as is indicated by the water-table graphs of profile N39 and N105 (Fig. 22). The submersion of profile N105 in 1969 is considered to be exceptional.

Bonjema soils are chemically rather poor. The cation-exchange capacity is low, varying from 6 to 8 me/100 g of soil in the topsoil, decreasing with depth to about 4 me/100 g, then usually increasing again in the lower subsoil to values of 8 to 13 me/100 g. Exchangeable contents of Ca, Mg, K, and Na are low. Exchangeable aluminum is lowest in the topsoil (about 1 me/100 g), increasing with depth to about 3 to 4 me/100 g or sometimes even higher. These values are lower than in Momenga soils but are somewhat higher than in Njala soils. Base saturation is very low except for the upper few inches. The pH is very low (pH KCl is about 3.4; pH H_2O increases with depth from 4.3 to 4.8). Organic carbon content of the A_1 horizon is about 2 percent, sharply dropping with depth. Total contents of Fe_2O_3, K_2O, and P increase with depth.

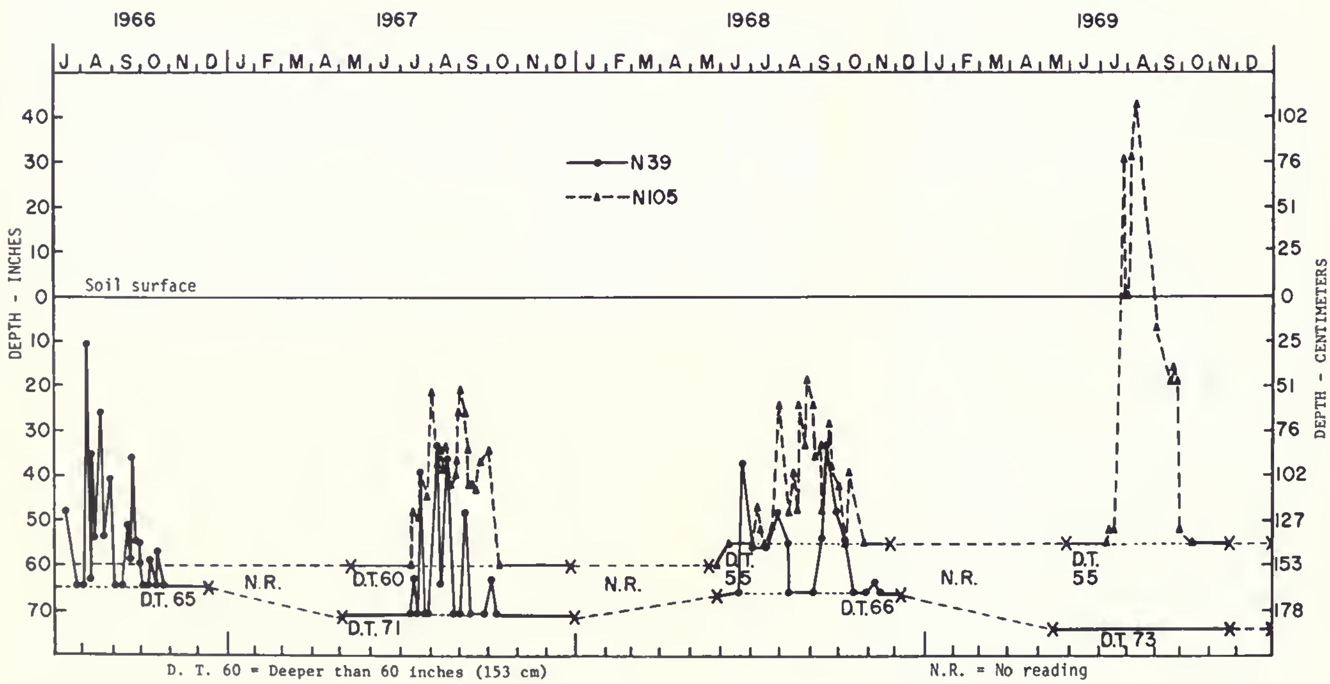


Figure 22. Water levels in Bonjemo profiles N39 and N105.

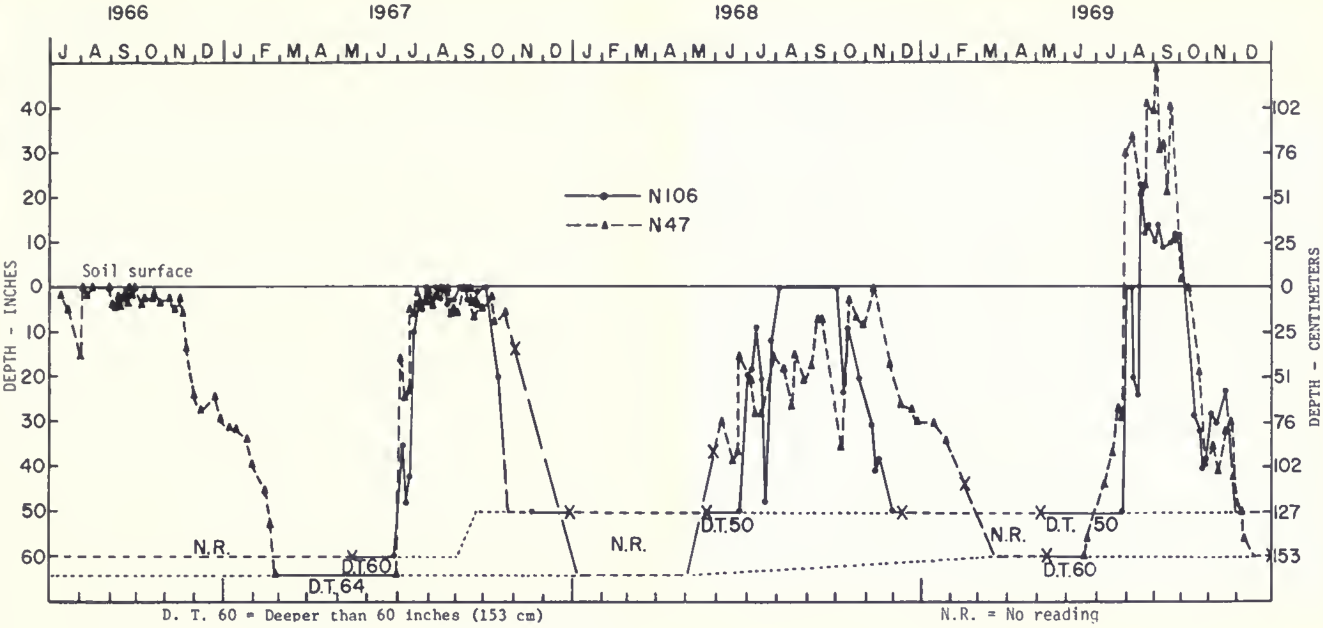


Figure 23. Water levels in Pelewahun profiles N106 and N47.

Erosion danger is slight, runoff is little, and permeability is moderately rapid. The available water-holding capacity is medium but varies somewhat, depending upon the silt content. The soil moisture content is low during four months of the dry season (Table 2).

Detailed descriptions and analytical data for two profiles, N39 and N105, of the Bonjema series are given in Appendix B.

Pelewahun Series. The poorly drained Pelewahun soils occur in the drainageways or inland swamps that dissect the higher parts made up of Njala, Mokonde, and Bonjema soils (Fig. 15). Usually, Pelewahun soils are found in the upper reaches of the drainageways; closer to the Taia River, they gradually fade into Taiama soils (Section 4:8:3). The terrain is nearly level to depressional, with concave slopes of 1 to 3 percent. Pelewahun soils occupy 5 percent of the mapped area (Table 6).

The parent material is a gravel-free colluvium or alluvium, over gravelly colluvium, over residual material derived from the parent rock (Rokel River Series). The gravel-free layer is 24 to 48 inches (61 to 122 cm) thick. The gravelly colluvial layer varies in thickness and can be compared with that of the Bonjema soils. Its gravel content ranges from 20 to 60 percent by volume, and often an important part (up to one-half) consists of quartz gravels. The transition to the underlying residual material is often obscure. Weathering bedrock (saprolite) may be found locally about 70 inches (178 cm) below the surface.

Textures are loam to fine sandy loam in the topsoil, changing into clay loam in the upper subsoil, gravelly clay loam in the lower subsoil, and, as the bedrock is approached, clay. The silt content often increases in the lower subsoil, especially where saprolite is present. Clay coatings are present in the subsoil, which is argillic. The dark A_1 horizon ranges in thickness from 7 to 15 inches (18 to 38 cm), so that both ochric and umbric epipedons are included. The surface soil colors are very dark gray to dark grayish brown (10YR 3/1-4/2). Subsurface soil colors range from yellowish brown to gray (10YR 5/4-5/1); by a depth of 40 inches (102 cm) the color has changed to light gray (10YR 6/1-7/1). Prominent red mottles (2.5YR 4/6-4/8) are present in the subsoil, usually at depths of 20 to 30 inches (51 to 76 cm) or more.

The Pelewahun soils are poorly drained. The water table is near, at, or above the soil surface during three to four months, as is indicated in the water-table graphs of profiles N47 and N106 (Fig. 23). In some years, the soils may be deeply flooded during more than one month.

Pelewahun soils have poor chemical properties. The cation-exchange capacity is low, varying from 6 to 12 me/100 g of soil. Higher cation-exchange capacity values are due to a higher clay content in certain horizons. Exchangeable Ca, Mg, K, and Na are low. Exchangeable aluminum is fairly high, ranging from about 2 to 3 me/100 g in the surface layer to 3 to 8 me/100 g in the lower subsoil. Base saturation is very low, ranging from 3 to 7 percent. The pH is very low (pH KCl is about 3.3; pH H_2O increases with depth from 4.3 to 4.8). Organic carbon content in the A_1 horizon is 1 to 3 percent, sharply dropping with depth.

Erosion is not a problem, and runoff is slow. Permeability is moderate. The water-holding capacity is high. The soil moisture content is low during about two months of the dry season (Table 2). These soils are suited for rice production during the rains and for vegetables in the dry season.

Figure 24. Grass and shrub vegetation on Nyawama soils.

Detailed descriptions and analytical data for two profiles, N47 and N106, of the Pelewahun soils are given in Appendix B.

4:8:3. Soils on stream terraces

The moderately well-drained Nyawama soils, imperfectly drained Kania soils, and poorly drained Taiama soils (Table 2) are the major soils on the lower terraces of the Taia (or Jong) River (Fig. 15); they also occur in other areas. Although they are of only modest extent (Table 6), these soils are very important because they are gravel-free and they occur on topography that is favorable for intensive cultivation. A wide variety of crops can be grown, including oil palm, rubber, coffee, local food crops, feed grains, and vegetables. Many of the areas near the Taia River could be irrigated during the dry season.

Nyawama Series. The Nyawama soils constitute an important part of the nearly level (0 to 3-percent slope) terraces within the large meanders of the Taia River (Fig. 15). The parent material is gravel-free alluvium of the Taia River or, in a few occasions, a deep gravel-free colluvium. The gravel-free material is always more than 48 inches (122 cm) thick. The natural vegetation is grass with scattered shrubs and trees (Fig. 24).

Textures are sandy clay loam to clay loam in the topsoil, usually changing towards clay or sandy clay in the subsoil. The clay content always increases with depth. The A_1 horizon is usually more than 10 inches (25 cm) thick (umbric epipedon). Surface soil colors range from very dark grayish brown to dark brown (10YR 3/2-3/3). Subsoil colors are usually yellowish brown (10YR 5/4-5/6-5/8). Mottling is typical for the subsoil, being distinct and yellowish red (5YR 4/6-5/8) in the upper subsoil, and prominent, abundant, and usually red (2.5YR 4/8-5/8) in the lower subsoil.

Nyawama soils are moderately well drained and never have waterlogging problems at the soil surface, as is indicated in the water-table graphs of profiles N100, N15, and N71 (Fig. 25).

The Nyawama soils have poor chemical properties, but they are better than the soils discussed in Sections 4:8:1 and 4:8:2 — primarily because of the absence of concretions and the presence of a thick A_1 horizon with an organic carbon content of 1 to 3 percent. Organic carbon content decreases rather gradually with depth. The cation-exchange capacity is low, ranging from 6 to 10 me/100 g of soil in the A_1 horizon and 5 to 6 me/100 g in the subsoil. Exchangeable aluminum decreases with depth from 2 to 1.2 me/100 g and is lower than in the gravelly soils. Base saturation is usually low, 3 to 6 percent; much higher values are also possible, however, with up to 35 percent in the A_1 horizon and 8 to 15 percent at lower depths (profile N15). The pH is very low (pH KCl is about 3.8; pH H_2O usually increases with depth from 4.3 to 5.0), but it is slightly

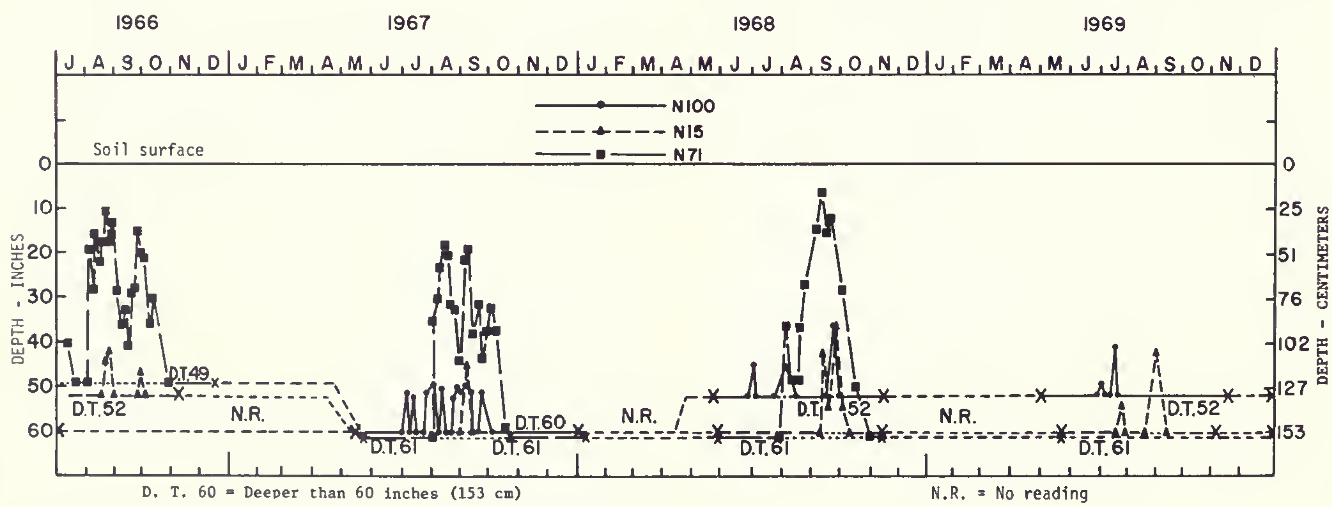


Figure 25. Water levels in Nyawama profiles N100, N15, and N71.

higher than in Bonjema and Pelewahun soils. Total Fe_2O_3 content ranges from 1.5 to 5 percent and increases with depth.

Erosion is not a problem, and runoff is negligible. Permeability is moderate to rapid. The available water-holding capacity is medium. The soil moisture content is low during about four months of the dry season (Table 2).

Detailed descriptions and analytical data for three profiles, N100, N15, and N71, of the Nyawama series are given in Appendix B.

Kania Series. Kania soils occupy the lower areas of the nearly level terraces of the Taia River (Fig. 15). They occur near drainageways on nearly level terrain, with slopes of 0 to 2 percent. These soils are of minor extent (Table 6).

The parent material is gravel-free alluvium from the Taia River, or occasionally gravel-free colluvium. The gravel-free material is always more than 48 inches (122 cm) thick.

Textures are sandy clay loam to clay. The clay content increases with depth. The A_1 horizon is more than 10 inches (25cm) thick (umbric epipedon). Surface soil colors range from black to very dark grayish brown (10YR 2/0-3/2), changing towards yellowish brown or pale brown (10YR 5/4-5/8-6/3) in the upper subsoil and towards light brownish gray to light gray (10YR 6/2-7/1) in the lower subsoil. Mottling starts within 22 inches (56 cm) from the surface, being first strong brown (7.5YR 4/4-5/6) and gradually changing into distinct and prominent red (2.5YR 4/8).

Kania soils are imperfectly drained. They are usually waterlogged at the surface for about two months, including submergence of approximately one month, as is indicated in the water-table graph of profile N70 (Fig. 26).

The Kania soils are slightly finer textured, darker colored, and have a higher cation-exchange capacity than Nyawama soils. The organic carbon content of Kania is approximately 3 percent in the thick A_1 horizon and about 1 percent in the A_3 horizon; below this, it gradually declines with depth. The cation-exchange capacity is relatively high in the A_1 horizon (11 me/100 g) but drops sharply in the subsurface and subsoil to 4 to 7 me/100 g. Exchangeable Ca, Mg, K, and Na are low. Exchangeable aluminum increases gradually with depth from 1.3 to 1.9 me/100 g. Base saturation is very low, 2 to 5 percent. The pH is also low (pH KCl is about 3.9; pH H_2O is usually 4.3 to 5.0). Total Fe_2O_3 contents are within the range of those in the Nyawama soils.

Runoff and erosion are negligible. Permeability is moderate. The available water-holding capacity is medium, and the soil moisture content is low during approximately three months of the dry season (Table 2).

A detailed description and analytical data for a representative profile, N70, of the Kania series are given in Appendix B.

Taiama Series. Soils of the Taiama series occur in the drainageways of the terraces of the Taia River and in the downstream portions of its tributaries (Fig. 17). They are scattered throughout the surveyed area, next to Kania and Nyawama soils or, more frequently, near soils of the colluvial footslopes and uplands (Fig. 15). On tributaries of the Taia River, Taiama soils often occupy the downstream portion, and Pelewahun soils occur upstream. The terrain is almost flat, with gentle slopes of 0 to 3 percent. Taiama soils occupy approximately 6 percent of the area that was mapped (Table 6).

The parent material is a gravel-free alluvium of the Taia River or a usually gravel-free colluvium and alluvium of the tributaries. The gravel-free layer is more than 48 inches (122 cm) thick, except in a few areas where a thin (less than 10 inches or 25 cm) gravelly colluvial layer, consisting of plinthite and quartz, may be present within 48 inches (122 cm) from the surface. The thickness of the gravel-free layer is an important difference between Taiama and Pelewahun soils (Section 4:8:2).

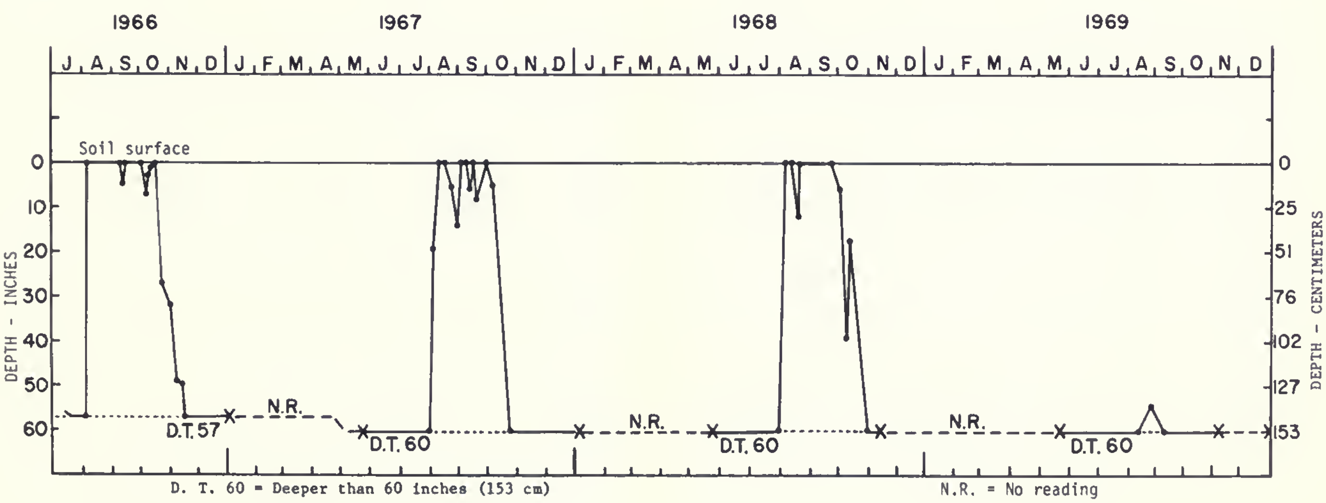


Figure 26. Water levels in Kania profile N70.

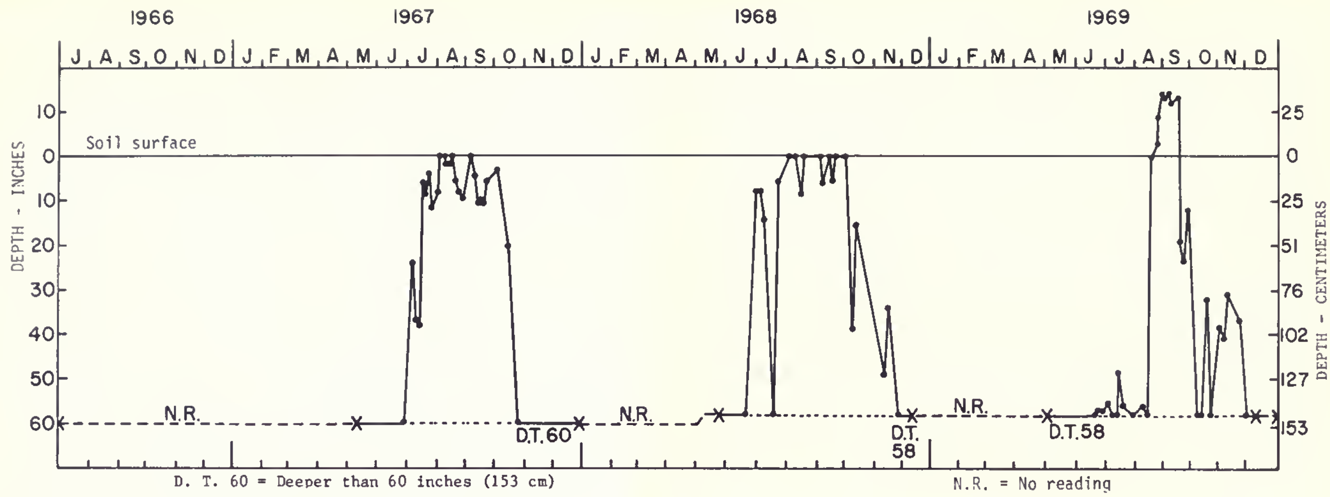


Figure 27. Water levels in Taiama profile N101.

Textures are usually clay loam in the topsoil, changing into sandy clay and clay in the subsoil. The A_1 horizon varies in thickness, but it is typically more than 10 inches (25 cm) thick. It is usually an umbric epipedon, but in some of the upstream portions of the tributaries it does not always qualify. Surface soil colors range from black to dark grayish brown (10YR 2/1-3/1-3/2-4/2), changing into dark gray to light brownish gray (10YR 4/1-5/2-6/2) in the subsurface soil. In the subsoil, colors are light gray to white (10YR 7/1-8/1-2.5Y 7/2-8/2-8/0); chromas are 2 or less. Mottling starts at the surface or at shallow depths, being brownish and faint near the surface, changing rapidly towards distinct and prominent red or dark red (2.5YR 4/8-3/6) in the subsoil, and increasing in abundance with depth.

Taiama soils are poorly drained. They have waterlogging problems at the surface for three to four months during the rainy season, including submergence for more than one month, as is indicated in the water-table graph of profile N101 (Fig. 27).

The chemical properties of the Taiama soils are similar to those of the Kania soils. Organic carbon content is high in the topsoil (about 3 percent); below this, it decreases sharply with depth. The cation-exchange capacity is highest in the A_1 horizon, up to 14 me/100 grams of soil, but it drops sharply to 5 to 6 me/100 g in the subsurface and subsoil. Exchangeable Ca, Mg, K, and Na are low. Exchangeable aluminum ranges from 2 to 3 me/100 g, slightly more than in Kania soils. Base saturation is very low, 3 to 5 percent. The pH is also low (pH KCl is about 3.3 in the subsoil; pH H_2O ranges from 4.2 to 4.8). Total Fe_2O_3 and K_2O are lower in Taiama soils than in Kania soils.

Runoff is slow, and erosion is not a problem. Permeability is moderate. The available water-holding capacity is medium; the soil moisture content is low during about two months of the dry season (Table 2). These soils can be used for rice during the rains and for vegetables in the dry season.

A detailed description and analytical data for a representative profile, N101, of the Taiama series are given in Appendix B.

4:8:4. Soils on alluvial floodplains

Along the Taia (or Jong) River banks on the current floodplain, gravel-free soils occur that have loamy or clayey textures and still contain weatherable minerals, especially mica. These soils, which belong to the Pujehun, Gbesebu, and Mokoli series (Table 2), are among the most productive in Sierra Leone. Their scattered occurrence, difficult accessibility during the wet season, and the danger of occasional flooding have deterred the intensive use of these soils.

Pujehun Series. Pujehun soils occur on very gentle, convex slopes on natural levees next to the Taia River (Fig. 15). These soils are of limited extent (Table 6).

The parent material is gravel-free alluvium from the Taia River. Its textures are fine sandy loam to fine sandy clay loam in the topsoil, changing towards sandy clay loam or clay loam in the subsoil. The sand fraction is dominated by the fine and very fine fractions (0.25-0.05 mm). There are many mica particles in the sand fraction. The silt content is low.

The A_1 horizon is usually less than 10 inches (25 cm) thick (ochric epipedon). The colors of the surface soil are very dark grayish brown to dark brown (10YR 3/2-3/3-4/3). Subsoil colors are yellowish brown to brownish yellow or strong brown (10YR-7.5YR 5/6-5/8). Red mottles may be present in the subsoil, usually becoming more prominent and increasing in abundance with depth.

Pujehun soils are well drained; they are seldom waterlogged at the surface or submerged. However, the ground water fluctuates in the lower subsoil from 30 to 60 inches (76 to 153 cm) during the rainy season, under the influence of changes of the water level in the adjacent stream, as is indicated in the water-table graph of profile N80 (Fig. 28).

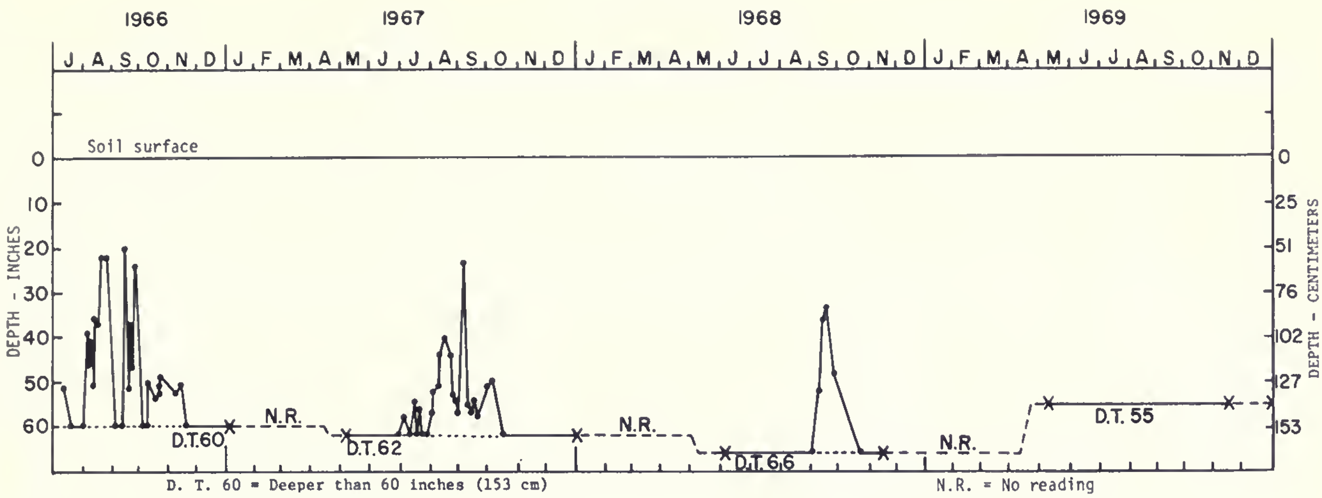


Figure 28. Water levels in Pujehun profile N80.

Organic carbon content is nearly 3 percent in the thin A_1 horizon but decreases sharply with depth. Pujehun soils have poor chemical properties. Cation-exchange capacity is low, varying from 3 to 9 me/100 grams of soil. Exchangeable Ca, Mg, K, and Na are very low. Exchangeable aluminum is comparatively low, 1 to 2 me/100 g. Base saturation is low (3 to 7 percent), as is pH. The pH KCl is approximately 3.9; pH H_2O ranges from 4.4 to 4.8, with the higher values in the lower subsoil. Total K_2O and CaO contents are greater in Pujehun soils, which are currently receiving deposition, than in other soils in the area.

Permeability is rapid, and runoff is negligible. There may be occasional deposition by flowing water and occasional streambank erosion. Available water-holding capacity is medium to high because of the fine sandy clay loam texture. The soil moisture content is low during about three months of the dry season (Table 2).

A detailed description and analytical data for a representative profile, N80, of the Pujehun series are given in Appendix B.

Gbesebu Series. The soils of the Gbesebu series make up the major portion of the current alluvial floodplain of the Taia River (Fig. 15 and Table 6). They always occur near the river at slightly lower elevations than the associated Pujehun soils. The terrain is nearly level.

The parent material is clayey alluvium, always more than 48 inches (122 cm) thick. Its textures are silty clay in the topsoil and usually clay in the subsoil. The silt content is moderately high, 35 to 45 percent, most of which is fine silt (0.02 to 0.002 mm). Mica flakes are nearly always present in varying amounts.

The colors of the surface soil are very dark brown to brown (10YR 2/2-3/2-3/3-4/3). The A_1 horizon varies in thickness. Although it is usually less than 10 inches (25 cm) thick (ochric epipedon), it is sometimes thick enough and dark enough to be umbric — for example, as in part of the area northwest of the bridge over the Taia River at Taiama. In the subsoil, the colors gradually change with depth towards yellowish brown, strong brown, reddish yellow, or yellow (10YR-7.5YR 5/6-5/8-6/6-6/8-7/8). Mottles are usually present in the subsoil, increasing in frequency and prominence with depth. Mottle colors are strong brown, yellowish red, and red (7.5YR-2.5YR 4/6-5/8).

Gbesebu soils are moderately well drained to well drained. In most years, however, they are waterlogged at the surface for some time; local spots may briefly be deeply flooded by the Taia River. This is illustrated by the water-table graph of profile N125 (Fig. 29).

Gbesebu soils have better chemical properties than most other soils in the Njala area. The organic carbon content of the A_1 horizon is high, up to 4.5 percent. It decreases rapidly with depth but still is greater than in most other soils. The cation-exchange capacity of the A_1 horizon is also fairly high, up to 19 me/100 grams of soil, whereas subsoil values range from 6 to 9 me/100 g, still somewhat higher than in Pujehun soils. Exchangeable aluminum is slightly higher in Gbesebu than in Pujehun soils. Base saturation is usually low, 3 to 9 percent, except in some A_1 horizons where it is higher. The pH is also low (pH KCl is about 3.7; pH H_2O ranges from 4.0 to 4.8, increasing with depth). Total K_2O and CaO are lower in Gbesebu than in Pujehun soils, but the total Fe_2O_3 content of Gbesebu is higher.

Runoff and erosion are negligible. Permeability is moderately rapid. The available water-holding capacity is high because of the relatively high content of silt in this soil. The soil moisture content is low during about two months of the dry season (Table 2). With proper fertilization, the Gbesebu soils can be used intensively to produce up to three crops annually. One crop, such as rice, can be grown from May to August during the rains; a second crop, such as maize, can be produced during the declining rains from September to December; and a third crop can be grown from January to April with irrigation water from the Taia River.

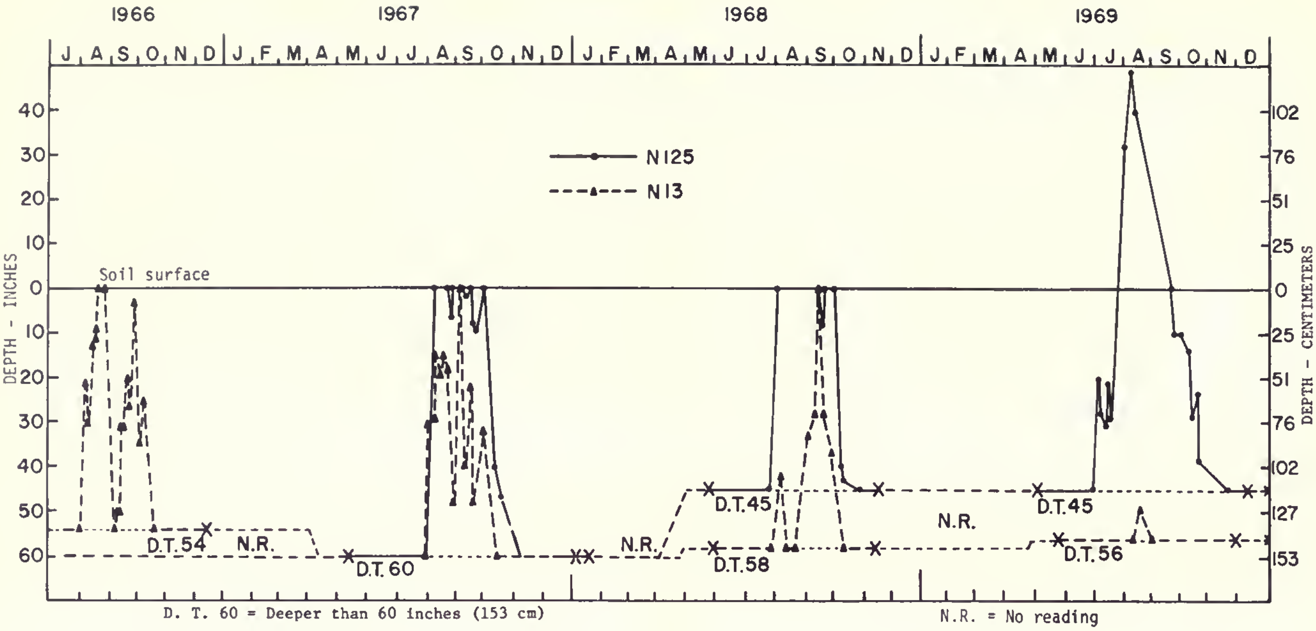


Figure 29. Water levels in Gbesebu profiles N125 and N13.

A detailed description and analytical data for two profiles, N125 and N13, of the Gbesebu series are given in Appendix B.

Mokoli Series. The Mokoli soils occur in drainageways on the alluvial floodplain of the Taia River (Fig. 15). They are usually surrounded by Gbesebu soils or occur between those and higher terrace soils such as Nyawama or Bonjema. Mokoli soils are of limited extent (Table 6). The terrain is nearly level and usually slightly depressed.

The parent material is more than 48 inches (122 cm) of gravel-free alluvium from the Taia River. Its textures are silty clay to clay. The silt content is moderately high, 30 to 40 percent, most of it in the fine silt fraction (0.02 to 0.002 mm). Mica flakes are usually present in varying amounts.

The dark-colored A_1 horizon varies in thickness; it may be less than 10 inches (25 cm) thick (ochric epipedon) or sometimes more than 10 inches thick (umbric). The colors of the surface soil are black to dark grayish brown (10YR 2/1-2/2-3/2-4/2), changing with depth towards yellowish brown (10YR 5/4-6/4) in the upper subsoil and towards pale brown (10YR 6/3-7/3) in the lower subsoil. Reddish-brown to red (5YR 4/4-2.5YR 4/6) mottles may be present throughout the profile (with the exception of the A_1 horizon), increasing in abundance and prominence with depth. Mottles with chromas of 2 or less may also be present.

Mokoli soils are imperfectly to poorly drained. They are usually waterlogged at the surface and submerged as long as three months during the rainy season, as is indicated by the water-table graph of profile N14 (Fig. 30). Natural drainage, subsoil colors, and mottles are the most important differences between Mokoli and Gbesebu soils.

The chemical and physical properties of Mokoli soils and Gbesebu soils are somewhat similar, except those associated with organic matter content and moisture regime. The organic carbon content of the A_1 horizon (5.5 percent) is greater than in Gbesebu soils and decreases regularly with depth. The cation-exchange capacity is usually higher in the A_1 horizon of Mokoli soils, up to 23 me/100 grams of soil, gradually decreasing to 9 me/100 g in the subsoil. Exchangeable Ca, Mg, K, and Na are low. Exchangeable aluminum decreases with depth from 2.9 to 1.6 me/100 g. Base saturation is very low, 2 to 8 percent. The pH is also low (pH KCl = 3.7; pH H_2O increases from 4.5 in the topsoil to 5.0 in the subsoil).

Runoff is slow, and Mokoli soils are subject to slight deposition during periods of flooding. Permeability is moderate. Available water-holding capacity is high. Mokoli soils are low in moisture content during only about one month of the dry season (Table 2).

A detailed description and analytical data for a representative profile, N14, of the Mokoli series are given in Appendix B.

4:9. AREA J* — GRANITE AND ACID GNEISS, MAKENI AREA

The interior plateaus and hills of the eastern part of Sierra Leone are separated from the low-lying interior plain to the west by an escarpment region in which the elevation increases from 250 feet (76 m) in the west to 1,000 feet (305 m) in the east. Area J* consists of that part of the escarpment region that is under secondary bush or forest. It consists of a northwest-southeast strip 15 to 50 miles (24 to 80 km) wide through central Sierra Leone, including the towns of Makeni, Magburaka, Yele, Bo, Blama, and Zimi. The escarpment is most abrupt in

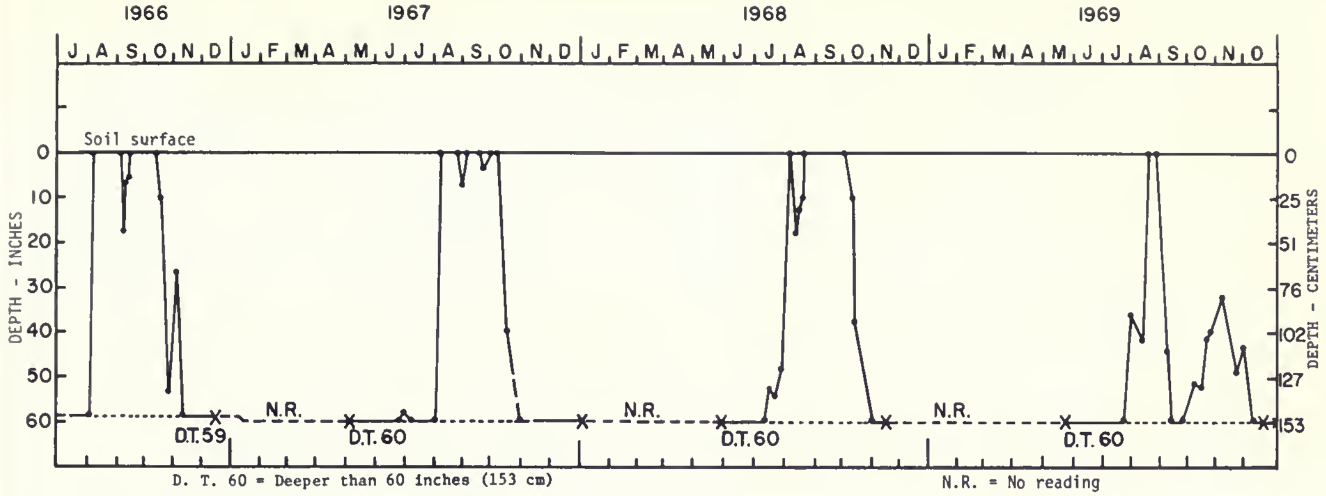


Figure 30. Water levels in Mokoli profile N14.

northern Sierra Leone. In central Sierra Leone, the erosion of the scarp is more advanced, and there are many large dome-shaped hills (inselbergs) near Makeni. Farther south, the escarpment region is much broader, more highly dissected, and less clearly defined than in the north.

Annual rainfall ranges from 100 to 140 inches (254 to 356 cm), with 121 inches (308 cm) at Makeni (Appendix A). In the northwestern part of this area, 90 to 95 percent of the rain falls from May to November; in the southeastern part, 85 to 90 percent of the precipitation falls during that period. Thus, the severity of the dry season decreases in a southeastern direction. The vegetation consists mainly of secondary bush, but remnants of moist evergreen forest are present in the southeastern part, especially in the Gola Forest Reserve (*17*). The bedrock is acid gneisses and granite and contains a moderate amount of weatherable minerals; thus, soils developed from it have a moderate nutrient status, especially the soils on steep slopes where fresh minerals are exposed.

A soil survey has been conducted in the northern part of this area, near Makeni. The four major landscapes in the mapped area are the steep hills or inselbergs of hard granite or gneiss designated "Rock Land," upland erosion surfaces, colluvial footslopes and upper terraces and swamps, and current alluvial floodplains. The major soil series occurring on these landscapes (Table 2) are discussed in the remainder of Section 4:9; additional information is also available (*75*). The distribution of various soils is shown in the soil association map of the Makeni area, Sierra Leone (Fig. 31), and the extent of each soil association is given in Table 7.

4:9:1. Soils on steep hills or inselbergs

Inselbergs, large dome-shaped granite hills with steep slopes (Fig. 32), predominate in the area designated "Rock Land" on Figure 31. However, some other areas with outcropping granitic bedrock are also included with Rock Land. Bedrock occurs on the surface or at very shallow depths. A thin layer of soil material up to 20 inches (51 cm) thick may occur locally, usually in small pockets. If a thin soil is present, its properties can be compared to Mabanta soils (see Table 2), described by van Vuure and Miedema (*75*).

Erosion danger is very great, especially on very steep slopes (up to more than 100-percent gradient). Because water must flow on the surface of the rock, runoff is very rapid. These areas of Rock Land have no value for commercial plant production and should be limited to uses for wildlife, water supply, recreation, or esthetic purposes.

4:9:2. Soils on upland erosion surfaces

On the uplands, there are deep gravelly soils (Makeni and Timbo), shallow soils over granite bedrock (Mabanta, described in *75*), and soils with gravel-free colluvial surface material over gravelly subsoils (Mabassia).

Timbo Series. Timbo soils, scattered throughout the mapped area (Fig. 31), occupy approximately 5 percent of the uplands (Table 7). They occur on moderate to steep slopes.

Table 7. Area of different soil associations in the Makeni area, as shown in Figure 31

Soil association		Area		Percent of total area
Symbol on map	Name	Acres	Hectares	
J	Makeni, Timbo	14,400	5,765	54.9
K	Mabanta and Mabassia, shallow	1,900	764	7.3
L	Mabassia, deep and very shallow	1,100	444	4.2
M	Masuba, Tubum	2,185	874	8.3
N	Masheka, Bosor	315	126	1.2
O	Makundu	540	217	2.1
P	Mankane, Panlap	5,040	2,022	19.3
R	Rock Land	720	288	2.7
	Total	26,200	10,500	100.0

FIGURE 31. SOIL ASSOCIATION MAP OF THE MAKENI AREA, SIERRA LEONE

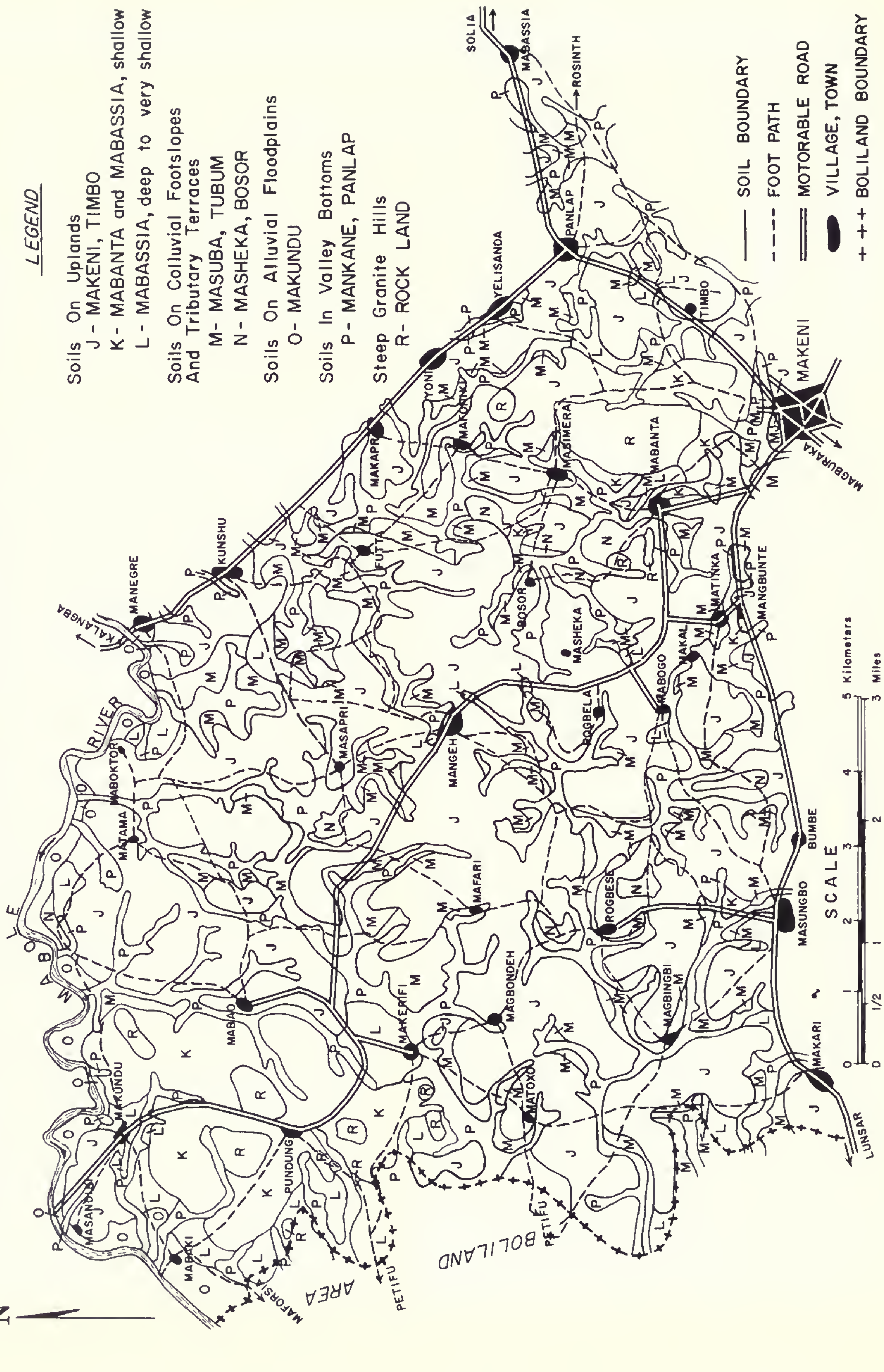


Figure 32. Rock Land in the background and rice growing on Panlap soils in the valley in the foreground.

The parent material is a gravelly colluvium, overlying gravelly residual material, over weathered bedrock (saprolite of granite or of acid gneiss). Partly decomposed bedrock fragments, which contain some weatherable minerals, are encountered within 48 inches (122 cm) of the soil surface. The colluvial hardened plinthite glaebules, which are nodular, very hard, and relatively dense, amount to approximately 50 percent of the volume of this soil. The residual hardened plinthite glaebules, formed *in situ*, are more irregular, more porous, softer, and usually coarser. The gravel content decreases gradually with depth, whereas the proportion of weathered bedrock increases. A gravel-free surface layer is very thin (less than 10 inches or 25 cm) or absent. The texture is gravelly sandy clay loam in the surface, subsurface, and subsoil. The clay content increases slightly with depth. The very coarse sand fraction is fairly high.

The very dark gray to dark brown (10YR 3/1-3/3) A horizon is usually 10 to 20 inches (25 to 51 cm) thick (umbric epipedon). Subsoil colors vary in hue from 7.5YR to 2.5YR, with values of 4 or more and chromas of 6 or more. A common subsoil color is yellowish red (5YR 5/8). Mottles are usually absent in the subsoil but are common at greater depths (80 to 90 inches or 203 to 229 cm). Timbo soils are well drained and are never waterlogged at the surface (Table 2).

Timbo soils have low nutrient levels for plant growth. The cation-exchange capacity varies from almost 8 me/100 g of soil smaller than 2 mm in the A_1 horizon to less than 4 me in the subsoil. Exchangeable aluminum is fairly low, being highest in the A_{12} horizon (1.09 me/100 g) and gradually decreasing with depth to 0.24 me/100 g in the B_{22} horizon. Base saturation is rather low, being lowest in the A_{12} horizon (9.9 percent) and increasing markedly in the lower subsoil (21.4 percent). The pH is low, also, increasing slightly in the subsoil (pH KCl is 4.2 to 4.6, and pH H_2O is 4.6 to 4.9). Exchangeable contents of Ca, Mg, K, and Na are low, being highest in the upper 12 inches (30 cm) and much lower in the underlying horizons; in the B_{22} horizon, however, higher contents are found again. Organic carbon content is highest in the A_1 horizon (2.34 to 1.87 percent) and much lower in the deeper soil layers; however, the carbon content remains fairly high in the subsoil. The water-holding capacity is very low, mainly because of the high gravel content. Total contents of Fe_2O_3 are high in all horizons and increase with depth, but total K_2O and CaO are low.

Erosion danger is usually moderate, depending upon the degree of slope. Runoff is moderate, reflecting the soils' rapid to moderate permeability. Runoff and erosion are also affected by farming methods.

Timbo soils are very low in moisture content during approximately four months of the severe dry season (Table 2) and are below the wilting point (15 atmospheres moisture content) in the A horizon in February and in the upper B horizon during March (Fig. 33 and Appendix B).

A detailed description and analytical data for a representative profile, P19, of the Timbo series are given in Appendix B.

Makeni Series. The Makeni soils are by far the most extensive ones in the Makeni area, occupying approximately 50 percent of the mapped area (Table 7 and Fig. 31). In area J on Figure 31, Makeni soils occupy the ridge summits and usually the gentle to moderate slopes with gradients not exceeding 15 percent, but they are occasionally interspersed with Timbo soils on some steeper slopes.

The parent material is a gravelly colluvium, overlying gravelly residual material, over weathered bedrock (saprolite); the latter is always found at depths of more than 48 inches (122 cm). A very thin gravel-free surface layer of 0 to 10 inches (0 to 25 cm) may be present. The colluvial hardened plinthite glaebules are rounded and nodular, very hard and dense, and fine to medium sized, with red and yellow colors. The gravel content of the colluvial surface layer varies from 40 to 80 percent by

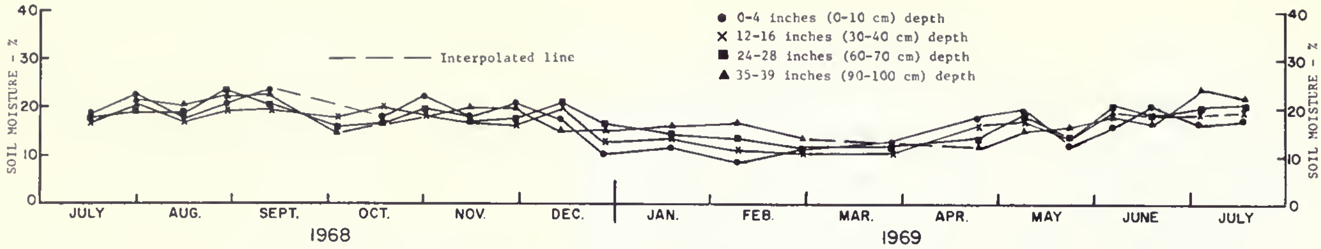


Figure 33. Moisture content in Timbo profile P19.

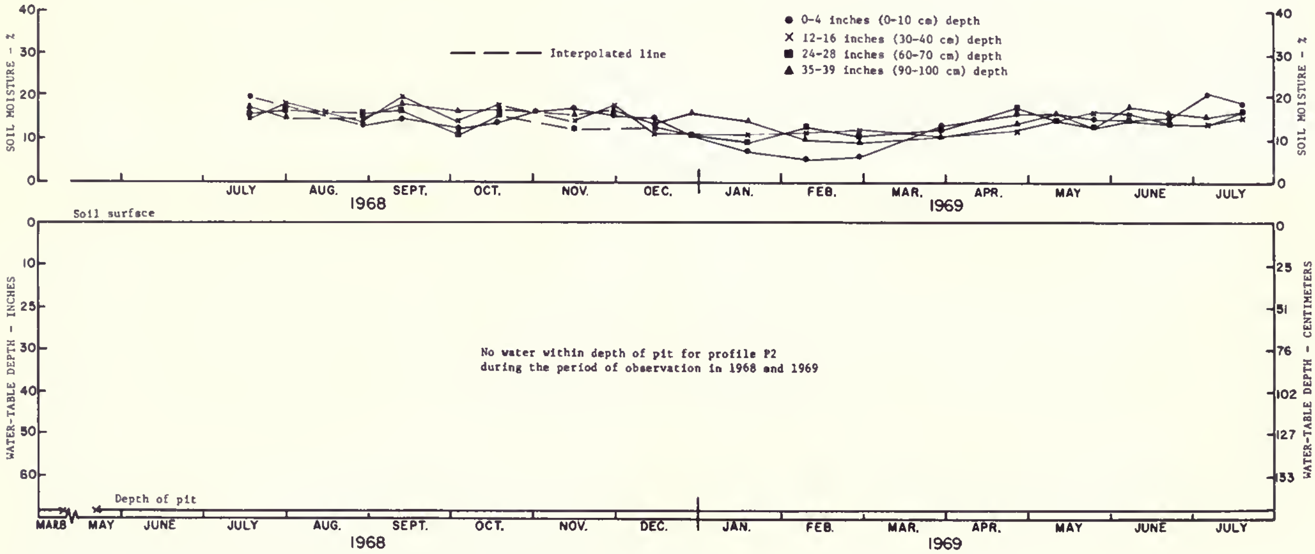


Figure 34. Moisture content and water levels in Makeni profile P2.

volume, and its thickness ranges from 20 to 60 inches (51 to 153 cm). The residual hardened plinthite glaebules are medium and coarse nodular to angular; with increasing depth, they become relatively more porous and softer. They have been formed *in situ*. The gravel content is still very high, gradually declining with depth and being replaced at about 80 to 90 inches (203 to 229 cm) or more by red plinthite mottles in a light gray to white matrix that is often rich in quartz fragments and coarse sand particles. The total thickness of both colluvial and residual gravelly layers may be up to 10 feet (3 m). The transition between the two layers is very diffuse.

Textures of the fine earth (the fraction smaller than 2 mm) are sandy clay loam in the surface soil and sandy clay or clay in the subsoil.

The A_1 horizon is very dark gray (10YR 3/1) to dark brown (7.5YR 4/4), 10 to 20 inches (25 to 51 cm) thick (umbric epipedon). Subsoil colors vary in hue from 7.5YR to 2.5YR, with values of 4 or more and chromas of 6 or more. A common subsoil color is yellowish red (5YR 5/8). Mottles are usually absent in the surface and subsurface soil but are common at greater depths (80 to 90 inches, or 203 to 229 cm). Makeni soils are well drained and are never waterlogged at the surface, as is indicated in the water-table graph of profile P2 (Fig. 34).

Makeni soils have a low nutrient status for plants. Compared with most other soils in the survey area, however, and with other upland soils in Sierra Leone (for example, the Njala series, described in Section 4:8:1), the Makeni soils are relatively rich in nutrients. Except for the A_1 horizon, the cation-exchange capacity is less than 10 me/100 g of soil smaller than 2 mm. Exchangeable aluminum is fairly low, varying from 0.16 to 1.05 me/100 g of soil. Base saturation is rather low, ranging from 14.5 to 36 percent, and the pH is also low (pH H_2O is 4.7 to 5.2, and pH KCl is 4.2 to 4.6). Exchangeable contents of Ca, Mg, K, and Na are fair in the A_1 horizon but low in the subsoil. The organic carbon content of the A_1 horizon is high (about 4 percent) but declines sharply in the B horizon. However, the carbon contents remain fairly high to considerable depths: about 1 percent at 70 inches (178 cm) is possible. The water-holding capacity is very low, because of the high gravel content. Total contents of Fe_2O_3 are high in all horizons and increase with depth. Total K_2O is low, and CaO is low except in the A_1 horizon.

The erosion hazard is slight on nearly level summits and moderate on sloping areas. Runoff is little to moderate, depending upon slope and farming practices. Permeability is rapid to very rapid. Makeni soils are very low in moisture content during approximately five months of the severe dry season (Table 2). They were below the wilting point (15 atmospheres moisture content) during January, February, and March, 1969 (Fig. 34 and Appendix B).

A detailed description and analytical data for a representative profile, P2, of the Makeni series are given in Appendix B.

Mabassia Series. Mabassia soils occupy approximately 15 percent of the uplands or 10 percent of the total mapped area in the Makeni area (Table 7). They occur on relatively lower concave gentle slopes of the uplands, primarily in areas K and L on Figure 31.

Mabassia soils have developed in colluvial material that is washed down from the neighboring higher areas; it can be aptly called "hill-wash." The colluvial layer is almost gravel-free and varies considerably in thickness. It is underlain by a gravelly subsoil (see description of Makeni series), which, in turn, gradually merges into the weathered bedrock (saprolite). The amount of hardened plinthite glaebules in the subsoil varies considerably; it may be slightly gravelly to very gravelly.

Three phases of the Mabassia series have been recognized, based upon the thickness of the gravel-free colluvium over gravelly subsoil: the *very shallow* phase, 10 to 24 inches (25 to 61 cm) gravel-free; the *shallow* phase, 24 to 48 inches (61 to 122 cm) gravel-free; and the *deep* phase, more than 48 inches (122 cm) gravel-free. Detailed descriptions and analytical data are given in Appendix B for soil profiles P71 and P108, which are representative of the shallow and deep phases, respectively, of the Mabassia series. Textures of the fine-earth fraction (< 2.0 mm) are sandy loam to sandy clay loam in the A horizon and sandy clay loam to sandy clay in the B horizon.

The A_1 horizons range from very dark gray (10YR 3/1) to dark brown (10YR 3/3) in color and from 10 to 25 inches (25 to 63 cm) thick (umbric epipedon). Subsoil colors usually have a hue of 10YR or 7.5YR, with values of 5 or more and chromas of 4 or more. Typical subsoil colors are yellow (10YR 7/8) to reddish yellow (7.5YR 6/8). Mottles are usually absent. Mabassia soils are well drained and are never waterlogged at the soil surface (Table 2).

The nutrient status of Mabassia soils is low except in the A_{11} horizon, which contains more organic matter than the other horizons. The cation-exchange capacity ranges from 8 to 12 me/100 g of soil in the A horizon and declines to 2 to 4 me/100 g in the lower subsoil. Exchangeable aluminum is low, usually less than 1 me/100 g of soil. Exchangeable contents of Ca, Mg, K, and Na are low, being highest in the surface horizon and much lower in underlying horizons. Base saturation is approximately 30 percent in the A_{11} horizon, declines to 6 to 9 percent at depths of about 3 feet (1 m), and then increases to 17.5 percent at greater depths. The pH is low (pH H_2O is 4.7 to 5.2, and pH KCl is 4.1 to 4.6). Total contents of Fe_2O_3 are moderately high (5 to 12 percent). Total K_2O is low, and CaO is low except in the A_{11} horizon. The available water-holding capacity is low for Mabassia, shallow phase, and medium for Mabassia, deep phase.

Permeability is moderately rapid. Runoff and erosion hazards are slight. Mabassia soils are low in moisture content during approximately four months of the dry season (Table 2). During the dry season early in 1969, the Mabassia deep phase profile, P108, stayed above the wilting point in moisture content (Fig. 35 and Appendix B), but the Mabassia shallow phase profiles, P74 and P79, were below the wilting point (15 atmospheres moisture content) in the A horizon during January and February and in the B horizon during February, March, and into April (*75*).

4:9:3. Soils on colluvial footslopes and upper terraces and in swamps

The well- and moderately well-drained soils that occur on colluvial footslopes and upper tributary terraces include soils of the Bosor, Tubum, Masheka, and Masuba series (Fig. 31). Bosor and Tubum have gravel-free soil layers over gravelly subsoils; Masheka and Masuba soils developed in gravel-free, fine-loamy alluvium and colluvium (Table 2).

In the poorly drained valley bottoms and swamps (area P on Fig. 31), rather extensive areas of Panlap and Mankane soils developed in coarse-loamy alluvium and colluvium (Table 2 and Table 7).

Bosor Series. Bosor soils occur in small areas on the older tributary terraces and colluvial footslopes, and occupy about 1 percent of the area that was mapped (Fig. 31 and Table 7). They are on nearly level to sloping topography (2- to 8-percent gradient) near large streams. They occur on higher elevations than the Tubum soils and usually in different places in the survey area.

Bosor soils consist of a gravel-free colluvial or alluvial layer 24 to 48 inches (60 to 122 cm) thick over a gravelly subsoil. The thick gravel-free layer originates from higher parts in the terrain and may be transported either from adjoining hills (hill-wash) or by a stream from other places. The gravel-free layer is fine sandy loam in the topsoil and fine sandy clay loam in the underlying layers. The lower subsoil is gravelly sandy clay loam.

The A_1 horizon is very dark grayish brown (10YR 3/2) to dark brown (10YR 3/3) and is 10 to 20 inches (25 to 51 cm) thick (umbric epipedon). The subsoil colors are browner than those of Tubum soils; hues are 5YR to 7.5YR, values are 4 or more, and chromas are 6 or more. Common subsoil colors are yellowish red to strong brown (5YR 5/8-7.5YR 5/8). Bosor soils are well drained and are never waterlogged at the surface, as is shown in the water-table graph of profile P60 (Fig. 36).

The nutrient status for plant growth is rather low. The cation-exchange capacity varies from about 7 me/100 g of soil smaller than 2 mm in the A_1 horizon to about 4 me in the subsoil. Exchangeable amounts of Ca, Mg, K, and Na are low. Exchangeable aluminum is fairly low, being highest in the lower A horizon (1.24 me) and de-

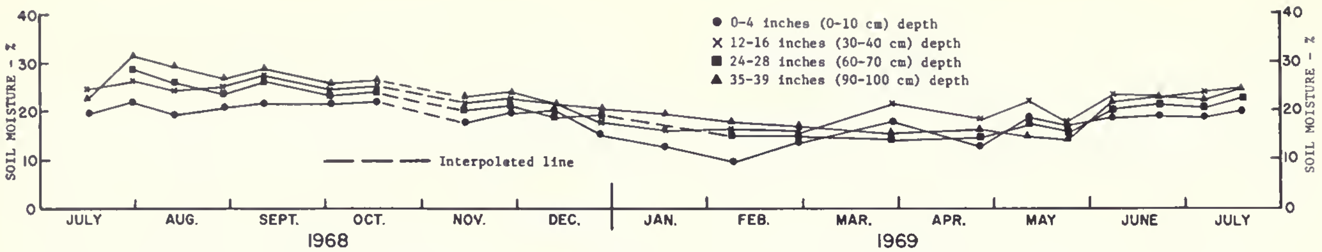


Figure 35. Moisture content in Mabossia, deep profile P108.

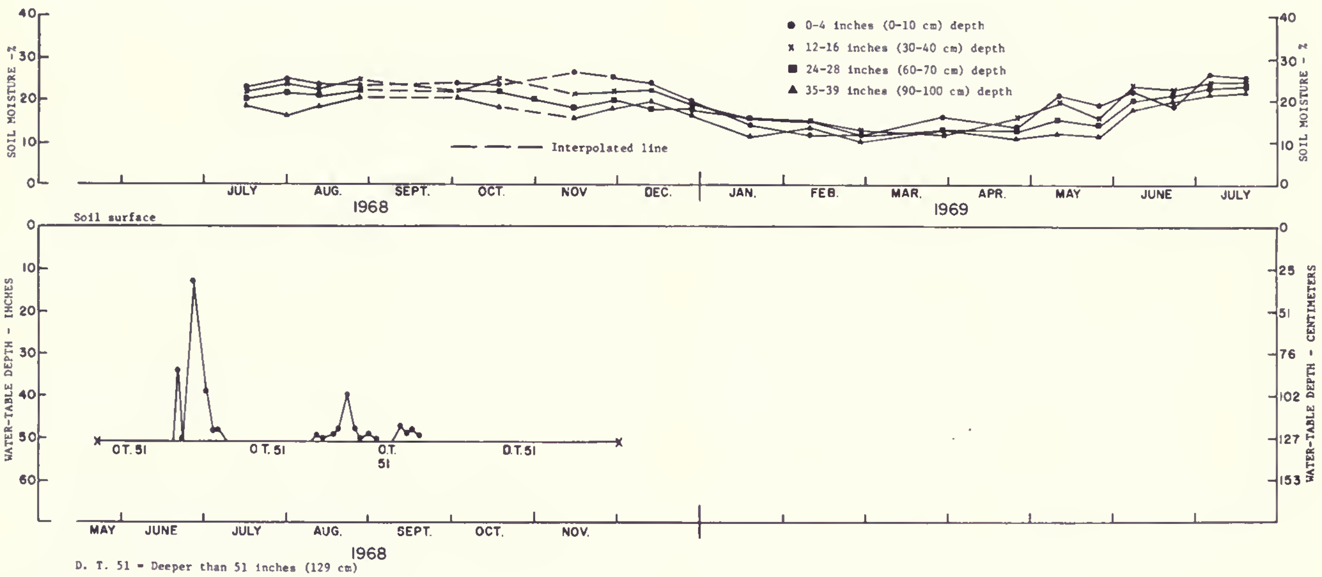


Figure 36. Moisture content and water levels in Bosor profile P60.

creasing with depth to 0.63 me/100 g in the subsoil. Base saturation is very low, being highest in the A_{11} horizon (about 13 percent) and sharply dropping to about 3.5 percent in the A_{12} horizon; underneath this layer, gradually higher values are found until in the gravelly subsoil the base saturation again drops to 5 percent. The pH is low, also, and is constant throughout the profile (pH KCl = 4.1, and pH H_2O = 4.7 to 4.8). The organic carbon content is highest in the A_1 horizon (2.34 to 1.40 percent) and lower in the subsoil (to 0.62 percent). Total contents of Fe_2O_3 are medium (5 to 8 percent), but total K_2O and CaO are low. Bosor soils are low in available water-holding capacity.

Permeability is moderately rapid. Runoff and erosion hazards are slight. Bosor soils are low in moisture content during about four months of the severe dry season; early in 1969, however, their moisture content did not drop below the wilting point (Fig. 36 and Appendix B).

A detailed description and analytical data for a representative profile, P60, of the Bosor series are given in Appendix B.

Tubum Series. Tubum soils have much in common with Bosor soils. However, Tubum soils are part of the recent tributary terraces and coincide in part with the colluvial footslopes. They are found all over the survey area near the streams and occupy about 4 percent of the mapped area (Fig. 31 and Table 7). The terrain is usually sloping, with gradients of 2 to 8 percent.

The soils of the Tubum series have a gravel-free colluvial or alluvial layer 24 to 48 inches (60 to 122 cm) thick, overlying a gravelly to very gravelly subsoil. The thick gravel-free surface layer is washed down from higher areas in the landscape or is deposited by streams. Tubum soils are slightly sandier than Bosor soils. Textures of Tubum soils are typically sandy loam in the A horizon, sandy clay loam in the upper B horizon, and very gravelly sandy clay loam in the lower B horizon.

The A_1 horizon is very dark brown (10YR 2/2) to dark brown (10YR 3/3) and is 10 to 15 inches (25 to 38 cm) thick (umbric epipedon). The subsoil colors are yellower than those of Bosor soils: hues are 10YR, values are usually 4 or less, and chromas are usually 4 (sometimes 6). A common subsoil color is dark yellowish brown (10YR 4/4). Tubum soils are usually well to moderately well drained and never have waterlogging problems at the soil surface, as is indicated in the water-table graph of profile P13 (Fig. 37).

The nutrient status for plant growth is at a rather low level. The cation-exchange capacity in the A_1 horizon is about 7 me/100 g of soil smaller than 2 mm and

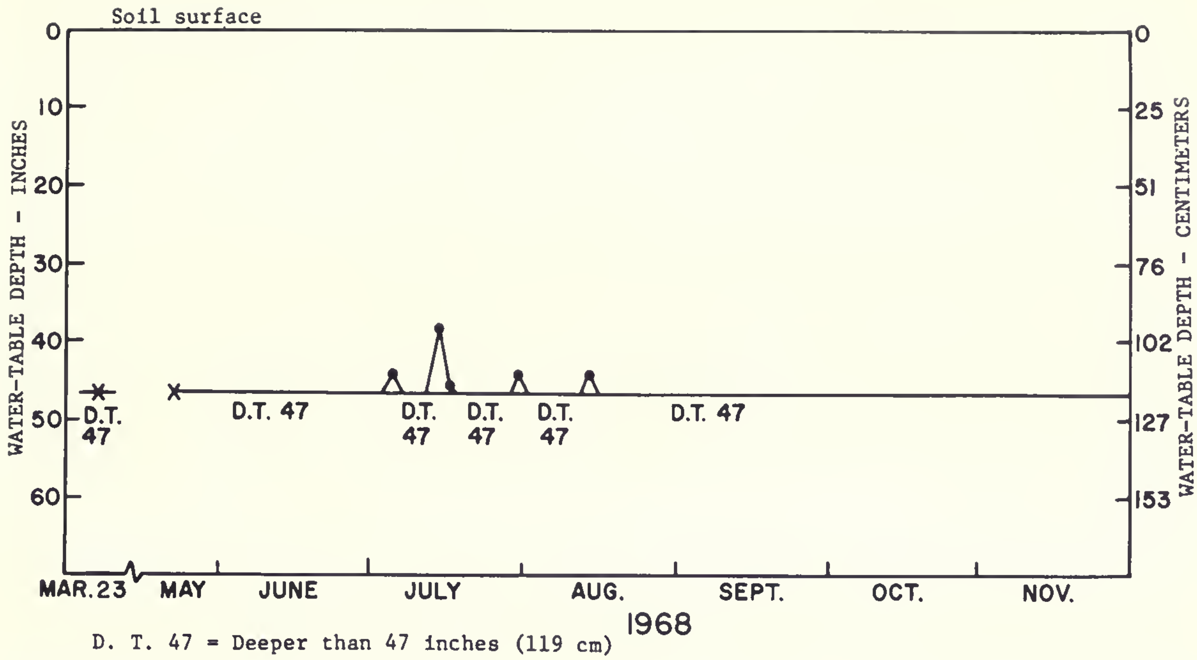


Figure 37. Water levels in Tubum profile P13.

gradually decreases with depth to less than 4 me in the subsoil. The amount of exchangeable bases is low. Exchangeable aluminum is fairly low, being highest in the upper B horizon (1.3 me/100 g). The base saturation is low, being highest (22 percent) in the upper 4 inches (10 cm) and lower (about 10 percent) in the underlying horizons. Base saturation is somewhat higher than in Bosor soils. The pH is low and almost constant throughout the profile (pH KCl = 4.2, and pH H_2O = 4.7). Organic carbon contents are highest in the A_1 horizon (2.65 to 1.64 percent), gradually decreasing to 0.55 percent in the lower subsoil. These values are at least partly due to the charcoal distributed throughout the profile. Total Fe_2O_3 content is low (2.0 to 3.3 percent), as is total CaO, but total K_2O values (1.4 percent) are higher than in many soils in higher rainfall areas in Sierra Leone. Tubum soils have a low available water-holding capacity.

Permeability is moderately rapid. Runoff and erosion hazards are slight. Tubum soils are low in moisture during approximately four months of the dry season. Early in 1969, the subsoil (24 to 39 inches, or 61 to 99 cm) of Tubum profile P62 was below the wilting point (15 atmospheres moisture content) during February; the moisture content of Tubum profile P32, however, stayed above the wilting point during this period (*75*).

A detailed description and analytical data for a representative profile, P13, of the Tubum series are given in Appendix B.

Masheka Series. The Masheka soils, which are part of the old tributary terraces, occur near streams on slopes of 2- to 8-percent gradient. They occupy less than 1 percent of the mapped area (Fig. 31 and Table 7). Masheka soils are related to Bosor, Tubum, and Masuba soils, and may be found adjacent to them; in other places of the survey area, they may occur at about the same elevation as Bosor soils — that is, somewhat higher than Tubum and Masuba.

The soils consist of a gravel-free colluvial or alluvial layer more than 48 inches (122 cm) thick overlying a gravelly subsoil. The origin of the gravel-free colluvial or alluvial layer is the same as for Bosor and Tubum soils. The texture is sandy loam in the topsoil and sandy clay loam in the subsoil.

The A_1 horizon is very dark brown to very dark grayish brown (10YR 2/2-3/2) and is 15 to 25 inches (38 to 63 cm) thick (umbric epipedon). The subsoil colors are usually somewhat yellower than in Bosor soils but browner than in Masuba soils. The hues are 10YR with values of 5 or more and chromas of 6 or more. A common subsoil color is yellowish brown (10YR 5/6). Masheka soils are well drained and have no waterlogging problems at the soil surface, as is indicated in the water-table graph of profile P49 (Fig. 38).

The cation-exchange capacity varies from nearly 9 me/100 g of soil smaller than 2 mm in the topsoil to about 4 me in the subsoil. Exchangeable bases are low. Exchangeable aluminum follows the same pattern as described for Bosor and Tubum soils; highest figures (1.3 me/100 g) are found between 16 and 26 inches (41 to 66 cm). The base saturation is comparatively high in the A_{11} horizon (about 29 percent) and much lower (less than 10 percent) in all other layers. Base saturation is somewhat higher than in Bosor soils but somewhat lower than in Tubum and Masuba. The pH is low, being somewhat higher in the upper 16 inches (41 cm) but lower in the subsoil (pH KCl varies from 4.6 to 4.0,

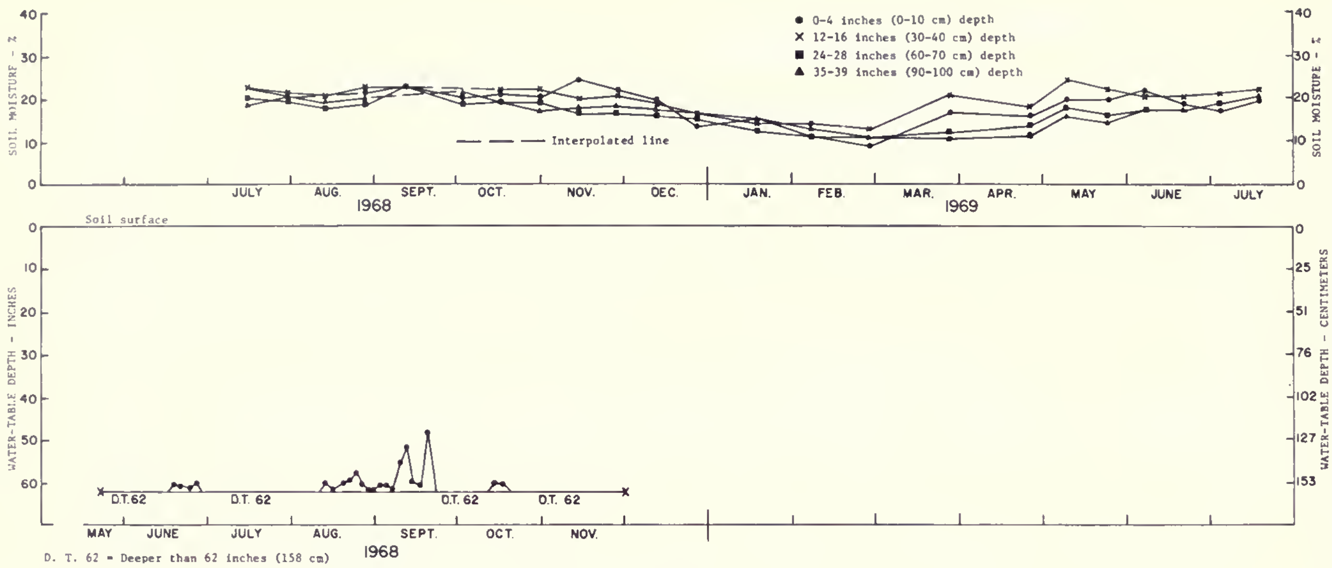


Figure 38. Moisture content and water levels in Masheka profile P49.

and pH H_2O from 5.4 to 4.5). The organic carbon content is high in the A_1 horizon (2.96 to 1.17 percent); in the subsoil, it gradually decreases to less than 0.5 percent. Total contents of Fe_2O_3 are relatively low (3.2 to 4.6 percent), and CaO is low except in the surface horizon. Total K_2O content (1.1 percent) is higher than in many soils in higher rainfall areas in Sierra Leone. Masheka soils have a low available water-holding capacity.

Permeability is moderate. Runoff and erosion danger are slight. Masheka soils are low in moisture content during approximately four months of the dry season (Table 2). During February, 1969, the moisture content of the topsoil and also of a subsoil layer at a depth of 35 to 39 inches (89 to 99 cm) in Masheka profile P49 was below the wilting point (Fig. 38 and Appendix B).

A detailed description and analytical data for a representative profile, P49, of the Masheka series are given in Appendix B.

Masuba Series. The Masuba soils occur on the lowest parts of recent tributary terraces, bordering larger streams and swamps in areas where Panlap and Mankane soils predominate (Fig. 31). Masuba soils usually occur on gentle slopes of less than 4-percent gradient. They occupy approximately 4 percent of the area near Makeni in which soils were mapped (Table 7).

The parent material is deposited by colluvial or alluvial action or both, which has resulted in a gravel-free soil layer more than 48 inches (122 cm) thick, overlying gravelly or gravel-free residual material in the lower subsoil. The texture is rather uniform sandy clay loam throughout the solum.

Topsoil colors are very dark grayish brown or very dark brown (10YR 3/2-2/2). The dark A_1 horizon is usually 10 inches (25 cm) or more thick (umbric epipedon), but in profile P9 it is only 7 inches (18 cm) thick (ochric epipedon). Colors in the subsoil are characterized by hues of 10YR or yellower, chromas of 3 or more, and values of 5 or more, accompanied by distinct to prominent mottles (7.5YR or redder). Masuba soils are usually moderately well drained; however, they gradually merge into almost imperfectly drained conditions in the transition zone to Panlap soils. Masuba soils never have waterlogging problems at the soil surface (Table 2). During the rainy season of 1968, groundwater fluctuated between about 50 and 65 inches (127 and 165 cm) below the surface in profile P9, as is indicated in Figure 39.

The nutrient status for plant growth in Masuba soils is very low. The cation-exchange capacity varies from nearly 6 me/100 g of soil in the surface horizon to 3 me in the subsoil. Amounts of exchangeable bases are low; exchangeable aluminum is approximately 1 me/100 g of soil throughout the profile. Soil tests for available K and P are very low, especially in the topsoil, when compared with Tubum, Masheka, and Bosor soils. Base saturation varies from 16 to 11 percent and remains somewhat higher than in Masheka and Bosor. The pH is low and nearly uniform throughout the profile (pH KCl = 4.1 to 4.0, and pH H_2O = 4.6 to 4.8). Organic carbon content is highest in the A_p horizon (1.25 percent), declining to 0.5 percent in the subsoil. The organic carbon content of the topsoil is less than in Masheka, Bosor, and Tubum soils. Total Fe_2O_3 content is low (2.7 to 3.2 percent), as is total CaO, but total K_2O values (1.4 to 1.2 percent) are higher than in many soils in higher rainfall areas in Sierra Leone. Masuba soils have low to medium available water-holding capacity, which is better than the other soils mentioned: Tubum, Masheka, and Bosor.

Permeability is moderate. Runoff and erosion danger are slight. Masuba soils are low in moisture content during approximately three months of the dry season (Table 2). However, from July, 1968, to July, 1969, the moisture

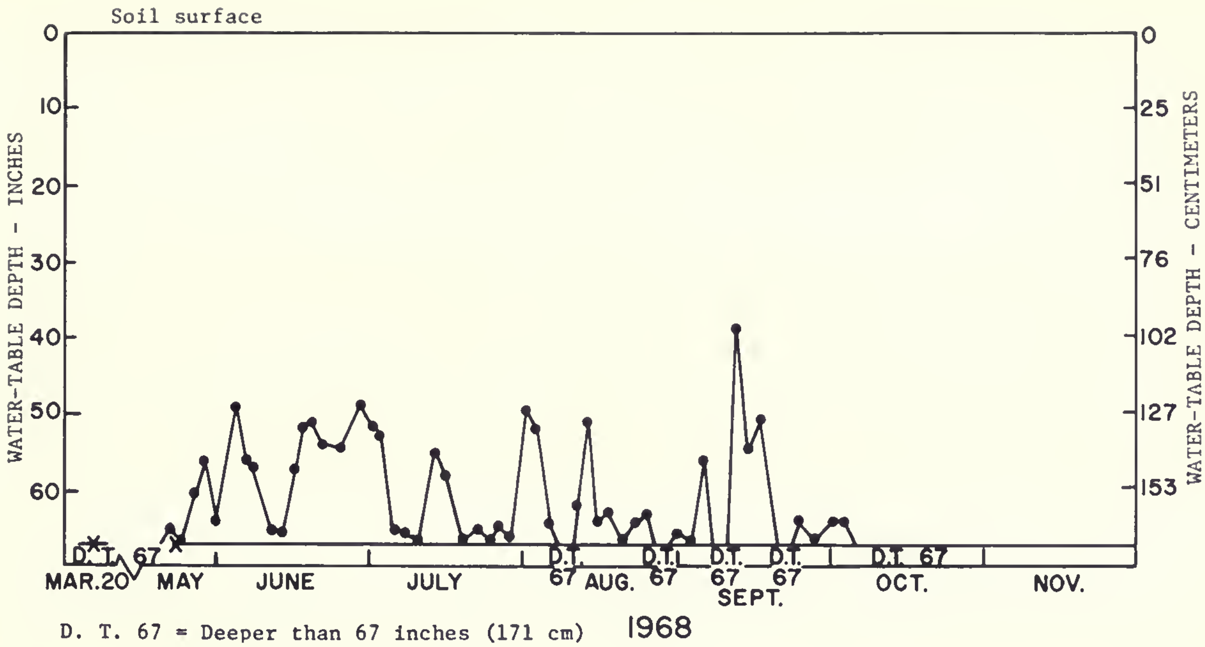


Figure 39. Water levels in Masuba profile P9.

content in two Masuba profiles, P33 and P55, did not drop below the wilting point (*75*).

A detailed description and analytical data for a representative profile, P9, of the Masuba series are given in Appendix B.

Panlap Series. Panlap soils occur near streams throughout the Makeni area (Fig. 31) and occupy about 11 percent of the area that was mapped (Table 7). Part of the so-called inland freshwater swamps belongs to the Panlap series. The terrain is nearly level, sloping less than 3 percent toward the streambed (Fig. 32). Panlap soils usually occur adjacent to and above Mankane soils and below Masuba soils.

Panlap soils consist of a deep gravel-free layer more than 48 inches (122 cm) thick deposited by the streams. Colluvium from higher terrain may be present locally. The gravel-free alluvial or colluvial layers are sometimes underlain within a depth of 100 inches (254 cm) by kaolinitic residuum from the quartz-rich granitic bedrock. The textures are sandy loam or loamy sand throughout the profile. Panlap soils are distinctly sandier than soils (such as Masuba) on the adjacent tributary terraces.

The thick A_1 horizon is black to very dark grayish brown (10YR 2/1-3.5/2), which qualifies as an umbric epipedon. The subsoil colors have hues of 10YR, values of 5 or more, and chromas of 2 (sometimes 3) or less, accompanied by prominent brown to red mottles (7.5YR or redder). Panlap soils are imperfectly drained (adjacent to Masuba soils) to poorly drained. They are waterlogged at the soil surface during four months, and partly submerged during about one to three months, as is indicated in the water-table graphs of soil profile P1 (Fig. 40).

The nutrient status for plant growth is very low. The cation-exchange capacity varies from 3.6 me/100 g of soil to less than 2 me, which is lower than in the tributary terrace soils. The amounts of exchangeable bases, especially Ca and Mg, remain comparatively high, whereas exchangeable aluminum is low (0.8 to 0.3 me/100 g). This results in a relatively high base saturation, from 31 percent in the topsoil to about 57 percent in the subsoil. The pH is low and nearly uniform throughout the profile (pH KCl = 4.2 to 4.0, and pH H_2O = 5.0 to 4.7). Organic carbon content is highest in the A_{11} horizon (1.6 percent), sharply decreasing with depth to lower values than in the tributary terrace soils. Total contents of Fe_2O_3 (1.1 to 3.1 percent) and CaO are low, but total K_2O content (1.0 to 0.8 percent) is medium. Panlap soils have a medium available water-holding capacity.

Permeability is rapid, runoff is slow, and there is very little danger of erosion. Panlap soils are low in moisture content late in the dry season (April and May), but usually the soil moisture content does not fall below the wilting point (Fig. 40 and Appendix B).

A detailed description and analytical data for a representative profile, P1, of the Panlap series are given in Appendix B.

Mankane Series. Mankane soils are found in the lowest parts of some stream valleys and in most of the depressions that are sometimes referred to as inland freshwater swamps (Fig. 31). They occupy about 8 percent of the mapped area (Table 7). The terrain is nearly level or concave, often with a stream in the lowest part of the area. Panlap soils usually occur above and adjacent to Mankane soils. Locally, rock outcrops may be encountered within this soil series.

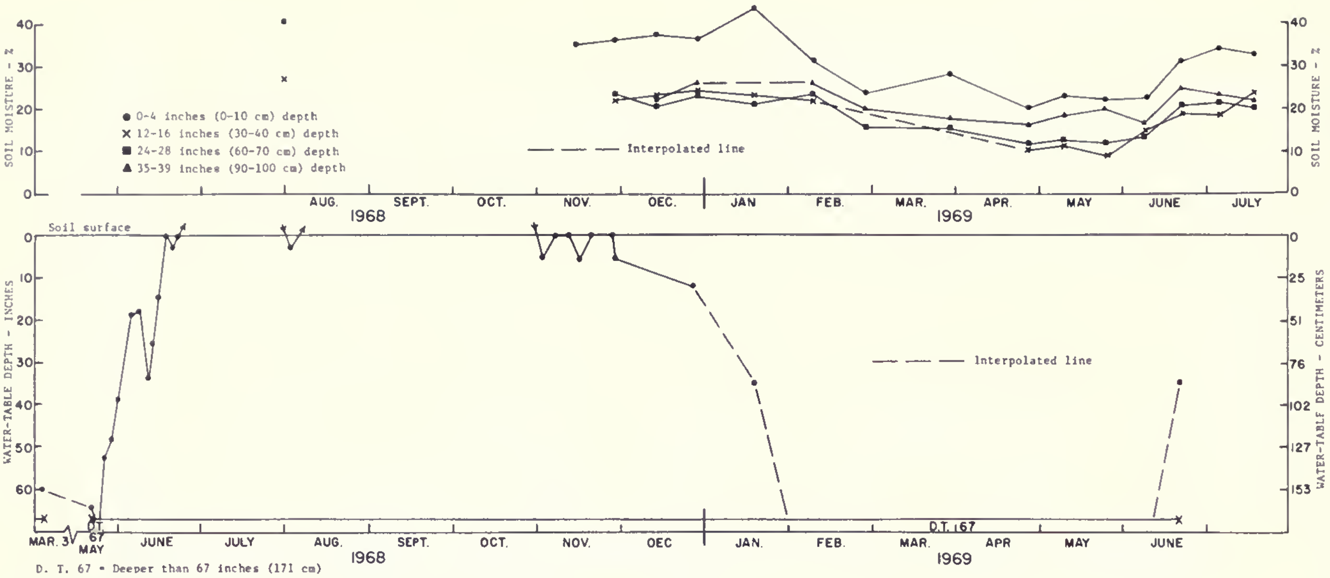


Figure 40. Moisture content and water levels in Panlap profile P1.

Mankane soils consist of a deep, gravel-free, alluvial layer more than 48 inches (122 cm) thick. Locally, colluvium from adjacent higher terrain may be present. The gravel-free layers are locally underlain within a depth of 100 inches (254 cm) by kaolinitic residuum from the quartz-rich granitic bedrock. The textures are sandy loam or loamy sand throughout the profile, in which respect they are similar to the Panlap soils.

The A_1 horizon is dark gray (10YR 4/1) or very dark gray (10YR 3/1) and ranges in thickness from 6 inches (15 cm), which is an ochric epipedon, to 12 inches (30 cm) or more, which is an umbric epipedon. The subsoil colors have hues of 10YR, values of 5 or more, and chromas of 2 or less, accompanied by brown to red mottles (7.5YR or redder). The depth of mottling and the amount of mottles are usually less than in Panlap soils. Mankane soils are very poorly to poorly drained (Table 2). They are waterlogged at the soil surface during about five months and are even submerged for two to four months, as is indicated in the water-table graph of profile P8 (Fig. 41).

The nutrient status for plant growth is very low. The cation-exchange capacity varies from 4.2 me/100 g of soil to less than 2 me, which is the same as Panlap soils. The amount of exchangeable bases is somewhat lower. The base saturation is lower than in Panlap soils but higher than the tributary terrace soils (18 to 25 percent). Exchangeable aluminum is low (0.8 to 0.3 me/100 g). The pH is low and almost constant throughout (pH KCl = 4.1 to 4.2, and pH H_2O = 4.6 to 4.9). Organic carbon content ranges from 1.8 percent in the A_1 horizon to 0.4 percent in the C horizon. Total contents of Fe_2O_3 (2.2 to 0.5 percent) and CaO are low, but total K_2O values (2.0 to 1.4 percent) are higher than in many other soils in Sierra Leone. Mankane soils have a low to medium available water-holding capacity.

Permeability is rapid, runoff is very slow, and there is deposition rather than erosion on these soils. Because of their low topographic position, Mankane soils are never very low in moisture content, even during the dry season (Fig. 41 and Appendix B).

A detailed description and analytical data for a representative profile, P8, of the Mankane series are given in Appendix B.

4:9:4. Soils on alluvial floodplains

On the alluvial floodplain and natural levees along the Mabole River, only one soil series, Makundu, was recognized (Fig. 31). It occupies 2.1 percent of the mapped area (Table 7).

Makundu Series. The Makundu soils occur in a strip of land approximately 650 to 1,650 feet (200 to 500 m) wide along the Mabole River, on the northern border of the mapped area (Fig. 31). The nearly level Makundu soils on the alluvial floodplain are bordered by more sloping soils on the upland.

Makundu soils consist of deep clayey alluvium deposited by the Mabole River. The textures are very different from other soils in the Makeni soil survey area but are similar to other clayey alluvial soils such as Taso in Area D*, Gbesebu in Area G*, and Moa in Area L* (Fig. 8). All of the horizons of Makundu soils are in the clay or silty clay textural classes, the clay content increasing from 47 percent in the A_1 horizon to about 61 percent in the subsoil. Silt content is also high (34 to 42 percent), but sand content is low, especially in the subsoil.

The A_1 horizon is very dark gray to very dark brown (10YR 3/1-3/2.5) and is usually 10 to 20 inches (25 to 51 cm) thick (umbric epipedon). The subsoil colors have hues of 10YR or redder, values of 5 or more, and chromas of 6 or more, accompanied by common to many

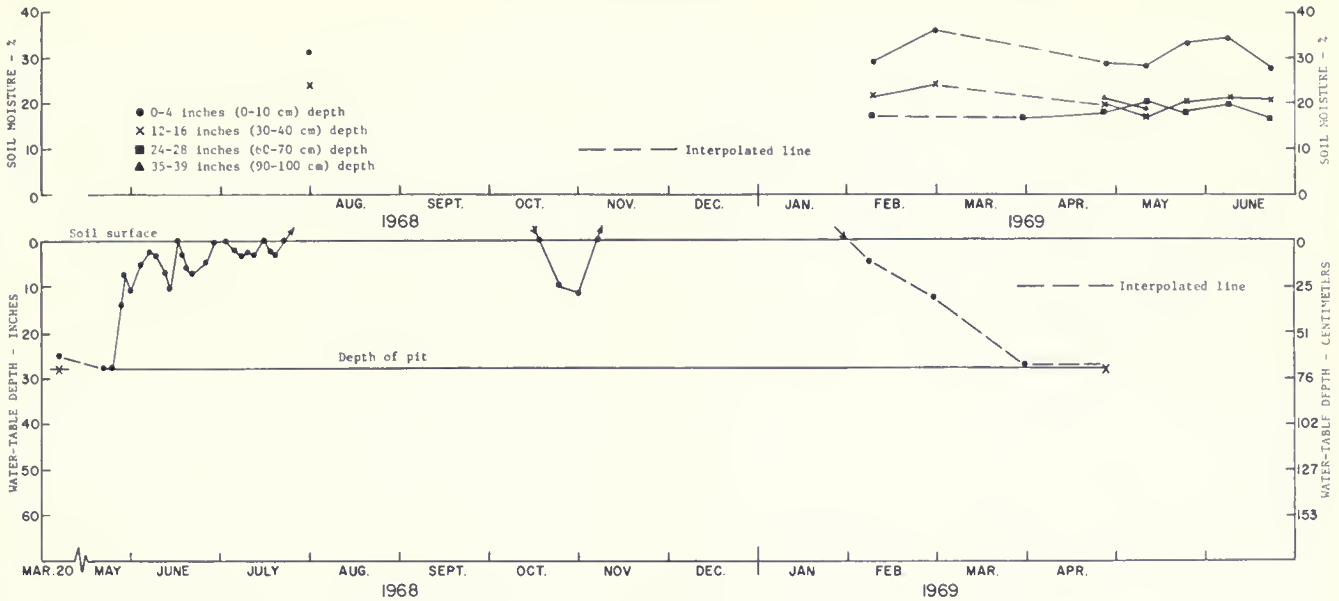


Figure 41. Moisture content and water levels in Mankane profile P8.

mottles with hues of 7.5YR or redder. A typical subsoil color is brownish yellow (10YR 6/6). Makundu soils are moderately well to well drained (Table 2) but may be waterlogged at the soil surface or even flooded by the Mabole River during brief periods, probably for less than 15 days.

The nutrient status for plant growth is fairly high, especially in the A_{11} horizon. In this horizon, the cation-exchange capacity ranks highest in the Makeni area (23.6 me/100 g of soil). With greater depth, the cation-exchange capacity declines rapidly, and reaches levels of less than 4 me in the subsoil. The amount of exchangeable bases remains at about the same level below a depth of about 16 inches (41 cm). In the upper 8 inches (20 cm) the base saturation is about 23 percent but declines rapidly to about 4 percent between depths of 16 and 28 inches (41 to 71 cm), then increases to 13 percent in the lower subsoil. Exchangeable aluminum ranges from 0.4 me/100 g of soil in the upper 8 inches (20 cm) to a high of 1.9 to 1.7 me between depths of 16 and 28 inches (41 to 71 cm). The pH is low (pH KCl = 4.5 to 4.1, and pH H_2O = 5.4 to 4.7), with minimum values in the upper B horizon and higher values both above and below in the profile, as was the case with base saturation. Organic carbon content is high in the topsoil (5 percent), gradually decreasing with depth to 0.4 percent in the lower subsoil. Total contents of Fe_2O_3 are high (10.4 to 11.8 percent) in all horizons, as is K_2O (1.4 to 1.2 percent), but total CaO is low except in the A_{11} horizon. Makundu soils have a medium *available* moisture-holding capacity, ranking highest in this respect among the soils in the Makeni area. Their *total* moisture-holding capacity is very large (Fig. 42) because of their high clay content, but much of this moisture is held by the clay and is not available to plants.

Permeability is moderately slow, and runoff is very slow. There is no danger of erosion except stream-bank cutting by the Mabole River. Makundu soils are low in moisture content during about two months of the dry season, but moisture content normally does not fall below the wilting point (Fig. 42 and Appendix B).

A detailed description and analytical data for a representative profile, P104, of the Makundu series are given in Appendix B.

4:10. AREA L* — GRANITE AND ACID GNEISS IN THE UPPER MOA BASIN, KENEMA AREA

In the southeastern part of Sierra Leone, erosion and denudation of the escarpment between the interior plateaus and hills in the northeast and the low-lying interior plain in the southwest have been so extensive that the scarp face is replaced by an undulating to gently rolling erosion surface. This is especially true in the Moa Basin, an area along the Moa River about 30 miles (48 km) wide and 75 miles (121 km) long that includes the towns of Kenema, Daru, and Pendembu. In this area (L* on Fig. 8), the erosion surface rises from about 400 to 800 feet (122 to 244 m) above sea level and is broken by numerous monadnocks (isolated hills of earlier plateaus) of elevations generally between 600 and 1,000 feet (183 to 305 m). The area is underlain by granite and acid gneiss. Annual rainfall ranges between 100 and 120 inches (254 to 305 cm), with 101 inches (257 cm) reported at Daru (Appendix A). About 85 percent of the rain falls between May and November. The dry season is less severe in this area than in most of the rest of Sierra Leone. The dominant vegetation is secondary bush with some remnants of moist evergreen forest (*17*). The Moa Basin is the main cocoa-growing region in Sierra Leone.

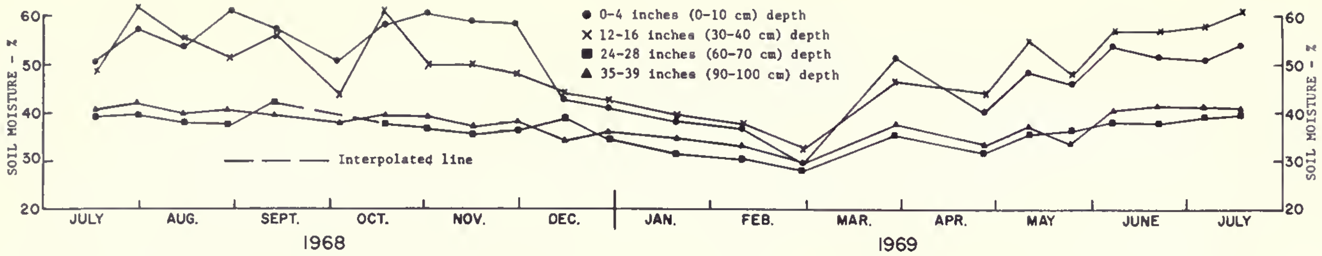


Figure 42. Moisture content in Makundu profile P104.

A soil survey conducted by Sivarajasingham (*64*) and Stark (*66*) included most of Area L* on Figure 8 and the extension of Sierra Leone east of Kailahun. The four major landscapes in the mapped area are steep hills, upland erosion surfaces, colluvial footslopes and upper terraces and swamps, and current alluvial floodplains. Some of the major soil series that occur on these landscapes (see Table 2) are discussed in the remainder of Section 4:10. Additional information concerning these soils and other soils in the Kenema area not discussed in this publication (such as Fanima and Waima in Table 8) is given by Sivarajasingham and Stark. The distribution of various soils shown on the soil association map of the Kenema area, Sierra Leone (Fig. 43, in three sheets), was adapted from soil maps they made. The extent of each soil association in Figure 43 is listed in Table 8.

4:10:1. Soils on steep hills

Steep hills occupy one-half of the mapped area east of Kenema (Table 8). These include one land type, Rock Land, and two soil associations in which Vaahun and Segbwema soils are dominant. Many of the moderately steep and steep slopes have Segbwema and Vaahun soils, which contain weathering bedrock pieces in their subsoil or even solid bedrock. Soils of this kind usually are fairly fertile, especially if the bedrock contains some weatherable minerals. They should not be used for upland farms, however, because the erosion danger is great. They can best be put into forest or used for tree crops such as coffee, cocoa, or oil palm. Rock Land is unsuitable for any agricultural use.

Table 8. Area of different soil associations in the upper Moa Basin, Kenema area, as shown in Figure 43

Soil association		Area		Percent of total area
Symbol on map	Name	Acres	Hectares	
Q	Vaahun, Rock Land	288,000	116,550	21.6
R	Rock Land	20,500	8,300	1.5
S	Segbwema, Vaahun	352,000	142,450	26.4
T	Fanima, Manowa	83,200	33,700	6.2
U	Manowa, Fanima	211,200	85,500	15.8
W	Waima, Baama	108,800	44,000	8.2
X	Pendembu, Waima	115,200	46,600	8.6
Y	Keya, Kparva	67,200	27,200	5.0
Z	Moa, Kparva	89,600	36,250	6.7
	Total	1,335,700	540,550	100.0

Rock Land. This is a land type used to delineate areas that are dominated by bedrock at the surface. Most of the Rock Land is steep granite domes (monadnocks) that rise above the surrounding areas. They occupy 1.5 percent of the mapped area (Table 8). They are widely scattered but tend to occur more frequently east of Kailahun (Fig. 43). Rock Land is unsuitable for the production of economic plants and should be left with its scanty natural vegetation for watershed protection, wildlife use, or esthetic purposes.

Vaahun Series. Vaahun soils occur extensively near Kailahun and Koindu and on the northern and western margins of the mapped area (Fig. 43), but they are also widely scattered elsewhere (Table 8). They are most frequently associated with Segbwema soils and some Rock Land. Vaahun soils are associated with the steepest slopes on which soil develops, and their solum tends to be less than 36 inches (91 cm) thick.

Vaahun soils develop in coarse-grained granite high in quartz and low in dark ferromagnesium minerals. Most of the fine gravel and sand is quartz. The fine-earth fraction (< 2.0 mm) is sandy clay loam in the surface horizon and clay in the subsoil.

The very dark gray to dark brown (10YR 3/1-3/3) A_1 horizon is less than 7 inches (18 cm) thick (ochric epipedon). Subsoil colors are yellowish brown (10YR 5/6) with faint mottles in the lower part. Vaahun soils are moderately well drained or sometimes well drained. Although they occur on steep slopes with rapid runoff, the subsoil is somewhat slowly permeable and transmits seepage over the shallow bedrock. Erosion is a serious hazard.

These relatively youthful soils have better chemical properties than some of the more highly weathered soils, but even this potential advantage is limited by their high quartz content. The cation-exchange capacity varies from approximately 19 to 15 me/100 g of soil smaller than 2 mm. Exchangeable bases are higher than in other soils in the area, with base saturation ranging from 39 percent in the surface horizon to 10 percent in the subsoil. Exchangeable aluminum varies from 0.3 to 2.3 me/100 g of soil. The pH is low (pH KCl = 3.8 to 4.4, and pH H_2O = 4.8 to 5.3). Total CaO is high (1.2 to 0.6 percent), total content of Fe_2O_3 is medium (5.8 to 7.5 percent), and total K_2O is low (0.7 to 0.25 percent). The available moisture-holding capacity is low. The soil moisture content is low during about three months of the dry season (Table 2).

A detailed description and analytical data for a representative profile, 145010, of the Vaahun series are given in Appendix B.

Segbwema Series. Segbwema soils are the most extensive ones in the mapped area (Table 8), being especially common in the central and southwestern parts (Fig. 43). They are most frequently associated with Vaahun soils (described previously) and with limited areas of Rock Land and other soils. Segbwema soils occur on moderately steep to steep slopes, typically with gradients less than those of Vaahun soils.

Segbwema soils have developed in fine-grained granodiorite, which is low in quartz and high in ferromagnesium minerals and feldspars. In these soils, the textures are typically sandy clay loam in the A and C horizons and clay loam in the B horizon. Some detrital hardened plinthite gravel may be present in the upper layers.

The strong brown (7.5YR 5/6) A_1 horizon qualifies as an ochric epipedon. Subsoil colors are typically red (2.5YR-10R 4/6). Segbwema soils are well drained and are never waterlogged at the surface (Table 2).

Levels of plant nutrients are low in Segbwema soils. Cation-exchange capacity ranges from nearly 11 me/100 g of soil in the surface horizon to 6 me in the lower subsoil. Exchangeable bases are low except in the A_1 horizon. Exchangeable aluminum is approximately 1 me/100 g of soil. Base saturation varies from 17 percent in the surface horizon to about 4 percent in the subsoil. The pH is low (pH KCl = 3.8 to 4.0, and pH H_2O = 4.7 to 5.5). The organic carbon content is 2 percent in the A_1 horizon and very low in the subsoil. Contents of total Fe_2O_3, K_2O, and CaO are medium to low. The available moisture-holding capacity is medium, which is the best among soils on the steep hills.

Because of the moderately steep to steep slopes, runoff is rapid and erosion is a serious hazard. Permeability is rapid. The soil moisture content is low during approximately three months of the dry season (Table 2).

A detailed description and analytical data for a representative profile, 145005, of the Segbwema series are given in Appendix B.

4:10:2. Soils on upland erosion surfaces

On the upland erosion surfaces of intermediate relief, the deep, very gravelly Manowa soils are most extensive; they are accompanied by smaller areas of redder, less gravelly Baoma soils. Both soils are described here. Other important soils on these upland erosion surfaces, Fanima and Waima, are described by Sivarajasingham (*64*) and Stark (*66*).

Manowa Series. Manowa soils are the most extensive ones on the upland erosion surfaces, especially between Kenema and Pendembu (Fig. 43 and Table 8). They are often associated with Fanima soils (*64, 66*). Manowa soils usually occur on convex summits and convex upper slopes.

Manowa soils have developed in very gravelly (usually more than 60 percent gravel by volume), reworked material. The gravels are predominantly dark-coated, dense, hardened plinthite glaebules. The fine earth ($<$ 2.0 mm) is sandy clay loam in the A_1 horizon, sandy clay in the upper subsoil, and clay in the lower subsoil. The A_1 horizon is usually low in gravel content.

The very dark grayish-brown to dark brown (10YR 3/2-3/3) A horizon is usually 10 to 20 inches (25 to 51 cm) thick (umbric epipedon). The subsoil is usually dark yellowish brown (10YR 4/4) to strong brown (7.5YR 5/8). Manowa soils are moderately well drained and are never waterlogged at the surface (Table 2).

Manowa soils are very low in plant nutrients. Cation-exchange capacity ranges from nearly 12 me/100 g of soil smaller than 2 mm in the surface horizon to 6 me in the subsoil. Exchangeable bases are very low, and base saturation is only 2 to 3 percent in the soil profile. Exchangeable aluminum is 3.1 me/100 g in the A_1 horizon and 0.7 me in the lower subsoil. The pH is low (pH KCl = 3.8 to 4.2, and pH H_2O = 4.3 to 4.8). The organic carbon content is 2.7 percent in the A_1 horizon and occurs down into the very gravelly subsoil. Total contents of Fe_2O_3 are moderately high (8.1 to 11.2 percent), but total CaO is low (0.07 percent) and K_2O is very low (0.2 percent). The available moisture-holding capacity is very low because of the high gravel content.

Permeability is medium and runoff is rapid. The erosion hazard ranges from slight on gently sloping summits to serious on steeper slopes. The moisture content is low during approximately four months of the dry season (Table 2).

A detailed description and analytical data for a representative profile, Kpuabu 1, of the Manowa series are given in Appendix B.

Baoma Series. Baoma soils occur primarily in the central and western part of the mapped area (Fig. 43), associated with Waima (*64, 66*), Manowa, and Segbwema soils. Baoma soils are similar in color (red) to Segbwema soils; in gravel content they are intermediate between Segbwema and Manowa soils. Baoma soils occur on upper convex slopes of approximately 3- to 15-percent gradient. Cocoa and coffee plantations are common on these soils.

Baoma soils have developed in 24 to 48 inches (61 to 122 cm) of relatively gravel-free material over a red to dark red (10R 4/6-3/6) gravelly subsoil. The gravel, usually less than 50 percent of the subsoil volume, is dark-coated, dense, hardened plinthite glaebules plus weathered and fresh rock fragments. The hardened plinthite glaebules are probably transported material. Textures are sandy clay loam in the surface horizon, clay in the upper subsoil, and gravelly clay in the lower subsoil. Baoma soils are well drained and are never waterlogged at the soil surface (Table 2).

Baoma soils are similar to Segbwema soils in cation-exchange capacity, exchangeable bases, base saturation, and reaction, but exchangeable aluminum is lower in the Baoma subsoil. Baoma is extremely high in phosphorus in all horizons. This may be due to local min-

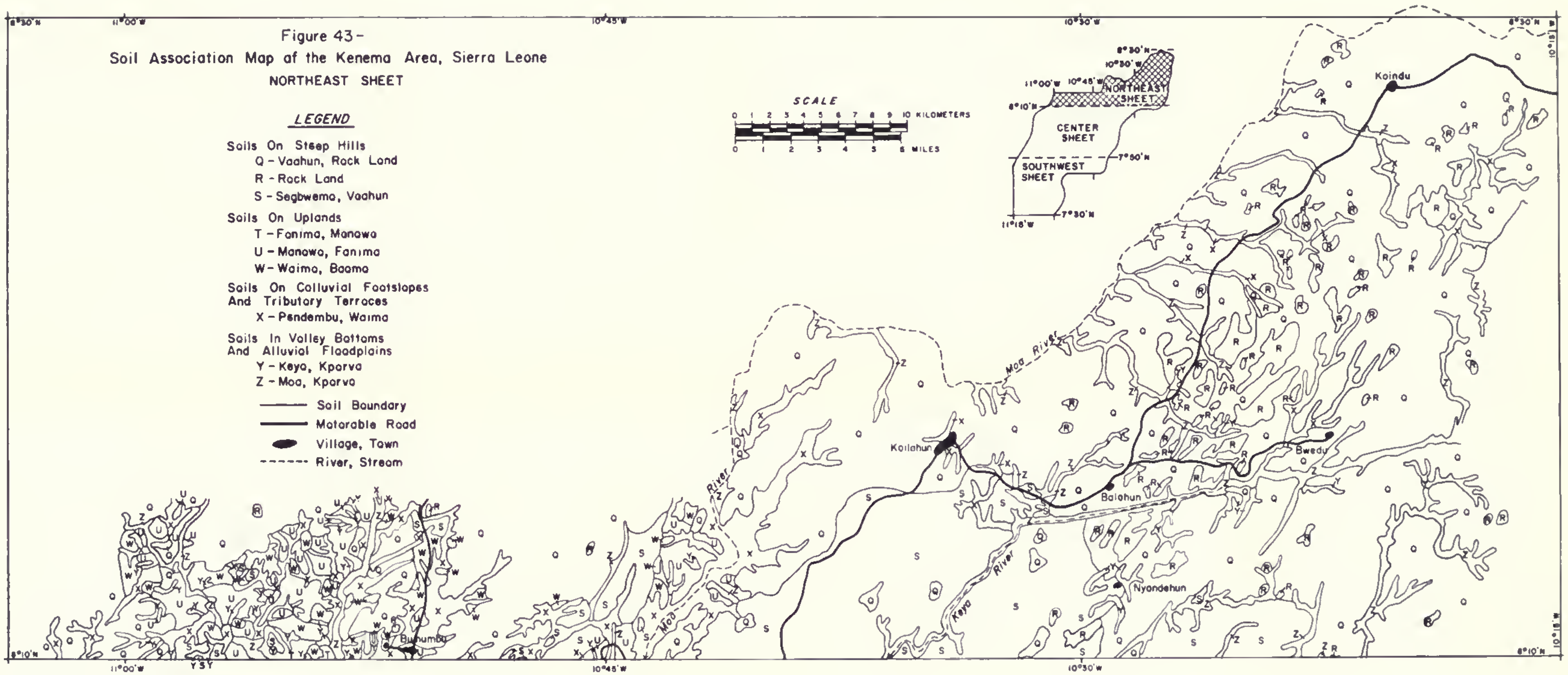


Figure 43 is in three sheets, on pages 60, 61, and 63.

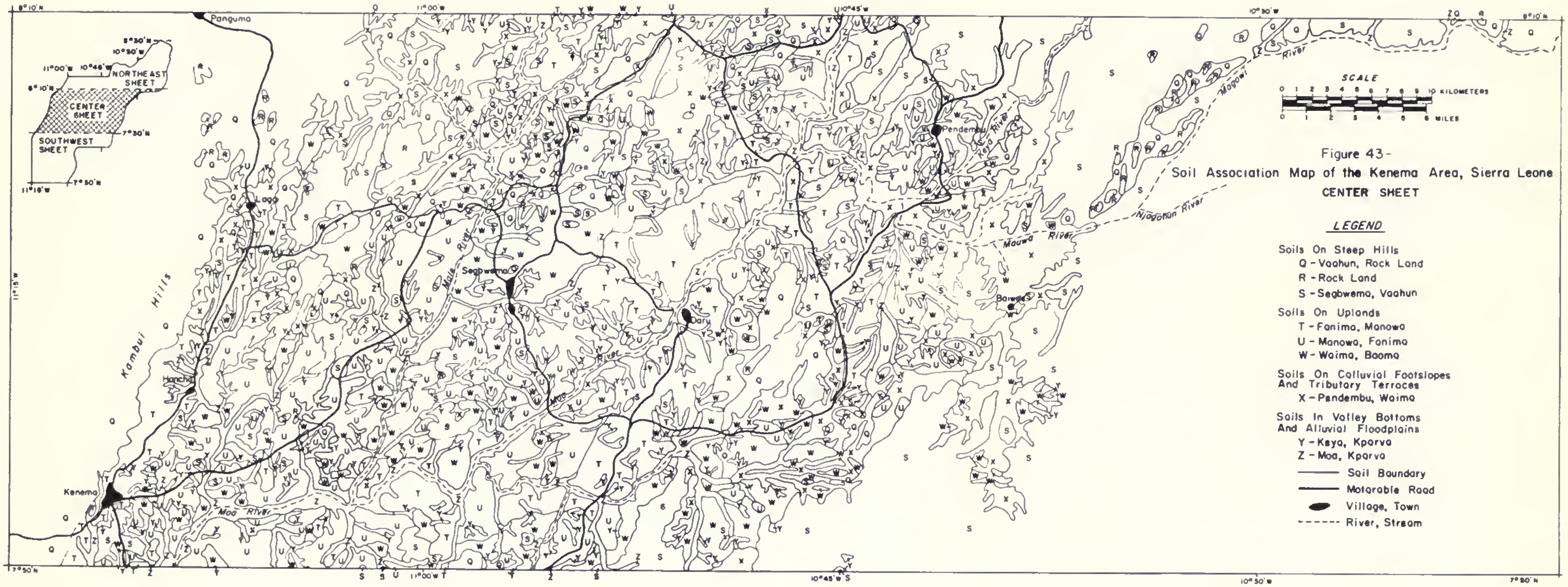


Figure 43- Soil Association Map of the Kenema Area, Sierra Leone
CENTER SHEET

eralogy, location on a former village or burial site, or possibly fixation of phosphorus by the very high content of total Fe_2O_3 (16.4 to 19.0 percent). Total content of CaO is low (0.1 percent) and K_2O is very low (0.2 percent). The available moisture-holding capacity is low.

Permeability and runoff are medium. The erosion hazard is slight. The moisture content is low during approximately four months of the dry season (Table 2).

A detailed description and analytical data for a representative profile, 144801A, of the Baoma series are given in Appendix B.

4:10:3. Soils on colluvial footslopes and upper terraces and in swamps

This group of soils includes imperfectly drained Pendembu on colluvial footslopes and upper tributary terraces, poorly drained Kparva in stream valleys and around the edge of swamps, and very poorly drained Keya in the lowest parts of inland valley swamps. These soils are widely scattered along the drainage networks in the mapped area (Fig. 43).

Pendembu Series. Pendembu soils are the most extensive ones on colluvial footslopes and upper tributary terraces. They occupy approximately 5 percent of the mapped area (Table 8). They occur on gentle slopes between the upland and the alluvial floodplains or swamps.

Pendembu soils have developed in fine-loamy colluvium and alluvium. The textures are fine sandy loam in the surface horizon and sandy clay loam in the B horizon.

The very dark gray (10YR 3/1) A_1 horizon is usually 6 to 10 inches (15 to 25 cm) thick (ochric epipedon). Colors in the B horizon are yellowish brown (10YR 5/4) to yellow (2.5Y 7/6) with prominent red mottles in the lower subsoil. Pendembu soils are imperfectly drained because of seepage and are waterlogged at the soil surface during one to two months of the rainy season (Table 2).

Pendembu soils are very low in plant nutrients. Cation-exchange capacity ranges from 9.4 me/100 g of soil in the A_1 horizon to 3.5 me in the lower subsoil. Exchangeable bases are very low, and base saturation is only 2 to 5 percent in the soil profile. Exchangeable aluminum ranges from 3.6 me/100 g of soil in the surface horizon to 1.2 me in the lower subsoil. The pH is low (pH KCl = 3.6 to 3.9, and pH H_2O = 4.1 to 4.7). Total contents of Fe_2O_3 (2.5 to 3.1 percent) and CaO (0.07 percent) are low, and total K_2O is very low (0.2 percent). The available moisture-holding capacity is low.

Permeability is moderately rapid, runoff is medium, and the erosion danger is slight. The moisture content is low during about two months of the dry season (Table 2).

A detailed description and analytical data for a representative profile, Kpuabu 2, of the Pendembu series are given in Appendix B.

Kparva Series. Kparva soils occur throughout the mapped area on nearly level terrain (slopes of less than 3 percent) around the edges of swamps and in low areas at the bottom of slopes from the upland to alluvial floodplains (Fig. 43 and Table 8).

Kparva soils have developed in fine-loamy colluvium and alluvium. The textures are sandy clay loam in the surface horizon, sandy clay in the B horizon, and usually sandy clay loam in the substratum with occasional thin gravelly layers.

The A_1 horizon is very dark gray to very dark grayish brown (10YR 3/1-3/2) and is usually less than 10 inches (25 cm) thick (ochric epipedon). Colors in the B horizon are brownish yellow (10YR 6/8) with light yellowish-brown (2.5Y 6/4) mottles in the upper part, and white (2.5Y 8/2) with strong brown (7.5YR 5/6) mottles in the lower part. Kparva soils are poorly drained and are waterlogged at the soil surface two to four months, including submergence of about one month (Table 2). Because of flooding, seepage, and the low topographic position of Kparva soils, the water table recedes slowly.

Plant nutrient levels are low in Kparva soils but are slightly better than in the Pendembu soils. Cation-exchange capacity varies from 5 to 11 me/100 g of soil. Exchangeable bases are low, and base saturation varies from 6.6 to 3.1 percent. Exchangeable aluminum ranges from 2.3 me/100 g in the upper part of the soil profile to 1 me in the lower part. The pH is low (pH KCl = 3.7 to 4.2, and pH H_2O = 4.4 to 5.0). In the solum, the contents of total Fe_2O_3 (1.8 to 4.1 percent), CaO (0.10 to 0.08 percent), and K_2O (0.4 to 0.6 percent) are low. The available moisture-holding capacity is low.

Permeability is medium, and runoff is slow. Kparva soils are subject to deposition rather than erosion. These soils are not too dry for plant growth, even during the dry season (Table 2).

A detailed description and analytical data for a representative profile, 145042, of the Kparva series are given in Appendix B.

Keya Series. Keya soils occur in depressions in the lowest parts of inland valley swamps throughout the mapped area (Fig. 43). Though not extensive (Table 8), they are important and easily-recognized features in the landscape. The vegetation is raphia palms, sedges, and other plants that tolerate very wet conditions.

Keya soils develop in coarse loamy colluvium and alluvium transported from surrounding higher areas. Textures are variable, both vertically and horizontally, but are distinctly coarser than in the associated Kparva soils. Upper horizons of Keya soils are typically loamy sand, and lower horizons are usually sandy loam.

The A_1 horizon is grayish brown to dark grayish brown (2.5Y 5/2-4/2) and is about 8 to 10 inches (20 to 25 cm) thick (ochric epipedon). The subsurface horizon is grayish brown (2.5Y 5/2), and the subsoil is white (N 8/). Keya soils are very poorly drained, being entirely waterlogged three to five months and sub-

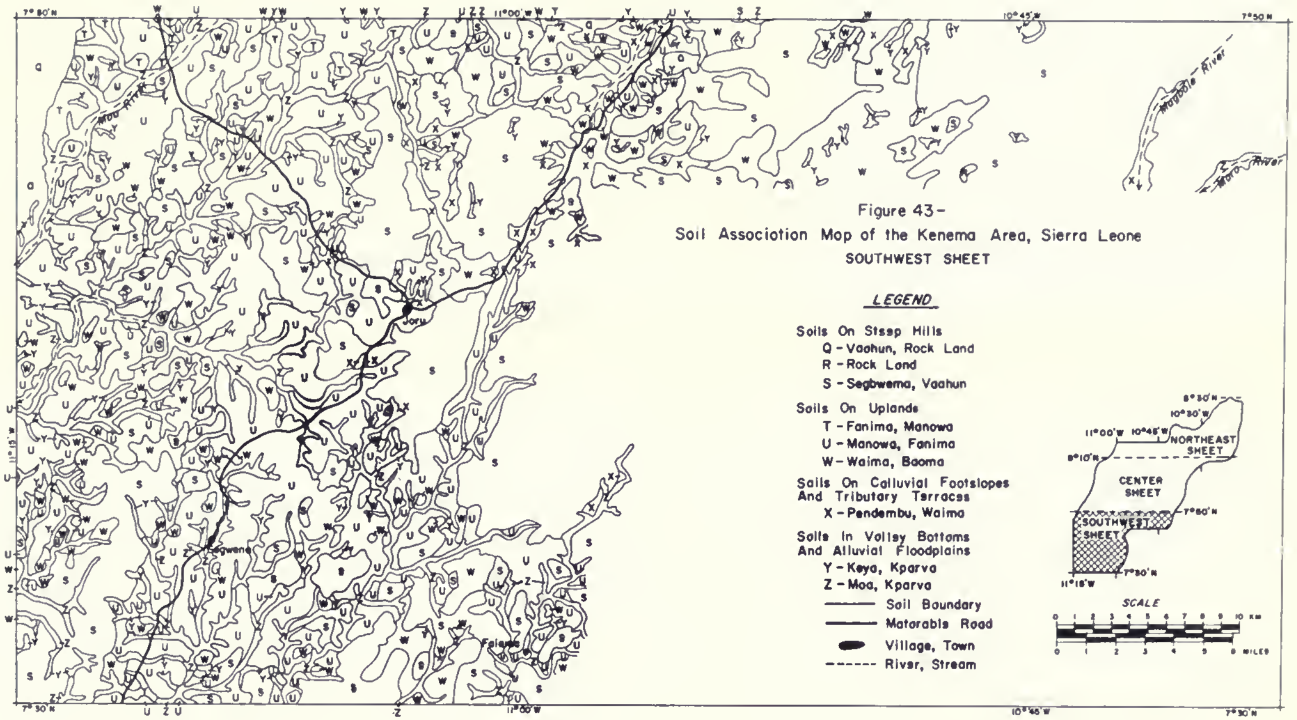


Figure 43 - Soil Association Map of the Kenema Area, Sierra Leone
SOUTHWEST SHEET

merged more than one month (Table 2). Late in the dry season, the water table usually drops to depths of about 3 to 6 feet (1 to 2 m).

Cation-exchange capacity is very low (2.4 to 3.4 me/100 g) because of the low content of organic matter (1.1- to 0.3-percent organic carbon) and of clay. Base saturation (13 to 24 percent) is better than in Kparva soils. The pH is low (pH KCl = 3.9 to 4.0, and pH H_2O = 4.5 to 5.0). Total Fe_2O_3 (0.1 to 0.7 percent) is very low, and total K_2O (0.7 to 1.4 percent) and CaO (0.10 to 0.14 percent) are low. The available moisture-holding capacity is low.

Permeability is rapid, but Keya soils are ponded because they occupy the lowest position in the landscape and receive much water and some sediment from surrounding higher areas. These soils remain moist even during the dry season (Table 2).

A detailed description and analytical data for a representative profile, 145041, of the Keya series are given in Appendix B.

4:10:4. Soils on alluvial floodplains

Along the banks of many of the larger streams, clayey alluvial soils of the Moa series occur (Fig. 43). They occupy nearly 4 percent of the mapped area (Table 8). Moa soils are nearly level and occur slightly above the streams. These are the most productive soils in the area and are often used for cocoa production.

Moa Series. Moa soils developed in clayey alluvium that is approximately 40- to 50-percent clay and 20-percent silt, the remainder being mostly fine sand.

The very dark grayish-brown (10YR 3/2) A_1 horizon is usually thin (ochric epipedon). Colors in the upper B horizon are strong brown to brown (7.5YR 5/8-4/4). Colors in the lower B horizon are variable but are often brownish yellow (10YR 6/8) with distinct mottles. Moa soils are considered to be moderately well drained (Table 2) with the upper part of the profile being better drained and the lower part more poorly drained. They may be flooded for brief periods of 1 to 15 days during the rains.

Levels of available nutrients are relatively low. Cation-exchange capacity ranges from 13.8 to 6.5 me/100 g of soil. Exchangeable bases are low, and base saturation ranges from 7.5 to 6.0 percent. Exchangeable aluminum ranges from 2.8 to 1.2 me/100 g of soil. The pH is low (pH KCl = 3.8 to 4.0, and pH H_2O = 4.5 to 5.1). Contents of total Fe_2O_3, CaO, and K_2O are medium to low. The available moisture-holding capacity is medium.

Permeability and runoff are medium. These soils are not subject to erosion except by stream-bank cutting. The soil moisture content is low for only about one month during the dry season (Table 2) because the water table is relatively shallow and the moisture-holding capacity is favorable.

A detailed description and analytical data for a representative profile, Kpuabu 3, of the Moa series are given in Appendix B.

4:11. COMPARISON OF SOILS IN THE BOLILAND REGION (AREA I*) WITH THOSE IN ADJACENT AREAS G* AND J*

The Boliland Region (Area I* on Fig. 8) is a seasonally swampy area in a belt about 20 miles (32 km) wide stretching from Yonibana through Batkanu to the Guinea border. It is a low-lying, flat or very gently undulating grassland area thought to be a former delta formed by the merging of the Mabole, Rokel, and Pampana Rivers at a period of higher sea level (*70*, p. 18). Medium (Fig. 44) and tall grasses are the most common vegetation in the swamps; savanna woodland and *Lophira* bush predominate on the uplands. Mean annual rainfall is between 110 and 120 inches (280 to 305 cm), with 109 inches (277 cm) at Batkanu (Appendix A). Approximately 90 to 95 percent of this rain falls between May and November.

The soils in the Boliland Region are underlain by sandstones, siltstones, and mudstones of the Rokel River Series, similar to those in Area G* to the south (discussed in Section 4:8). Stobbs (*70*) mapped the soils in the southern one-half of Area I* and made the following separations on his soil map:

Upland peneplain drifts

Map unit 1. Nearly bare exposures of ironpan
Map unit 2. Red-brown concretionary drifts (Batkanu, Wari, Malinka, and Belia series)
Map unit 3. Yellow-brown concretionary drifts (Matutu, Makoima, and Mayanki series)

Upland colluvial drifts

Map unit 4. Over concretionary weathered parent material (Mankahun and Masuri series)
Map unit 5. Over nonconcretionary parent material

Upland sedentary soils

Map unit 6. Over locally weathered parent material (Diabama series)

Alluvial deposits and local colluvial drifts

Map unit 7. Over river terrace deposits: concretionary (Mara, Makoli, Matamba, Malop, and Mamalia series)
Over river terrace deposits: nonconcretionary (Mabang and Maroki series)
Map unit 8. Over contemporary levee deposits (Seli and Magbunga series)
Map unit 9. Over old levee deposits (Tabai, Bom, and Mateboi series)
Map unit 10. Over contemporary slough deposits (Rokel, Mabole, and Malansa series)
Over old slough deposits or inland bolis (Masebra, Madina, Makonte, Kontobe, Massimo, Romankne, and Babaibunda series)
Map unit 11. Over old river channel deposits (Rochin series)
Map unit 12. Developed in drainage grooves (complex of map units 7 and 10)
Map unit 13. Mixed bottom soils (complex of map units 7 to 12)
Map unit 14. Recent alluvium

Figure 44. Short and medium grasses of the *Anadelphia/Rhytachne* association, which are characteristic of the seasonally flooded Boliland area.

The soil series established by Stobbs in Area I* have been included in Table 2 (Section 4:1) with other soil series in Sierra Leone. Comparing Stobbs' results with those reported herein indicates that they correspond closely.

4:11:1. Comparison of soils in Area G* and Area I*

The characteristics of soils in Area G* are discussed in detail in Section 4:8. The soils in both Areas G* and I* (Fig. 8) have developed over sandstones, siltstones, and mudstones of the Rokel River Series (see Section 3:2). The physiography in the two areas is similar except that in Area G* the better-drained upland and colluvial footslope soils predominate, whereas in Area I* imperfectly and poorly drained soils on old and contemporary terraces and floodplains are more extensive.

The soils on uplands and colluvial footslopes especially have many features in common; in fact, the following pairs of soil series may be so nearly alike that it would be desirable to correlate each pair as one series (see Table 2):

Soil series in Area G*		Soil series in Area I*
Momenga	vs.	Belia
Njala	vs.	Batkanu
Mokonde	vs.	Malinka
Bonjema	vs.	Mankahun

The range of soils on old and contemporary terraces and floodplains is greater in Area I* than in Area G*, but correlation of some soil series between the two areas may be possible. For example, the Mokoli series in Area G* and the Malansa series in Area I* are similar in many properties and should possibly be correlated into one series, especially in view of the similar mineralogy of the clay fraction in the clayey alluvial soils studied so far in Sierra Leone (see Section 4:3:1). More correlation needs to be done between these two areas in order to clearly establish relationships between soil series.

4:11:2. Comparison of soils in Area I* and Area J*

The characteristics of soils in Area J* are discussed in detail in Section 4:9. The physiography of this area is markedly different from Area I* (Fig. 8). Area J* consists of a highly dissected erosion surface with nearly level summits intersected by numerous swamps and streams; consequently, the proportion of sloping and nearly level uplands is much greater, and the swamps are much smaller, than in Area I*. The transition between the two areas is rather sharp and clearly marked by differences in topography and vegetation: the flat and treeless bolilands (seasonally flooded grasslands) in Area I* contrast with the dissected topography and secondary bush in Area J* near Makeni. The parent rock in Area J* consists of granites and acid gneiss, which outcrops frequently. These "richer" igneous rocks result in a higher fertility of the upland soils in Area J* near Makeni, compared with the poorer sedimentary rocks of both Area I* and Area G*.

The soil survey carried out by van Vuure and Miedema (*75*) northwest of Makeni in Area J* (Fig. 31) lies adjacent to the soils surveyed by Stobbs (*70*) in Area I*. Actually, there is a small overlap on the soil map of the boundary area (see Section 4:4 in *75*), which was constructed by matching the soil maps of the two areas. Unfortunately, the boundary area could not be checked in the field, so the soil map of the boundary area should be considered as somewhat tentative.

The texture of the soils near Makeni in Area J* is much sandier than most of the soils in Area I*. However, the terraces and levees on the alluvial floodplain of the Mabole River have similar textures in both areas. In fact, the Mateboi soils in Area I* and the Makundu soils near Makeni in Area J* may be similar enough that it might be desirable to correlate them as one series.

4:12. TAXONOMIC CLASSIFICATION OF SOIL SERIES

In the previous portions of Section 4, the characteristics of 44 soil profiles, representing 34 soil series in Sierra Leone, have been described in detail. Their areas of occurrence, physiography and parent material, moisture regime, and relationships among these and other soils in Sierra Leone are indicated in Table 2. In the rest of this section, the taxonomic classification of each of the 44 soil profiles listed alphabetically in Table 9 (pages 70 and 71) is discussed. Major emphasis is given to the soil classification system in *Soil Taxonomy* (*69*). This system, widely used in the United States and many other areas, is based on diagnostic surface and subsurface soil horizons, each of which has well-defined properties.

4:12:1. Diagnostic horizons

The most important diagnostic horizons that occur in Sierra Leone soils are described briefly here. More complete definitions are given in *Soil Taxonomy* (*69*). The diagnostic horizons in each soil profile are given with the description of the profile in Appendix B.

Ochric epipedon. This includes surface horizons that are either too light in color, too high in chroma, too low in organic matter, or too thin to be an umbric epipedon. The surface horizons of most of the soil series are ochric.

Umbric epipedon. This includes dark-colored (Munsell color values darker than 3.5 and chromas of less than 4.0 when moist) surface horizons, 10 or more inches (25 cm) thick, with well-developed structure, an organic carbon content of at least 0.6 percent (1-percent organic matter), and less than 50-percent base saturation. Only a few soil series have umbric surface horizons.

Argillic horizon. This is a subsurface horizon (unless exposed by erosion) in which illuvial layer-lattice clays have accumulated to a significant extent. If an overlying eluvial horizon remains, the requirements that a subhorizon be designated argillic are as follows: If the eluvial horizon contains 15- to 40-percent clay, the argillic horizon should have at least 1.2 times as much clay as the eluvial horizon; if the eluvial horizon contains more than 40-percent clay, the argillic horizon should have at least 8 percent more clay than the eluvial horizon — for example, 50 percent vs. 42 percent. These clay increases should occur within a vertical distance of 12 inches (30 cm) or less. An argillic horizon should usually be more than 6 inches (15 cm) thick. The ratio of illuvial to eluvial clay (I/E clay) for the various soil profiles is given in Appendix C. Argillic horizons should show clay skins in fine pores or, if peds exist, on some vertical and horizontal ped surfaces. Thin sections should show approximately 1 percent or more of oriented clay coatings in some part of the argillic horizon.

In many of the soils in Sierra Leone, clay content increases gradually with depth in the soil profile. However, the clay increases are often modest, and in many soils there is a lithologic discontinuity that precludes the possibility of adequately evaluating the vertical changes in clay content. Clay skins are poorly developed and difficult to observe in the field, except in a few imperfectly and poorly drained soils such as Pendembu and Pelewahun (*44*). Under these conditions, thin sections are often needed to determine where argillic horizons occur. Both field and laboratory data indicate that many of the soils in Sierra Leone have argillic horizons, but these horizons are often weakly developed; moreover, where clay skins do occur, they are frequently more evident in the lower part of the B horizon than in the upper part.

Thin sections show that subsoils of the Pelewahun (*44*), Makeni, Njala, and Taiama series have enough clay skins to qualify as argillic horizons, but Momenga and Gbesebu do not. The ratio of clay in the illuvial horizon to the overlying eluvial horizon — where there is no lithologic discontinuity between them — also indicates that many Sierra Leone soils have argillic horizons but that others do not (Appendix B and Appendix C).

Cambic horizon. A cambic horizon is a slightly altered horizon between the A and C horizons but without enough evidence of illuviation to be an argillic horizon and with no cementation or induration. The evidence of alteration may include (*a*) stronger chromas or redder hues or higher clay contents than the underlying horizons, or (*b*) gray colors associated with a regular decrease in organic carbon with depth. Cambic horizons have textures of loamy fine sand or finer in the fine-earth (< 2 mm) fraction; soil structure, or the absence of rock structure, in at least half of the volume; and significant amounts of weatherable minerals. They lack the dark colors, organic carbon, and structures that are definitive of umbric epipedons.

Momenga soils have a cambic horizon (Appendix C), and the Pujehun, Gbesebu, and Mokoli series contain more than enough (> 6 percent) muscovite and other properties to qualify as having cambic horizons (see Section 4:12:3).

Oxic horizon. This is a strongly altered subsurface horizon (exclusive of the argillic horizon) at least 12 inches (30 cm) thick in which the fine-earth fraction consists primarily of a mixture of hydrated oxides of iron or aluminum or both, with variable amounts of 1:1 lattice clays and highly insoluble minerals such as quartz sand. An oxic horizon (*a*) contains more than 15-percent clay and has a texture of sandy loam or finer in the fine-earth fraction, (*b*) in some subhorizon has no more than 5 percent of its clay dispersible in water, (*c*) has a total of less than 10 milliequivalents per 100 grams of clay of bases extractable with 1N NH_4OAc and of aluminum extractable with 1N KCl, (*d*) has an apparent cation-exchange capacity of the fine earth of 16 or less me/100 g of clay by NH_4OAc, unless there is appreciable content of aluminum-interlayered chlorite, (*e*) has no more than traces of primary aluminosilicates, (*f*) has mostly gradual or diffuse boundaries between its subhorizons, and (*g*) has less than 5 percent by volume that shows rock structure. The upper boundary of an oxic horizon is set at the least depth at which less than 5 percent of its clay is dispersible in water. Detailed information concerning items (*b*), (*c*), and (*d*) for each soil profile is given in Appendix C, Table I.

Compared with the argillic horizon, the oxic horizon has few or no clay skins and either no increase or a gradual increase in clay content with depth. The oxic horizon has a lower cation-exchange capacity or smaller amounts of weatherable minerals than the cambic horizon.

Some of the subsoils, such as those of the Njala, Makeni, Kania, and Taiama series, have the properties specified for oxic horizons, including those listed in Appendix C, except that they also have argillic horizons, as described above. Other soil series in Sierra Leone have some, but not all, of the properties specified for an oxic horizon. For example, Pujehun, Gbesebu, and Mokoli contain too much muscovite (more than 6 percent, as described in Section 4:12:3) to qualify as having oxic horizons, even though their lower subsoils meet the requirements for oxic horizons on the basis of the properties listed in Appendix C.

Spodic horizon. This is normally a subsurface horizon in which "active amorphous materials composed of organic matter and aluminum, with or without iron, have precipitated" (*69*). The horizon usually lies below an eluvial mineral horizon. Typical spodic horizons are sandy and have weak or no structure. The upper boundary is abrupt, and colors change markedly with depth; hues are usually redder than 10YR. Spodic horizons occur only in humid environments, primarily in cold and temperate climates but also in hot climates. In tropical areas, spodic horizons may occur at depths of more than 3 feet (91 cm). So far, the spodic horizon has been found in only one soil series, Gbamani, in Sierra Leone (see Section 4:5).

Sulfuric horizon. This is a horizon "composed either of mineral or organic material that has both (a) a pH of less than 3 (1:1 in water) and (b) jarosite mottles" (*69*); these mottles are iron sulfate that is the color of fresh straw in hues of 2.5Y or yellower and chromas of 6 or more. Sulfuric horizons form as a result of drainage and oxidation of sulfide-rich mineral or organic materials. Sulfuric horizons are toxic to plants, and roots usually do not live in them. These horizons occur in some soil profiles, such as Rokupr, R1, in the tidal swamps (see Section 4:6).

Plinthite. This is "an iron rich, humus poor, mixture of clay with quartz and other diluents, which commonly occurs as dark red mottles" (*69*). This iron segregation occurs in horizons that are saturated with water at some season. "The mottles are not considered plinthite unless there has been enough iron segregation to permit irreversible hardening on exposure to wetting and drying. Plinthite in the soil is usually firm or very firm when the soil moisture is near field capacity and hard when below the wilting point.... In moist soil, plinthite is soft enough that it can be cut with a spade" (*69*). After irreversible hardening, this material is designated ironstone rather than plinthite. Many of the soils in Sierra Leone contain plinthite, as indicated in the profile descriptions in Appendix B and by the subgroup designations in Table 9.

4:12:2. Comparison of the soil classification described in *Soil Taxonomy* with the FAO/UNESCO and French systems

FAO/UNESCO System. The FAO/UNESCO system (*28*) is designed to define mapping units for the soil map of the world. The categories of this system are based on diagnostic surface and subsurface horizons, of which most definitions are almost identical to those in *Soil Taxonomy* (*69*). A number of subsurface horizons, however, are defined in the FAO/UNESCO system that are not described in *Soil Taxonomy.* The additional horizons recognized in Sierra Leone are briefly described below.

The **gleyic horizon** "is indicative of pronounced wetness occurring within 50 cm of the surface and is reflected by bluish colors (bluer than 10Y) that change on exposure to the air, and/or prominent mottling and dominant moist colors of low chroma in the soil matrix" (*28*). Some poorly drained or very poorly drained soils such as Panlap, Mankane, and Keya have a gleyic horizon.

The **plinthic horizon** "consists of a continuous phase of sesquioxide-rich, humus-poor, highly weathered mixture of clay with quartz and other diluents, which commonly occurs as red mottles, which changes irreversibly to hardpans or irregular aggregates on repeated wetting and drying. If textures are coarser than loamy very fine sand, more than half of the volume of the horizon shows discrete nodules, or disconnected, soft, red mottles" (*28*).

The **concretionary horizon** "is a layer consisting of 60 percent or more, by volume, of oxidic concretions with other coarse fragments of hardened plinthite or ironstone, with a thickness of at least 25 cm, the upper part of which occurs within 100 cm of the surface" (*28*).

The **thionic horizon** is indicative of an amount of sulfides or elemental sulfur or a combination of the two that is high enough to cause acidification of the soil upon oxidation to a pH (KCl) of less than 3.5 within 100 cm of the surface. The Rokupr soils have a thionic horizon.

French System. The French soil classification system is a purely pedogenetic system. It is based on soil properties that have resulted from soil-forming processes. Diagnostic horizons, as defined in *Soil Taxonomy* and the FAO/UNESCO classification, are not mentioned in the French system (*2, 3*). Instead, the conventional ABC horizon nomenclature is used at the highest categorical level (*classe*). Diagnostic criteria are often very different from the *Soil Taxonomy* and FAO/UNESCO systems. Furthermore, these criteria are not well defined in the French system. Although the classification of Sierra Leone soils according to the *Soil Taxonomy* and FAO/UNESCO systems could be easily correlated, more difficulties were encountered with the French system, especially at *groupe* and *sous-groupe* levels. Thus, the correlations listed in the right-hand column of Table 9 should be considered tentative.

In the French system, four categories are distinguished: *classe* (the highest level), *sous-classe, groupe,* and *sous-groupe*. A complete description of taxa can be found in *Classifications des sols* (*2*) and *Projet de classification des sols ferrallitiques* (*3*). Brief explanations are given below for categories of soils believed to occur in Sierra Leone.

Sols ferrallitiques. These are mineral soils with an ABC profile, usually very thick, with strongly decomposed organic matter, very strong weathering, high in sesquioxides, dominated in the clay fraction by kaolinite (and sesquioxides), a low cation-exchange capacity, and usually a low base saturation. The most important *sous-classe* in Sierra Leone is the *Sols ferrallitiques fortement désaturés* (*en B*) (ferrallitic soils strongly desaturated in the B horizon). They are characterized by an amount of exchangeable bases less than 1 me/100 g of soil, a base saturation less than 20 percent, and a pH (H_2O) of less than 5.5. The pH of the A horizon is usually lower than in the B horizon. A few profiles were classified as *Sols ferrallitiques moyennement désaturés en B* (ferrallitic soils moderately desaturated in the B horizon). These soils have an amount of exchangeable bases varying from 1 to 3 me/100 g soil, a base saturation of 20 to 40 percent, and a pH (H_2O) of 4.5 to 6.0.

The *groupe typique* indicates the central concept of the *sous-classe*. Two *sous-groupes* of this *groupe* were found: *hydromorphe,* which indicates slight hydromorphism, usually reflected by mottling, and *faiblement appauvri,* which means that some clay has disappeared from the A horizon but did not accumulate in the B horizon.

The *groupe lessivé* indicates that clay has disappeared from the A horizon and accumulated in the B horizon. Two *sous-groupes* were recognized: *hydromorphe* (see above) and *induré,* which indicates indurated ironstone.

The *groupe remanié* indicates a change in the upper part of the profile, usually the addition of new material that has been weathered to the same degree as the original soil. A stone line is often present at the transition. Three *sous-groupes* were classified: *jaune,* indicating a yellow color; *hydromorphe* (see above); and *modal,* which is the most characteristic *sous-groupe* of the *groupe.*

In the *groupe pénévolué* the weathering still continues in the soil profile. This may be the result of additions of slightly weathered material, or erosion of the topsoil (leaving the less weathered subsoil close to the surface), or inadequate time of soil formation for removal of the weatherable minerals. Two *sous-groupes* have been distinguished: *hydromorphe* (see above) and *avec érosion et remaniement,* which indicates a change due to erosion.

Sols hydromorphes. Hydromorphism is considered the most important element of soil formation in this *classe,* which contains almost all the poorly and very poorly drained soils. One *sous-classe* was recognized, *Sols hydromorphes minéraux,* in which the soils have an organic matter content of less than about 10 percent, usually less than 4 to 5 percent, in the upper 20 cm (8 inches). Hydromorphism is reflected by mottles, the presence of which indicates reduction, reoxidation after reduction, or the redistribution of iron and manganese compounds that are soluble under reduced conditions. This should be present in about the upper meter (39 inches) or, when very intense, also in the subsoil between 1 and 2 meters (39 to 79 inches). One *groupe à gley* was recognized, indicating gley phenomena in the profile. Two *sous-groupes, Sols à gley de surface* and *Sols à gley de profondeur,* indicate gley characteristics at the soil surface or in the subsoil, respectively.

Podzols. These soils are characterized by an ABC profile, with an enrichment of iron or humus or both in the B horizon. The one profile, Gbamani, classified as Podzol (see Section 4:5 and Table 9) belongs to the *sous-classe Sols à "mor" enrichis en sesquioxides sans horizon de gley en profondeur,* which indicates podzols with "*mor*" humus and enriched with sesquioxides, without the influence of a groundwater table. The *groupe* that was recognized is *Podzols,* soils with a clear A_2 horizon that has ash-like colors. The *sous-groupe* is *Podzols humo-ferrugineux,* which indicates the presence of a B_1 horizon enriched with humus, separated from the B_2 horizon enriched with iron.

Sols peu évolués. Only one profile, Sahama (see Section 4:5 and Table 9), was classified in this *classe,* which refers to soils with an AC profile: the A horizon is either thin or low in organic matter, and the A and C horizons differ only slightly in degree of weathering. The *sous-classe* is *Sols peu évolués d'origine non climatique:* young or rejuvenated soils, not influenced by the atmospheric climate but under the influence of the pedoclimate. The *groupe* is *Sols peu évolués d'apport,* indicating soils usually formed in recent alluvium.

Sols minéraux bruts. These are soils with an (A)C profile. Two profiles (see Section 4:6 and Table 9) were classified in the *sous-classe Sols minéraux bruts d'origine non climatique* (see above), the *groupe Sols bruts d'apport,* and the *sous-groupe marin.* These soils are developing in marine alluvium that is still being deposited.

Relationships Among the Three Systems. Relationships among soils classified in the highest categories of the three soils classification systems are indicated below:

Soil Taxonomy (69): order	FAO/UNESCO (28): highest category	French system (2, 3): classe
Entisols	Gleysols	Sols hydromorphes
	Fluvisols	Sols minéraux bruts
	Regosols	Sols peu évolués
Inceptisols	Cambisols	Sols ferrallitiques
	Gleysols	Sols hydromorphes
	Fluvisols	Sols minéraux bruts
Spodosols	Podzols	Podzols
Ultisols	Nitosols	Sols ferrallitiques
		Sols hydromorphes
	Acrisols	Sols hydromorphes
Oxisols	Ferralsols	Sols ferrallitiques
		Sols hydromorphes

The most important soils in Sierra Leone are the Ultisols, Oxisols, and Inceptisols. Their FAO/UNESCO equivalents are Nitosols, Ferralsols, and Cambisols, respectively; in the French system, these are the *Sols ferrallitiques* for the better-drained soils and the *Sols hydromorphes* for the poorly drained soils. Hydromorphism is an important criterion in the French classification system. The *classe* of *Sols hydromorphes* has no equivalent in the *Soil Taxonomy* system, but degree of wetness is often segregated at the suborder category. Hydromorphism is also reflected in some names of the highest categories of the FAO/UNESCO system — for example, Gleysols, which belong to Entisols and Inceptisols of the *Soil Taxonomy.*

4:12:3. Soil classification

In Table 9 the *Soil Taxonomy* subgroup name and family are given for each of the 44 soil profiles studied in detail, together with their FAO/UNESCO soil unit name and their subgroup name in the French classification system. These are further discussed in the following paragraphs of this section, with major emphasis being given to the *Soil Taxonomy* classification. In the family name, the particle-size class is listed first, then the mineralogy class, and finally the soil temperature class. Most of the detailed information that forms the basis for classifying the soil profiles is given in Appendix B and Appendix C.

Data collected were not always sufficient to classify definitely whether some horizons were argillic, oxic, or cambic, according to the *Soil Taxonomy* and the FAO/UNESCO classification systems. The presence and amount of clay skins, used to determine whether a horizon is argillic (see Section 4:12:1), are often difficult to distinguish in field observations. Additional information from thin sections is needed to more definitively determine whether some of these Sierra Leone soils are Ultisols, Oxisols, or Inceptisols.

Some of the soil profiles for which thin-section data are available show the presence of an argillic horizon, although they also often have all the other properties of an oxic horizon (occasionally a cambic horizon). For example, the B_{22t} horizon of Njala profile N103 (Appendix C) is argillic, as is the horizon above it, but it also has all of the other properties of an oxic horizon. Because an argillic horizon is designated as taking precedence, however, Njala soils are classified as Ultisols rather than Oxisols, although they are very near the border between these two soil orders.

Many Sierra Leone soils are near the border between Ultisols and Oxisols or between Ultisols and Inceptisols, depending upon the presence of an argillic horizon. For some profiles, it was difficult to decide between Oxisol and Inceptisol because of inadequate information on the amount and composition of weatherable minerals. Most soils classified as Inceptisols are near the border with Oxisols. For soils in which the presence of an argillic or oxic horizon is not fully established, an alternate subgroup classification is given (in parentheses) in Table 9. Where appropriate, this is also done in the FAO/UNESCO and French classification systems.

The **Baoma soils** occur on the upland in eastern Sierra Leone. They are well drained and have developed in 24 to 48 inches (61 to 122 cm) of relatively gravel-free material over red gravelly subsoils. They have an ochric epipedon and, with an illuvial/eluvial clay ratio of 1.4 or higher in the profile (Appendix C), they probably have an argillic horizon. Therefore, they have been classified as a member of the clayey over clayey-skeletal, kaolinitic, isohyperthermic family of Typic Paleudults. However, the entire B horizon also has the properties of an oxic horizon. If later thin-section study shows that the B horizon is not argillic, Baoma soils would be classified in the Tropeptic Haplorthox subgroup.

Bonjema soils are moderately well and imperfectly drained and occur on colluvial footslopes and upper river and tributary terraces. They have a gravel-free layer 24 to 48 inches (61 to 122 cm) thick, overlying a gravelly subsoil. Bonjema soils usually are adjacent to Mokonde soils but have a thicker gravel-free layer. Both profiles N39 and N105 of the Bonjema series have an ochric epipedon, and there are many red plinthite mottles in the subsoil. Available evidence indicates that Bonjema soils have an argillic horizon (Appendix C), and they have been classified as Plinthic Paleudults. Profile N39 is in the fine-loamy over clayey-skeletal, mixed, isohyperthermic family, whereas profile N105 contains less clay and is in the fine-loamy over loamy-skeletal particle-size class. If subsequent thin-section studies indicate that these soils have a cambic horizon instead of an argillic horizon, they would be classified as "Plinthic" Udoxic Dystropepts.

The **Bosor soils** are part of the well-drained older tributary terraces and the colluvial footslopes. They have a gravel-free colluvial or alluvial layer 24 to 48 inches (61 to 122 cm) thick, overlying a gravelly subsoil. They have an umbric epipedon and an argillic or a cambic horizon in the gravelly subsoil. The subsurface horizon has many properties of the oxic horizon, but the amount of water-dispersible clay is too high (Appendix C). Bosor soils are classified as a member of the fine-loamy over loamy-skeletal, mixed, isohyperthermic family of Orthoxic Palehumults. If further study indicates that the B_2 horizon is not argillic, Bosor soils would be classified as Udoxic Dystropepts.

The well-drained, sandy **Gbamani soils** occur on beach ridges near the Atlantic coast. They have a thick ochric epipedon, characteristic of Podzols in the humid tropics, and a distinctive spodic horizon. Gbamani soils are in the sandy, mixed, isohyperthermic family of "Arenic" Tropohumods.

The **Gbehan soils** are poorly drained and occur on the alluvial floodplain grasslands in southern Sierra Leone. Although these soils have a very dark A_1 horizon, it is not thick enough to be umbric and thus is an ochric epipedon. The lower subsoil has the properties of an oxic horizon (Appendix C). Therefore, Gbehan soils are a member of the clayey, kaolinitic, isohyperthermic family of "Plinthic Tropeptic" Ochraquox.

Gbesebu soils are moderately well drained and occupy the major portion of the current alluvial floodplain of the Taia River. They present special classification problems in the higher categories because they contain more than 6-percent mica in the fraction between 20 and 200 microns (see descriptions of profiles N125 and N13 in Appendix B), but in other properties their lower subsoils have characteristics of oxic horizons (Appendix C). According to the current definition (*69*), this amount of mica excludes them from the oxic horizon, but they have

Table 9. Taxonomic classification of Sierra Leone soils according to three systems: *Soil Taxonomy* (69), FAO/UNESCO (28), and the French system (2, 3)

Soil series and profile number	Soil Taxonomy		FAO/UNESCO	French system
	Subgroup[a]	Family[b]		
Baoma 144801A	Typic Paleudults (or Tropeptic Haplorthox)	Clayey over clayey-skeletal, kaolinitic	Humic Nitosols (or Humic Cambisols)	Sols ferrallitiques fortement désaturés lessivés-modaux (ou remaniés modaux)
Banjema N39	Plinthic Paleudults (or "Plinthic" Udoxic Dystropepts)	Fine-loamy over clayey-skeletal, mixed	Dystric Nitosols (or Ferralic Cambisols)	Sols ferrallitiques fortement désaturés lessivés hydromorphes (ou pénévolués hydromorphes)
Bonjema N105	Same as Bonjema N39	Fine-loamy over loamy-skeletal, mixed	Same as Bonjema N39	Same as Bonjema N39
Bosor P60	Orthoxic Palehumults (or Udoxic Dystropepts)	Fine-loamy over loamy-skeletal, mixed	Humic Nitosols (or Humic Cambisols)	Sols ferrallitiques fortement désaturés lessivés-modaux
Gbamani T165	"Arenic" Tropohumods	Sandy, mixed	Humic Podzols	Podzols humo-ferrugineux
Gbehan T187	"Plinthic Tropeptic" Ochraquox	Clayey, kaolinitic	Humic Ferralsols	Sols hydromorphes à gley de surface
Gbesebu N125	Fluventic Udoxic Dystropepts	Fine-clayey, kaolinitic	Ferralic Cambisols	Sols ferrallitiques fortement désaturés pénévolués hydromorphes
Gbesebu N13	Same as Gbesebu N125	Same as Gbesebu N125	Same as Gbesebu N125	Same as Gbesebu N125
Kania N70	"Plinthic" Orthoxic Palehumults (or Plinthic Aquic Umbriorthox)	Clayey, kaolinitic	Humic Nitosols (or Humic Ferralsols)	Sols ferrallitiques fortement désaturés lessivés hydromorphes (ou typiquement hydromorphes; ou sols hydromorphes minéraux à gley de profondeur)
Keyo 145041	Fluventic Tropaquents	Coarse-loamy, mixed	Dystric Gleysols	Sols hydromorphes minéraux à gley de profondeur
Kparva 145042	Aquic Paleudults (or Aquic Tropeptic Haplorthox)	Clayey, kaolinitic	Humic Nitosols (or Humic Ferralsols)	Sols hydromorphes minéraux à gley lessivés (ou gley de profondeur; ou sols ferrallitiques fortement désaturés remaniés hydromorphes)
Mabassia, shallow P71	"Plinthic" Udoxic Dystropepts	Fine-loamy, mixed	Humic Cambisols	Sols ferrallitiques fortement désaturés pénévolués hydromorphes
Mabassia, deep P108	Orthoxic Palehumults	Clayey, kaolinitic	Humic Nitosols	Sols ferrallitiques fortement désaturés lessivés
Makeni P2	Typic Paleudults	Clayey-skeletal, oxidic	Humic Nitosols	Sols ferrallitiques moyennement désaturés en B "lessivés indurés"
Makundu P104	Plinthic "Tropeptic" Umbriorthox	Clayey, kaolinitic	Humic Ferralsols	Sols ferrallitiques fortement désaturés pénévolués hydromorphes
Mankane P8	Plinthic Tropaquepts	Coarse-loamy, mixed	Dystric Gleysols	Sols hydromorphes minéraux à gley de surface
Manowa Kpuabu 1	Orthoxic Palehumults (or Typic Umbriorthox)	Clayey-skeletal, oxidic	Humic Nitosols (or Humic Ferralsols)	Sols ferrallitiques fortement désaturés lessivés indurés (ou remaniés jaunes)
Masheka P49	Orthoxic Palehumults (or Udoxic Dystropepts)	Fine-loamy over loamy-skeletal, mixed	Humic Nitosols (or Humic Cambisols)	Sols ferrallitiques fortement désaturés lessivés hydromorphes (ou humifères-modaux)
Masuba P9	"Plinthic" Udoxic Dystropepts	Fine-loamy, mixed	Ferralic Cambisols	Sols ferrallitiques fortement désaturés typiquement hydromorphes
Moa Kpuabu 3	Tropeptic Haplorthox (or Fluventic Udoxic Dystropepts)	Clayey, kaolinitic	Humic Ferralsols (or Ferralic Cambisols)	Sols ferrallitiques fortement désaturés pénévolués hydromorphes
Mokoli N14	Fluventic Udoxic Dystropepts	Very fine clayey, kaolinitic	Ferralic Cambisols	Sols ferrallitiques fortement désaturés pénévolués hydromorphes
Mokonde N42	Plinthic Paleudults (or "Plinthic" Udoxic Dystropepts)	Coarse-loamy over loamy-skeletal, mixed	Dystric Nitosols (or Ferralic Cambisols)	Sols ferrallitiques fortement désaturés lessivés indurés (ou pénévolués hydromorphes)
Momenga N123	"Plinthic" Dystropepts	Clayey-skeletal, oxidic	Chromic Cambisols	Sols ferrallitiques fortement désaturés pénévolués avec érosion et remaniement
Momenga N86	Same as Momenga N123	Same as Momenga N123	Same as Momenga N123	Same as Momenga N123
Momenga N44	Same as Momenga N123	Same as Momenga N123	Same as Momenga N123	Same as Momenga N123

[a] Names in quotation marks are suggested new subgroup designations not listed in *Soil Taxonomy* (69).
[b] All families belong to the isohyperthermic temperature class and acid reaction class.

Table 9 (continued).

Soil series and profile number	*Soil Taxonomy*		FAO/UNESCO	French system
	Subgroup[a]	Family[b]		
Njala N109	Orthoxic Palehumults	Clayey-skeletal, oxidic	Humic Nitosols	Sols ferrallitiques fortement désaturés lessivés indurés
Njala N108	Plinthic Paleudults	Same as Njala N109	Same as Njala N109	Same as Njala N109
Nyawama N100	"Plinthic" Orthoxic Palehumults (or Plinthic Umbriorthox)	Fine-loamy, mixed	Humic Nitosols (or Humic Ferralsols)	Sols ferrallitiques fortement désaturés lessivés hydromorphes (ou typiquement faiblement appauvris)
Nyawama N71	Same as Nyawama N100	Clayey, kaolinitic	Same as Nyawama N100	Same as Nyawama N100
Nyawama N15	Plinthic "Orthoxic" Paleudults (or Plinthic Haplorthox)	Same as Nyawama N71	Same as Nyawama N100	Same as Nyawama N100
Panlap P1	Aeric Plinthic Tropaquepts	Coarse-loamy, mixed	Humic Gleysols	Sols hydromorphes minéroux à gley de profondeur
Pelewahun N47	Typic Plinthaquults	Fine-loamy over clayey-skeletal, mixed	Plinthic Acrisols	Sols hydromorphes minéraux à gley de surface
Pelewahun N106	Plinthic Paleaquults	Fine-loamy over loamy-skeletal, mixed	Dystric Nitosols	Same as Pelewahun N47
Pendembu Kpuabu 2	Typic Paleudults	Fine-loamy, mixed	Humic Nitosols	Sols ferrallitiques fortement désaturés lessivés hydromorphes
Pujehun N80	Fluventic Udoxic Dystropepts	Fine-loamy, mixed	Ferralic Cambisols	Sols ferrallitiques fortement désaturés pénévolués hydromorphes
Rokupr R1	Typic Sulfaquepts	Fine-clayey, kaolinitic	Thionic Fluvisols	Sols minéraux bruts d'apport marin
Rokupr R2	Typic Sulfaquents	Same as Rokupr R1	Same as Rokupr R1	Same as Rokupr R1
Sohama T149	Typic Quartzipsomments	Sandy, siliceous	Dystric Regosols	Sols peu évolués non climatiques d'apport-isohumiques
Segbwema 145005	Tropeptic Haplorthox (or Udoxic Dystropepts)	Fine-loamy, mixed	Humic Ferralsols (or Ferralic Cambisols)	Sols ferrallitiques fortement désaturés pénévolués avec érosion et remaniement
Toiama N101	Plinthic Umbric Paleaquults	Fine-loamy, mixed	Humic Nitosols	Sols hydromorphes minéraux à gley de surface
Taso T183	Plinthic "Tropeptic" Umbriorthox	Clayey, kaolinitic	Humic Ferralsols	Sols ferrallitiques fortement désaturés pénévolués hydromorphes
Timbo P19	Typic Umbriorthox (or Udoxic Dystropepts)	Fine-loamy skeletal, mixed	Humic Ferralsols (or Humic Cambisols)	Sols ferrallitiques fortement désaturés pénévolués avec érosion et remaniement
Tubum P13	Udoxic Dystropepts	Fine-loamy over loamy-skeletal, mixed	Humic Cambisols	Sols ferrallitiques fortement désaturés pénévolués
Vaohun 145010	Typic Dystropepts	Clayey, kaolinitic	Dystric Cambisols	Sols ferrallitiques moyennement désaturés en B pénévolués avec érosion et remaniement

[a] Names in quotation marks are suggested new subgroup designations not listed in *Soil Taxonomy* (69).
[b] All families belong to the isohyperthermic temperature class and acid reaction class.

a cambic horizon with udoxic properties. These soils have an ochric epipedon and show evidence of stratification, including charcoal fragments deposited in various layers. Gbesebu soils are a member of the fine-clayey, kaolinitic, isohyperthermic family of Fluventic Udoxic Dystropepts.

Kania soils are imperfectly drained and usually occur in somewhat lower areas of the nearly level terrace of the Taia River or in similar topographic positions. They developed in gravel-free, sandy clay loam to clay alluvium. These soils have an umbric epipedon and usually have an argillic horizon and the properties of an oxic horizon (Appendix C). Analyses of other Kania profiles indicate that the ratio of illuvial to eluvial clay may not always be as great as in profile N70. Low chromas are present in the subsoil, and plinthite mottles are abundant. Kania soils have been classified as a member of the clayey, kaolinitic, isohyperthermic family of "Plinthic" Orthoxic Palehumults on the basis of available information. If thin-section studies indicate that the B horizon does not contain enough clay skins to be argillic, these soils would be classified as Plinthic Aquic Umbriorthox.

The **Keya soils** are very poorly drained and occur in depressions in the lowest parts of inland valley swamps in eastern Sierra Leone. They are developing in coarse-loamy colluvium and alluvium that is transported from surrounding higher areas. They have an ochric epipedon but no other diagnostic horizons. Keya soils are classified as a member of the coarse-loamy, mixed, acid, isohyperthermic family of Fluventic Tropaquents, although the colors do not entirely fit the definition for Aquents.

Kparva soils are poorly drained and occur on nearly level, low-lying areas in eastern Sierra Leone. They have an ochric epipedon and, with an illuvial/eluvial clay ratio of 1.8 in the profile (Appendix C), they probably have an argillic horizon. Therefore, they have been classified as a member of the clayey, kaolinitic, isohyperthermic family of Aquic Paleudults. Chromas in the B_{2t} horizon are not as gray (Appendix B) as is characteristic of the aquic moisture regime (*69*), but saturation with water in the upper 30 inches (75 cm) of the profile is enough for this soil to be aquic. The B_{3t} horizon has the properties of an oxic horizon. If subsequent thin-section study shows that the B horizon is not argillic, Kparva soils would be classified in the Aquic Tropeptic Haplorthox subgroup, but this seems unlikely.

The **Mabassia soils** are well drained and have developed in a hill-wash that was deposited in relatively lower and concave parts of the uplands. The colluvial top layer may range considerably in thickness — from 10 to more than 48 inches (25 to 122 cm) — and consists of almost gravel-free sandy loam to sandy clay. The colluvial layer is underlain by gravelly material. Mabassia soils usually have an umbric epipedon and some properties of an oxic horizon. The shallower phase, P71, has a cambic horizon and is classified as a member of the fine-loamy, mixed, isohyperthermic family of "Plinthic" Udoxic Dystropepts. The deep phase of Mabassia, P108, which probably has an argillic horizon (Appendix C), is classified as a member of the clayey, kaolinitic, isohyperthermic family of Orthoxic Palehumults. Both of these soil profiles are very close to the Oxisols.

Makeni soils are well drained and occur extensively on both the summits and sloping sides of hills in the Makeni area. The soils consist of very gravelly colluvial and residual material, usually more than 10 feet (3 m) thick, overlying granitic bedrock. The main components are sesquioxides in the form of hardened to soft plinthite glaebules and mottles, quartz in sand grains and larger particles, and kaolinitic clay. The gravels consist mainly of hardened plinthite glaebules with some quartz. In the upper part of the profile, the hardened plinthite glaebules are dense, dark-coated, and mostly rounded, probably as a result of having been transported. With increasing depth, the glaebules become softer, more porous, and irregular because they are formed *in situ*. Below depths of 6 to 8 feet (2 to 2.5 m), red mottles of soft plinthite are present, having formed as a result of mobilization, displacement, and accumulation of iron in horizons that are seasonally saturated with water. With alternating wet and dry conditions, the plinthite mottles may irreversibly harden into iron glaebules, even in well-drained upland soils, under current climatic conditions in Sierra Leone.

Soil fauna, especially termites and worms, are responsible for intensive biological homogenization of the soil profile. Termites are also partly responsible for a gravel-free surface layer up to 10 inches (25 cm) thick, which may occur on top of the gravelly layers. Termites, such as the genus *Macrotermes natalensis,* build numerous mounds as high as 10 feet (3 m). These mounds consist entirely of material less than 2 mm in diameter, brought up from the gravelly subsoil by the termites. The gravels are left behind, and, as a result of these termite activities, the gravel content of the gravelly layers progressively increases. The termite mounds are chemically richer than the surrounding subsoils and often are richer than the topsoils (*51*).

Makeni soils are a member of the clayey-skeletal, oxidic, isohyperthermic family of Typic Paleudults. They have an argillic horizon on the basis of the illuvial/eluvial clay ratio (Appendix C) and on the basis of clay skins observed in thin sections. The clay skins appear to be relict rather than being formed currently, and they are weak enough that they were not described in the field. In fact, the B_{22t} horizon of Makeni profile P2 has all the properties of an oxic horizon, and the soil would be classified as an Oxisol if it did not have an argillic horizon. The Makeni soils usually have an umbric epipedon, but a few profiles with too thin a dark surface horizon are classified as having an ochric epipedon.

The **Makundu soils,** which occur on the alluvial floodplain along the Mabole River, are moderately well to well drained. They are much finer textured than the soils with which they are associated. They have an umbric epipedon and a thick oxic horizon (Appendix C). Makundu soils are a member of the clayey, kaolinitic, isohyperthermic family of Plinthic "Tropeptic" Umbriorthox. The Taso soils along the Sewa River in southern Sierra Leone are a member of this same family, and the two series have many similar characteristics.

Mankane soils occur in the lowest parts of the valley bottoms and are poorly to very poorly drained. They have sandy loam to loamy sand textures to depths of more than 48 inches (122 cm), often overlying white kaolinitic clay mixed with sand and quartz pebbles. The soils usually have an ochric epipedon and a cambic horizon. Mankane soils are a member of the coarse-loamy, mixed, acid, isohyperthermic family of Plinthic Tropaquepts.

The moderately well-drained **Manowa soils** occupy summits and upper convex slopes of upland hills in eastern Sierra Leone. These soils have an umbric epipedon and very gravelly subsoils. On the basis of their illuvial/eluvial clay ratio of 1.2 (Appendix C), Manowa soils are believed to have argillic horizons, as this ratio is similar to those of Makeni and Njala soils for which thin sections demonstrated the presence of argillic B horizons. Therefore, the Manowa soils are classified as a member of the clayey-skeletal, oxidic, isohyperthermic family of Orthoxic Palehumults. The B_{22t} horizon has the properties of an oxic horizon. If later thin-section study shows that the B horizon is not argillic, Manowa soils would be classified in the Typic Umbriorthox subgroup.

The **Masheka soils** belong to the well-drained older tributary terraces. They are similar to Bosor soils but differ in the thickness of the gravel-free layer, which is more than 48 inches (122 cm) thick in Masheka and overlies a gravelly subsoil. The soils have an umbric epipedon and an argillic or cambic horizon. If they have an argillic horizon, they would be classified as a member of the fine-loamy over loamy-skeletal, mixed, isohyperthermic family of Orthoxic Palehumults. If further study indicates that the B horizon is not argillic, Masheka soils would be classified in the Udoxic Dystropept subgroup.

The **Masuba soils,** which are moderately well drained, occur on the lower part of recent tributary terraces. These soils are sandy clay loam throughout the profile. They usually have an umbric horizon, but the dark A horizon of profile P9 is thin and, therefore, is an ochric epipedon. A cambic horizon present in the subsoil has some of the properties of an oxic horizon, but the amount of water-dispersible clay is too high to qualify as an oxic horizon (Appendix C). Masuba soils are a member of the fine-loamy, mixed, isohyperthermic family of "Plinthic" Udoxic Dystropepts.

The **Moa soils,** which occur on the alluvial floodplain along the larger streams in the upper Moa Basin in eastern Sierra Leone, are moderately well to well drained. They have an ochric epipedon and, in the lower B horizon, an oxic horizon. Moa soils are classified as a member of the clayey, kaolinitic, isohyperthermic family of Tropeptic Haplorthox. If further study indicates that these soils contain more than 3 percent of weatherable minerals in the fraction between 20 and 200 microns, they would be classified in the Fluventic Udoxic Dystropept subgroup.

The imperfectly to poorly drained **Mokoli soils** occur in drainageways on the alluvial floodplain of the Taia River. They contain more than 6-percent mica in the fraction between 20 and 200 microns (Appendix B), but in other properties their B horizons have characteristics of an oxic horizon (Appendix C). According to the current definition (*69*), this amount of mica excludes them from the oxic horizon, so they are classed as having a cambic horizon with udoxic properties. These soils have an ochric epipedon and evidence of stratification. Mokoli soils are a member of the very fine clayey, kaolinitic, isohyperthermic family of Fluventic Udoxic Dystropepts. Chromas of mottles in the upper 39 inches (1 m) of profile N14 are not gray enough (Appendix B) to be designated aquic, but the soil is saturated to the surface annually for about two months (Fig. 30).

Mokonde soils are moderately well drained and occur on upper terraces and colluvial footslopes. They have a gravel-free surface layer 10 to 24 inches (25 to 61 cm) thick, overlying a gravelly subsoil. Mokonde soils occur adjacent to Njala soils but differ from them in having a thicker gravel-free layer. The gravel-free materials are of colluvial origin and are the erosion products of fine earth brought up by the termites. Mokonde soils have an ochric epipedon and many plinthite mottles in the subsoil. Mokonde soils have been classified as a member of the coarse-loamy over loamy-skeletal, mixed, isohyperthermic family of Plinthic Paleudults because it is believed that they have an argillic horizon; however, thin-section data are not available to determine the extent of clay skins. If the latter are of minor extent, these soils would be classified as "Plinthic" Udoxic Dystropepts.

The **Momenga soils** occur on steep slopes of the uplands. The upper part of the profile is usually gravelly over an almost gravel-free lower subsoil, with soft bedrock pieces (saprolite) often within 48 inches (122 cm). The moderate depth of profile over bedrock is caused by active geologic erosion. The diagnostic horizons are an ochric epipedon and a cambic horizon. Cation-exchange capacity is more than 24 me/100 g of clay in all horizons (Appendix C). Base saturation is distinctly less than 50 percent in all horizons. Exchangeable aluminum is always high in the subsoil, typically ranging from 6 to 12 me/100 g of the fine-earth fraction (< 2.0 mm). Momenga soils (profiles N123, N86, and N44) are classified as a member of the clayey-skeletal, oxidic, isohyperthermic family of "Plinthic" Dystropepts, which reflects their relatively youthful stage of soil development. The subgroup prefix "plinthic" indicates that soft plinthite occurs within 50 inches (127 cm) of the soil surface.

The **Njala soils,** which make up the bulk of the upland soils in the Njala area, consist of a thick surface layer of gravelly colluvial and residual material. Main components are kaolinitic clay and sesquioxides in the form of indurated to soft plinthite glaebules and mottles. The colluvial layer consists of about 50-percent hard and dense glaebules with smooth surfaces in a clayey matrix. It is most likely that rounding of the glaebules is caused by transportation, most of which has taken place over only short distances (*80*). Underlying the gravelly colluvium is a layer of residual iron glaebules in a clayey matrix. These glaebules are relatively soft and porous and have irregular forms. Their amount decreases with depth. Soft plinthite is often present in the form of red mottles. They result from the mobilization, displacement, and accumulation of iron in horizons that are saturated with water at some season. Because of alternating wet and dry conditions, the plinthite mottles may irreversibly harden into iron glaebules. Under current climatic conditions, these criteria are met even in the moderately well- and well-drained upland soils. When iron segregation has been sufficient to permit irreversible hardening on exposure to wetting and drying, the mottles are considered plinthite (*69*).

The two Njala profiles that have been analyzed, N109 and N108, are different in some properties even though they are close together geographically (Appendix B). On the basis of the ratio of illuvial clay to eluvial clay (Appendix C) and on the basis of clay skins observed in thin sections, both profiles have an argillic horizon. The clay skins appear to be relict rather than being formed currently, and they are weak enough that they were not described in the field. The clay activity is very low. In fact, the B_{22t} horizon of Njala profile N109 has the properties of an oxic horizon, and the soil would be classified as an Oxisol if it did not have an argillic horizon. Njala soils usually have an ochric epipedon, as does N108, but the A_1 horizon of a few profiles, such as N109, is thick enough and dark enough to qualify as an umbric epipedon. Njala profile N109 is a member of the clayey-skeletal, oxidic, isohyperthermic family of Orthoxic Palehumults. Njala profile N108 is classified as a member of the clayey-skeletal, oxidic, isohyperthermic family of Plinthic Paleudults, although the upper B horizon is slightly low in clay content to qualify for this particle-size class.

The **Nyawama soils** are moderately well drained and occur primarily on the nearly level terrace of the Taia River. They developed in fine-loamy or clayey material that is gravel-free. Nyawama soils usually have an umbric epipedon, although the dark-colored A_1 horizon of Nyawama profile N15 is thin (5 inches, or 13 cm) so that it has an ochric epipedon (Appendix B). Profile N100 is fine-loamy, whereas profiles N71 and N15 are in the clayey particle-size class. On the basis of illuvial/eluvial clay ratios of 1.3 or 1.4 in their profiles, these soils have an argillic horizon (Appendix C), but thin-section data are not available to indicate the extent of clay skins. These soils also have the properties of an oxic horizon in their lower subsoils, and they would be classified as Oxisols (see subgroup names in Table 9) if later work shows that they do not have argillic horizons, which seems unlikely. Although these three Nyawama profiles are similar in most characteristics, they have different classifications, because of differences in thickness of the dark surface horizon (N15 is the thinnest) and differences in clay content in the B horizon (N100 contains the least clay):

N100 = Fine-loamy, mixed, isohyperthermic family of "Plinthic" Orthoxic Palehumults
N71 = Clayey, kaolinitic, isohyperthermic family of "Plinthic" Orthoxic Palehumults
N15 = Clayey, kaolinitic, isohyperthermic family of Plinthic "Orthoxic" Paleudults

The **Panlap soils** are imperfectly to poorly drained and occur on gentle concave slopes near streams or on the edges of inland swamps. They have developed in nearly gravel-free, coarse-loamy material that is more than 48 inches (122 cm) thick over a gravelly layer or residual material (often saprolite). From the upland toward the valley bottom, the layer of detrital hardened plinthite glaebules (if present) gradually decreases in thickness and finally disappears in the poorly drained swamps because of intense leaching of iron; only white kaolinitic clay, mixed with quartz sand and gravel, is left. Panlap soils usually have an umbric epipedon, with or without a cambic horizon. They have been classified as a member of the coarse-loamy, mixed, acid, isohyperthermic family of Aeric Plinthic Tropaquepts. The prefix aeric indicates a subhorizon at depths of less than 30 inches (75 cm) with chromas of more than 2.

Pelewahun soils occupy poorly drained drainageways and swamps of the colluvial footslopes and tributary stream terraces. They have a gravel-free layer 24 to 48 inches (61 to 122 cm) thick, overlying a gravelly subsoil. These soils are flooded for several months during the rainy season. Pelewahun soils often have an umbric epipedon, but in some areas it is ochric. They have a distinct argillic horizon on the basis of clay accumulation in the B horizon (Appendix C) and on the basis of clay skins observed in the field (Appendix B) and in thin sections (*44*). Pelewahun profile N47 is a member of the fine-loamy over clayey-skeletal, mixed, isohyperthermic family of Typic Plinthaquults. In the FAO/UNESCO classification, it is a Plinthic Acrisol (instead of a Nitosol, which is often equivalent to Ultisols) because it has a plinthic horizon and an abrupt textural change between the B_2 and overlying horizons. Pelewahun profile N106 contains less clay and is a member of the fine-loamy over loamy-skeletal, mixed, isohyperthermic family of Plinthic Paleaquults. Most Pelewahun soils have less than 50-percent red plinthite mottles in all subhorizons above a depth of 50 inches (125 cm) and so are similar to N106 in this property, rather than N47.

The **Pendembu soils** are imperfectly drained and occur on footslopes and upper tributary terraces in eastern Sierra Leone. They have an ochric epipedon and an argillic horizon. The latter is indicated by clay skins described in the field (Appendix B) and by the illuvial/eluvial clay ratio of 1.3 in the profile (Appendix C). Pendembu soils are a member of the fine-loamy, mixed, isohyperthermic family of Typic Paleudults.

Pujehun soils are well drained and occur on natural levees adjacent to the Taia River. They are stratified and have an ochric epipedon. They contain more than 6-percent mica in the fraction between 20 and 200 microns (Appendix B); but in other properties, their lower subsoils have characteristics of oxic horizons (Appendix C). According to the current definition (*69*), this amount of mica excludes them from the oxic horizon, so they are classed as having a cambic horizon with udoxic properties. Pujehun soils are a member of the fine-loamy, mixed, isohyperthermic family of Fluventic Udoxic Dystropepts.

The **Rokupr soils** are very poorly drained, occurring in tidal swamps and up adjacent stream estuaries. They are very high in sulfur content, 1 to 11.5 percent. The two profiles that have been studied are similar in most properties, except that profile R2 is in the natural, reduced condition, whereas profile R1 has been drained and oxidized enough that it has a sulfuric horizon. Both profiles have an ochric epipedon and are members of a fine-clayey, kaolinitic, acid, isohyperthermic family. Rokupr profile R2 is classified in the Typic Sulfaquent subgroup; profile R1 is in the Typic Sulfaquept subgroup.

The well-drained, sandy **Sahama soils** occur on beach ridges near the Atlantic coast. They are so high in sand content (mostly quartz) that no diagnostic horizon has developed except in the surface. Some organic matter has accumulated, and the A horizon (0 to 20 inches, or 0 to 51 cm) is borderline between an umbric and an ochric epipedon. The colors qualify for an umbric horizon, but the A_{12} horizon contains less than 0.6-percent organic carbon (Appendix B). Sahama soils are classified as a member of the sandy, siliceous, isohyperthermic family of Typic Quartzipsamments. Sahama profile T149 (Appendix B) is interesting in that the B_{21} horizon has a significant accumulation of organic carbon and the highest cation-exchange capacity in the profile, which suggests that it is developing toward a Spodic Quartzipsamment but does not yet qualify as a member of this subgroup.

The well-drained **Segbwema soils** occur extensively on steep hills in eastern Sierra Leone. They have an ochric epipedon and the properties of an oxic horizon, except that the cation-exchange capacity of the clay fraction is slightly high (Appendix C) and the amount of weatherable minerals may be slightly high (Appendix B). Segbwema soils are classified as a member of the fine-loamy, mixed, isohyperthermic family of Tropeptic Haplorthox. Should further study indicate that Segbwema soils do not have an oxic horizon, they would be a member of the Udoxic Dystropept subgroup.

The **Taiama soils** are poorly drained. They occur primarily in drainageways of the middle terraces of the Taia River and in the downstream portions of its tributaries. They usually have an umbric epipedon (Appendix B). Taiama soils are classified as a member of the fine-loamy, mixed, isohyperthermic family of Plinthic Umbric Paleaquults because they have an argillic horizon, based on the illuvial/eluvial clay ratio (Appendix C) and the observation of clay skins in thin sections. The clay activity is very low, and the lower subsoil has most of the properties of an oxic horizon.

The **Taso soils** are moderately well to well drained and occur on natural levees adjacent to the Sewa River. They have an umbric epipedon and a thick oxic horizon (Appendix C). They are high in clay and silt but low in sand content. Taso soils are a member of the clayey, kaolinitic, isohyperthermic family of Plinthic "Tropeptic" Umbriorthox. The Makundu soils along the Mabole River in central Sierra Leone are a member of this same family, and these two series have many similar characteristics.

The **Timbo soils** are well drained and occur on moderately steep to steep slopes of the uplands. They have developed in 24 to 48 inches (61 to 122 cm) of gravelly colluvium and residual material. Timbo soils differ from Makeni soils in having partly or wholly decomposed bedrock fragments, which always occur within 48 inches (122 cm) of the soil surface. The shallowness of these fragments suggests that erosion removed a considerable part of the overlying soil layers. The gravelly colluvial layer varies from about 12 to 20 inches (30 to 51 cm) thick; the gravels are very hard, dense, and nodular. In the residual layer, decomposed rock fragments occur that are very hard and porous in the upper part but soft to hard and porous deeper in the profile. Enrichment with iron probably caused the development of hardened decomposed rock fragments in which the rock structure is clearly visible. Some weatherable minerals may still be present, such as micas and probably some feldspars. Timbo soils usually have an umbric epipedon (Appendix B) and an oxic horizon (Appendix C). Within the latter, however, less than 5 percent by volume should be showing rock structure (*69*) — a restriction that often imposes problems in the recognition of an oxic horizon in Timbo soils. However, the other properties agreed so closely with the oxic horizon concept that it seemed desirable to waive the above-mentioned restriction. Timbo soils have been classified as a member of the fine-loamy skeletal, mixed, isohyperthermic family of Typic Umbriorthox. If the rock structure is taken into account, the subgroup name would be Udoxic Dystropept.

The **Tubum soils** are part of the moderately well- to well-drained recent tributary terraces and the colluvial footslopes. They have much in common with Bosor soils, but the gravel-free depositional layer is of a more recent age. The gravel-free layer is 24 to 48 inches (61 to 122 cm) thick, overlying a gravelly subsoil. Tubum soils have an umbric epipedon and a cambic horizon in the gravelly subsoil (Appendix B). The more recent age of Tubum soils compared with Bosor soils is reflected by the chemical properties of the subsurface horizon: Tubum soils have more water-dispersible clay, more extractable bases plus aluminum, and a higher cation-exchange capacity per 100 grams of clay (Appendix C). Tubum soils are a member of the fine-loamy over loamy-skeletal, mixed, isohyperthermic family of Udoxic Dystropepts.

The **Vaahun soils** occur on steep granitic hills in eastern Sierra Leone and usually have profiles less than 36 inches (91 cm) thick. They are moderately well to well drained. These soils have an ochric epipedon and a cambic horizon (Appendix B). Although the illuvial/eluvial clay ratio is 1.9 to 2.0 in the Vaahun profile that was analyzed (Appendix C), it is doubtful that an argillic horizon could form on the unstable, steep slope on which this profile occurs. The increase in clay content with depth is probably caused by colluviation rather than by illuviation. Vaahun soils are classified as a member of the clayey, kaolinitic, isohyperthermic family of Typic Dystropepts.

5. Adaptation and Management of Soils

Soil series, the lowest category in the natural classification, are homogeneous with respect to many properties and can therefore be grouped for a wide variety of practical purposes, such as suitability for general agricultural use and management, production of a specific crop or combination of crops, or nonagricultural uses. Only agricultural uses are considered in this report.

In Section 5, the soil series are grouped according to their suitability for general agricultural use and their major management problems. Primary focus is on crops that require aerated soils. However, each soil is also evaluated for swamp rice, an important crop on water-saturated, poorly aerated soils. Principles of soil fertility and management of selected crops are also discussed.

5:1. IMPORTANT FACTORS IN SOIL GROUPING

A number of soil properties influence the productivity of crops. Those that may limit plant growth in varying degrees are often designated as "limiting factors." These factors include slope (erosion hazard), texture, presence and characteristics of unfavorable layers such as gravel or rock, available moisture-holding capacity, waterlogging, level of available nutrients, and pH.

One of the most important limiting factors is the moisture-holding capacity of soils, especially moisture that is held available for plant growth. On soils with high available moisture-holding capacity, two crops can be grown annually without irrigation — one from May through August, another from September through December. (This second crop is not practical on gravelly upland soils with low moisture-holding capacity). Growing this second crop on the better soils during the declining rains (September through December) provides an excellent opportunity to produce grain crops economically and harvest them under more favorable conditions than during the rainy season. A third crop can be grown during the later part (January through April) of the dry season if cheap irrigation water is available. The available moisture-holding capacities of selected soil profiles to a depth of 60 inches (153 cm) are listed in Table 10. These values are calculated from bulk density, gravel content, and 1/3 atmosphere and 15 atmospheres moisture values for the various profiles in Appendix B.

Available moisture-holding capacity is greatest in soils or horizons that contain much silt. The high value for the Momenga profile N123 is due to the high silt content of its C horizon (see Appendix B). The Gbehan, Taso, Pujehun, Gbesebu, and Mokoli soils on the alluvial floodplains contain much silt (Sections 4:7 and 4:8:4) and have high available moisture-holding capacities. In contrast, the gravelly upland soils such as Makeni, Manowa, and Timbo or sandy soils such as Sahama and Gbamani have very low available moisture-holding capacities and, therefore, are droughty throughout the long dry season. On the basis of the data in Table 10, the available moisture-holding capacities are grouped as follows:

Designation	Inches of available moisture-holding capacity per inch of soil	Available moisture-holding capacity to 60 inches (1,524 mm)	
		(inches)	(mm)
Very low	.01-.03	0-2	0-51
Low	.03-.06	2-4	51-102
Medium	.06-.11	4-7	102-178
High	.11-.18	7-11	178-279
Very high	.18-.25	11-15	279-381

5:2. CAPABILITY GROUPING OF SOILS

To assist in the proper use and management of soils in Sierra Leone, they have been placed in capability groups that are similar to those in a system used in the United States of America (*46*). This is a practical grouping based on limitations of the soils, the risk of damage when they are used, and the way they respond to treatment. The soils are grouped according to degree and kind of permanent limitation but without consideration of major and expensive land-forming that would change the slope, depth, or other characteristics of the soils. All of the soils are grouped at two levels: capability class and subclass. One subclass, Iw, is further divided into two units, Iw-1 and Iw-2 (see Table 11, pages 79 and 80).

Capability classes, the broadest grouping, are designated by Roman numerals I through VIII. As the numerals increase, they indicate progressively greater limitations and narrower choices for practical use. The classes are defined as follows:

- Class I. Soils with few limitations on their use.
- Class II. Soils with some limitations that reduce the choice of plants or require moderate conservation practices.
- Class III. Soils with severe limitations that reduce the choice of plants, or require special conservation practices, or both.

Class IV. Soils with very severe limitations that restrict the choice of plants, or require very careful management, or both.

Class V. Soils subject to little or no erosion but with other limitations, usually impractical to remove, that restrict their use largely to pasture, woodland, or wildlife food and cover.

Class VI. Soils with severe limitations that make them generally unsuited to cultivation and restrict their use largely to forestry, tree crops such as oil palm and rubber, pasture, or wildlife food and cover.

Class VII. Soils with very severe limitations that make them unsuited to cultivation and restrict their use largely to forestry, grazing, or wildlife.

Class VIII. Soils and landforms (such as Rock Land) with limitations that preclude their use for commercial plant production and restrict their use to wildlife, watershed protection, recreation, or esthetic purposes.

Capability subclasses are soil groups within one class. They are designated by adding one or two small letters — e, w, s, or h — to the class numeral: IIIws, for example. The letter *e* shows that the main limitation is risk of erosion unless close-growing plant cover is maintained; *w* shows that excess water on or in the soil interferes with plant growth or cultivation; *s* indicates gravel or hard rock in the soil, which is unfavorable for root extension and plant growth; and *h* indicates restricted available moisture-holding capacity in the soil.

Almost all of the soils in Sierra Leone are acid and relatively low in available plant nutrients, but most of these deficiencies can be corrected economically on soils that are suitable for agriculture. Therefore, fertility status is not included directly in this soil grouping, but relative fertility of each soil is listed in Table 11. Fertility status as related to texture and organic carbon content is discussed in Sections 4:5 through 4:10 and Appendix B.

The nomenclature and description of the capability groups do not accurately reflect the suitability of various soils for swamp rice, which grows well on water-saturated, poorly aerated soils. Therefore, each soil is given a special rating for this important crop (see Table 11).

Table 10. Grouping of selected soils according to available moisture-holding capacity to a depth of 60 inches (153 cm)

Soil series	Profile number	Available moisture-holding capacity, inches	Available moisture-holding capacity, mm
Very low			
Makeni	P2	1.4	36
Sahama	T149	1.6	41
Gbamoni	T165	1.6[a]	42[a]
Manowa	Kpuabu 1	1.8[a]	47[a]
Timbo	P19	1.9	49
Low			
Bosor	P60	2.1	54
Masheka	P49	2.3[a]	59[a]
Pendembu	Kpuabu 2	2.4[a]	61[a]
Baoma	144801A	2.6	66
Tubum	P13	2.6	67
Mabassia, shallow	P71	2.8[a]	72[a]
Njala	N109	3.0[a]	76[a]
Mokonde	N42	3.4	87
Kparva	145042	3.8	97
Medium			
Mabassia, deep	P108	4.0	102
Masuba	P9	4.0	102
Panlap	P1	4.0	102
Mankane	P8	4.7[a]	119[a]
Moa	Kpuabu 3	4.7[a]	120[a]
Makundu	P104	5.7	145
Segbwema	145005	5.8[a]	148[a]
Nyawama	N100	6.3	159
Taiama	N101	6.5	165
Kania	N70	6.8	174
High			
Mokoli	N14	7.2	184
Gbesebu	N125	7.6	194
Pujehun	N80	7.7	195
Taso	T183	9.6[a]	244[a]
Gbehan	T187	10.6[a]	269[a]
Pelewahun	N47	10.8	274
Momenga	N123	12.4	314

[a] Based on estimated values for some part of the soil profile.

5:3. SOIL MANAGEMENT SUGGESTIONS

When considering the relative suitability of the various soils and crops, attention has to be given to the type of land utilization that is envisaged. The present land-use system on the upland is a shifting cultivation or bush-fallow system, in which a particular tract of land is farmed for only two years, after which the farmer moves on to another piece of land. Selected swamps are farmed more regularly, producing swamp rice during the rainy season and vegetables during the dry season. Perennial crops grow near the villages; most of them, except coffee and cocoa, are consumed by the family. In this traditional system, capital inputs are low: the most important inputs are clearing the land and burning the brush, which are done by hand labor. Seed is of low quality, usually having been raised by the farmer and saved from the harvest of the year before. Farm operations such as weeding and harvesting are all done by hand with family labor (Fig. 45). Technical know-how is limited. Consequently, crop yields are low. Further, as a result of the overcropping of farmland, which is, in turn, the result of increasing population, yields are expected to decline.

It is very desirable to develop a new type of land utilization in which the shifting cultivation system is fully replaced by a system of planned and coordinated perma-

Figure 45. Upland rice with interspersed maize being grown by traditional shifting cultivation practices.

nent allocation of land. A less drastic new kind of land utilization could be an intermediate type in which permanent cultivation is expanded in some areas, thus relieving the pressure on the remaining farm land. The fallow period in these areas could then be lengthened, which would improve the possibility for natural regeneration under the bush-fallow system. The permanent cultivation should be carried out on the better soils, with the use of modern management practices, fertilizers, etc. Considering the farmers' present level of technical know-how, the intermediate type of land utilization mentioned above is probably best, for it would allow them to make a gradual shift to a higher degree of technical know-how.

The soil management suggestions described in the rest of this section are aimed at the intermediate type of land utilization. This system is characterized by permanent cultivation on the better soils and by the traditional shifting cultivation system, tree crops, or forestry on the less productive soils. Under regular cultivation, farm practices must improve markedly to include good cropping systems, proper use of fertilizers, better crop varieties, and, where practicable, irrigation on the best soils during the dry season.

The soils within one capability or management group in Table 11 are enough alike that they are suited to the same crops or native plants, require similar management, and have similar productivity and other responses to management. Following are descriptions of each capability or management group listed in Table 11 and suggestions for the use and management of the soils in each group.

Management Group Ih: Nyawama, Makundu, and Moa. These soils are moderately well to well drained and aerated, but Makundu and Moa may be flooded for a few days during the rainy season. They have medium available moisture-holding capacity but suffer from drought during the later part of the dry season. These soils are permeable, occur on nearly level areas, and are not subject to erosion. They have good physical properties and can be cultivated easily. However, they are strongly acid and only fair in available plant nutrients, so that proper fertilization is necessary to obtain profitable crop yields. These soils can be used intensively for a wide variety of both annual and perennial crops: rice, maize, groundnuts, pineapple, coffee, oil palm, citrus, etc. The soils can be used throughout the year if irrigation water can be obtained economically from the major streams near which the soils occur. Peasant farmers should be encouraged to use these soils more intensively than they now do under the bush-fallow system. Rice, for example, can be grown during the rainy season (May through August), and maize during the season of declining rains (September through December). If irrigation water is provided, a third crop can be grown during the last part of the dry season (January through April).

Management Group Iw-1: Taso, Gbesebu, and Pujehun. These three soils are similar to those in Management Group Ih in many characteristics but have higher available moisture-holding capacities and may be subject to flooding for a few more days during the wet season. Accordingly, crops sensitive to brief flooding should be avoided in areas that are subject to this hazard. In other respects, however, Iw-1 soils should be managed the same as those in Group Ih. The Iw-1 soils, which occur primarily in moderately large areas near major streams, offer excellent possibilities for modern commercial farming with efficient capital and labor inputs. They are among the most productive soils in their area of occurrence.

Management Group Iw-2: Mokoli and Kania. These two soils have many characteristics in common with the soils in Management Groups Ih and Iw-1. The major differences are in natural drainage and the soil moisture regime. Kania is imperfectly drained, and Mokoli is imperfectly to poorly drained. Under natural conditions they are waterlogged at the surface for approximately two to three months during the rainy season. They may even be submerged for several weeks. During the dry season, however, these soils may be deficient in moisture for plant growth for one to three months. If these soils are properly drained and fertilized, their suitability is similar to those in Management Groups Ih and Iw-1, and they can be used for a wide variety of crops. Intensive use of these soils would require a modern farming system. Without supplementary drainage, the soils in Management Group Iw-2 can be used for swamp rice during the main rainy season and for crops such as maize and vegetables during the declining rains (September through December). On areas near a good source of irrigation water such as the Taia River, another crop can be grown under irrigation during the last part of the dry season (January through April).

Table 11. Selected characteristics of soils, their capability grouping, rating for swamp rice, and recommended use

Capability group	Soil series	Rating for swamp (paddy) rice[a]	Limitations: Erosion hazard	Limitations: Waterlogging at surface	Limitations: Presence of unfavorable gravel	Limitations: Available moisture-holding capacity	Limitations: Droughtiness	Limitations: Fertility	Recommended use
Ih	Nyawama	5, 3	None	Never	None	Medium	4 months	Fair to poor	Both annual and perennial crops such as rice, maize, groundnuts, cassava, pineapple, coffee, oil palm, and citrus. Dry season irrigation recommended.
	Makundu	4, 2	None	Never to a few days	None	Medium	2 months	Fair	
	Moa	4, 2	None	Never to a few days	None	Medium	1 month	Fair	
Iw-1	Taso	4, 2	Little or none	Never to 1 to 2 weeks	None	High	2 months	Fair	Same as for Ih.
	Gbesebu	4, 2	Little or none	Never to 2 to 4 weeks	None	High	2 months	Fair	
	Pujehun	5, 3	Little or none	Never to a few days	None	High	3 months	Poor	
Iw-2	Mokoli	1, 1	None	3 months	None	High	1 month	Fair	Suitability similar to group Iw-1, above, if soils are properly drained. Without supplementary drainage, swamp (paddy) rice during the rainy season with bunding and water control. Grains and vegetables during the dry season, preferably with irrigation.
	Kania	2, 1	None	2 months	None	Medium	3 months	Fair to poor	
IIw	Taiama	1, 1	Little or none	3 to 4 months	None	Medium	2 months	Fair to poor	Swamp rice during the rainy season, with bunding and water control, and vegetables during the dry season. With supplementary drainage a variety of crops can be grown.
	Kparva	2, 1	None	2 to 4 months	Very little or none	Low	None	Poor	
IIh	Mosuba	6, 4	Slight	Never	None	Medium	3 months	Poor	Both annual and perennial crops such as upland rice, maize groundnuts, cassava, coffee, oil palm, and citrus. Dry season irrigation desirable but not feasible in most places.
	Mabassia, deep	6, 4	Slight	Never	None	Medium	3 to 4 months	Poor	
	Masheka	7, 5	Slight	Never	None	Low	4 months	Poor	
IIhs	Bonjema	7, 5	Slight	Never to a few days	Begins at 24 to 48 inches	Medium	4 months	Poor	Same as for IIh.
	Baoma	7, 5	Slight	Never	"	Low	4 months	Fair	
	Mabassia, shallow	7, 5	Slight	Never	"	Low	4 months	Poor	
	Tubum	7, 5	Slight	Never	"	Low	4 months	Poor	
	Bosor	7, 5	Slight	Never	"	Low	4 months	Poor	
IIwh	Panlap	2, 1	Little	4 months	Local rock outcrops	Medium	1 to 2 months	Poor	Swamp rice during the rainy season, with bunding and water control. Vegetables on Panlap during the dry season. With supplementary drainage, a variety of crops can be grown.
	Pendembu	4, 2	Little	2 months	None	Low	2 months	Very poor	
IIIw	Gbehan	2, 1	None	2 to 4 months	None	High	None	Fair	Swamp rice during the rainy season, with bunding and water control. Vegetables during the dry season.
IIIws	Pelewahun	3, 2	Little or none	3 to 4 months	Begins at 24 to 48 inches	High	2 months	Poor	
IIIsh	Mokonde	8	Slight	Never to a few days	Begins at 10 to 24 inches	Low	4 months	Very poor	Annual crops such as upland rice, cassava, and groundnuts. Tree crops such as coffee, oil palm, citrus, and forestry.
	Njala, nearly level	9	Slight	Never	In entire profile	Low	5 months	Very poor	

(Footnote given on next page.)

Table 11 (continued).

Capability group	Soil series	Rating for swamp (paddy) rice[a]	Limitations: Erosion hazard	Waterlogging at surface	Presence of unfavorable gravel	Available moisture-holding capacity	Droughtiness	Fertility	Recommended use
IVw	Mankane	2, 1	None	5 months	Local rock outcrops	Medium	None	Poor	Swamp rice during the rainy season, with bunding and water control. Vegetables during the dry season.
	Keya	3, 2	None	4 to 5 months	Very little or none	Low	None	Poor	
IVsh	Njala, sloping	10	Moderate to severe	Never	In entire profile	Low	5 months	Very poor	Upland rice, cassava, and groundnuts. Tree crops such as coffee, oil palm, citrus, and forestry. Improved pasture is a promising use. Forestry is recommended on the steeper slopes.
	Manowa	10	Moderate	Never	In entire profile	Very low	4 months	Very poor	
	Makeni	10	Moderate	Never	In entire profile	Very low	5 months	Very poor	
Vw	Rokupr	2, 2	None	Floods daily at high tide unless protected	None	High	None	Fair	Swamp rice, with bunding and careful water control to avoid excess drainage, oxidation, and development of harmful acidity.
VIes	Segbwema	9	Severe	Never	30 to 10% in solum	Medium	3 months	Fair	Forestry. The steep slopes are unsuitable for agriculture. On moderote slopes, tree crops such as oil palm and citrus may be grown; upland rice and groundnuts are suitable on a few leveler areas.
	Momengo	10	Severe	No, except on lower slope	Throughout the solum	Usually high	4 months	Fair to poor	
	Timbo	10	Moderote to severe	Never	In entire profile	Very low	4 months	Very poor	
VIhs	Gbamani	10	Slight	Never	B5 to 95% sand	Very low	5 months	Very poor	Unsuitable for agricultural crops, except coconuts. Oil palms grow on these soils, but yields are very low.
	Sahama	10	Slight	Never	90 to 95% sand	Very low	5 months	Very poor	
VIIes	Voahun	10	Severe	Few days seepage over rock	Bedrock <36 inches	Low	3 months	Fair	Forestry. Unsuitable for agriculture.
VIIIsh	Rock Land	10	Severe	Never	Hard bedrock at surface	Very low	5 months	Very poor	Natural trees and shrubs. Not suitable for agriculture.

[a] The rating is from 1, the best, to 10, which is unsuitable. Bunding, leveling, and water control are necessary for successful production. Where two ratings are given, the second one is for oreos that can be irrigated economically.

Management Group IIw: Taiama and Kparva. These poorly drained soils are waterlogged at the soil surface for two to four months during the rainy season and even submerged for several weeks. Taiama may be deficient in moisture for plant growth during about two months of the dry season, but Kparva usually is not. Given adequate supplemental drainage, these soils would be suited for a variety of crops if modern farming methods were used. Otherwise, the soils can be used only for swamp (paddy) rice during the wet season. To limit risks of sudden, deep submergence and to maintain the proper water level, bunding is necessary. This can be done easily with earth bunds and wooden spillways. Fertilizers should be applied regularly. During the dry season, enough moisture remains to grow vegetables. Swamp soils such as Taiama can be farmed regularly and will produce much higher yields if proper water control, weed control, fertilization, and crop varieties are used. Much swampland, though not yet used, could, if fully utilized, contribute much to the rice supply in Sierra Leone.

Management Group IIh: Masuba, Masheka, and Mabassia, deep. These soils are similar to those in Management Group Ih in many characteristics but have lower fertility levels, lower available moisture-holding capacities, and longer droughty periods (Table 11). They are easy to cultivate and are usually not subject to erosion. Management recommendations for these soils are similar to those in Group Ih, except that irrigation during the dry season is usually less feasible. These soils are being used by farmers in a bush-fallow system. Improved farming practices, including proper application of fertilizers and better crop varieties, can produce profitable yields of both annual and perennial crops.

Management Group IIhs: Bonjema, Baoma, Tubum, Bosor, and Mabassia, shallow. These soils are primarily moderately well and well drained. They differ from the soils in Management Group IIh in having gravelly subsoils that begin at depths of 24 to 48 inches (61 to 122 cm). This reduces the available moisture-holding capacity (low, except in Bonjema) and increases the droughty period to four months. These soils occur on moderate slopes; under clean cultivation they may be subject to slight erosion, but this is easily controlled. These soils are relatively good for the traditional bush-fallow system of peasant farming. Adapted crops include annual crops such as upland rice, maize, groundnuts, and cassava and perennial tree crops such as coffee, oil palm, and citrus. Fertilization is essential for profitable crop yields.

Management Group IIwh: Panlap and Pendembu. These are imperfectly to poorly drained soils. Waterlogging at the soil surface during the rainy season is about four months in Panlap and two months in Pendembu. The available moisture-holding capacity is medium in Panlap and low in Pendembu. They are deficient in moisture for plant growth during one to two months of the dry season. These soils are permeable, occur on gentle slopes, and have little danger of erosion. They are strongly acid and poor to very poor in available plant nutrients, so that proper fertilization is necessary for profitable crop yields. With adequate supplemental drainage and modern farming methods, the Panlap soils are suited for a variety of crops; otherwise, these soils can be used only for swamp (paddy) rice during the rainy season. In order to limit risks of sudden submergence and to maintain the proper water level, bunding is necessary. This can be done easily with earth bunds and wooden spillways. During the dry season, enough moisture remains to grow vegetables. Swamp soils such as Panlap can be farmed regularly and are capable of producing much higher yields, especially of swamp rice, than they do now if proper water control, weed control, fertilization, and crop varieties are used. Pendembu soils are less subject to flooding than the Panlap soils.

Management Group IIIw: Gbehan. These are poorly drained, clayey soils with a high moisture-holding capacity. They are subject to waterlogging at the surface for two to four months and submergence for about one month. Floating rice can be grown without drainage improvement. If adequate drainage and flood protection are provided, other crops such as sugar cane, vegetables, bananas, and pineapples may be grown. Soil moisture is adequate for plant growth throughout the dry season.

Management Group IIIws: Pelewahun. These poorly drained soils are waterlogged at the surface approximately three to four months during the rainy season. They are deficient in moisture for plant growth about two months during the dry season. The depth of the gravel-free surface layer is 24 to 48 inches (61 to 122 cm). The available moisture-holding capacity is high. These soils are suited to a variety of crops if adequate drainage is provided; however, because of their occurrence in small patches and in long narrow strips, they can better be used for swamp rice during the rainy season and vegetables during the dry season. Fertilization and bunding for water control should be practiced.

Management Group IIIsh: Mokonde and Njala, nearly level. These two soils are moderately well to well drained and are rarely, if ever, waterlogged at the surface. They are droughty about four to five months during the dry season. Both of these soils contain unfavorable gravel, which causes a low moisture-holding capacity and impairs the extension of plant roots. Fertilization is necessary for satisfactory crop yields. Suggested annual crops include upland rice, groundnuts, and cassava. Tree crops such as coffee, oil palm, citrus, and lumber species may also be grown. These soils are fair for use with the traditional bush-fallow system of farming, if the fallow period is reasonably long.

Management Group IVw: Mankane and Keya. These soils are poorly to very poorly drained, medium to low in available moisture-holding capacity, and not droughty during the dry season. Supplementary drainage in order to use the soils for a variety of crops would not be practical. These soils are suited for swamp rice during the rainy season and vegetables during the dry season.

Management Group IVsh: Manowa, Makeni, and Njala, sloping. These are extensive gravelly soils that occur on slopes of about 3- to 15-percent gradient. They are well to moderately well drained and are never waterlogged at the soil surface. They have low to very low available moisture-holding capacities and are droughty during four to five months of the dry season. They are very acid and very low in available plant nutrients. Because of the high gravel content, these soils are poorly suited for cultivated crops grown with modern agricultural methods. They may be used under the traditional bush-fallow system of farming, but the fallow period should be long and frequent clearing should be discouraged. The slopes vary from gentle on the summits of the uplands to moderately steep; thus, if the vegetation cover is removed, the sloping soils are subject to erosion. Since a permanent vegetative cover is necessary to control erosion on these sloping soils, forestry is the best use for these areas, but tree crops such as oil palm and citrus can also be grown. The gently sloping summits have only slight erosion problems and can be used for the shallow-rooting annual field crops such as upland rice, cassava, and groundnuts that are currently grown on these soils. Fertilization should be practiced. The production of high-quality pasture on sloping Njala soils during 1971 and 1972 in experiments at Njala University College has been very encouraging. These experiments include both native and introduced pasture plants under fertilization and rotational grazing. Pasture produced by these improved management practices has given large cattle gains. If enough farmers adopt these practices, the beef shortage in Sierra Leone could be overcome. Properly managed pasture on these sloping Njala soils controls erosion and provides a profitable income when marketed through cattle.

Management Group Vw: Rokupr. These very poorly drained, fine-clayey soils occur in tidal mangrove swamps near the coast. They require major water-control structures, carefully designed and operated, before they can be used for agriculture. The water level must be maintained at the proper level in the soil to avoid excess drainage and oxidation and the resultant development of harmful acidity (see Section 4:6). These soils are restricted to swamp rice production because of the shallow water table that should be maintained in them.

Management Group VIes: Segbwema, Momenga, and Timbo. These well-drained, gravelly soils occur on steep slopes; unless a thick vegetative cover is maintained, they are subject to moderate to severe erosion. Segbwema contains less gravel than the other two soils, and in all of them the gravel content is less in the lower part of the profile. The available moisture-holding capacity is usually high in Momenga, medium in Segbwema, and very low in Timbo. Most areas of these soils are too steep and erosive for cultivated crops and should be kept under forest vegetation. Some tree crops such as oil palm and citrus may be used if care is taken to cover the soil surface consistently. In a few places where slopes are less steep, and erosion control is adequate, some shallow-rooting annual field crops may be grown in the traditional bush-fallow system of farming if a long fallow period is maintained.

Management Group VIhs: Gbamani and Sahama. These very sandy soils occur on beach ridges along the Atlantic coast. They are so droughty and low in fertility that they are unsuitable for any crops but coconuts. Oil palms grow on these soils, but yields are very low.

Management Group VIIes: Vaahun. Vaahun soils occur on high hills on the steepest slopes on which soil will form over the granitic bedrock. The profiles are less than 36 inches (91 cm) thick and are subject to severe erosion unless a thick vegetative cover is maintained on them. These soils are unsuitable for agricultural use. They should be used for forestry.

Management Group VIIIsh: Rock Land. This land type includes inselbergs and other areas of outcropping hard bedrock. The bedrock is always at or near the surface, but a thin soil layer up to 24 inches (61 cm) thick may occur locally in small pockets. The bedrock is usually granite. Slopes are usually steep, but gentler slopes occur in a few areas. This land type is unsuited for agricultural use and has little or no value for forestry production. It should remain under the natural vegetation for watershed protection, wildlife use, recreation, or esthetic purposes.

5:4. PRINCIPLES OF SOIL FERTILITY

5:4:1. Well-drained and aerated soils

All of the well- and moderately well-drained soils on uplands, colluvial footslopes, and terraces are extremely infertile, especially in nitrogen, phosphorus (*50*), and magnesium (*53, 54, 55*). They are also low in copper and other micronutrients, except for iron and manganese. Sulfur deficiencies also may be expected on some of the upland soils. Trends in soil organic matter content are discussed in Section 4:2:1.

The fertility status of the well-drained soils may, with the exception of phosphorus, be determined by standard analytical methods adapted for temperate-zone soils. The available form of the essential bases are the exchangeable cations. Classical methods for determining exchangeable bases and quick tests for available calcium, magnesium, and potassium are both quite satisfactory in Sierra Leone. Because of the high iron content of many of the well-drained soils, available phosphorus is more accurately determined by using the Bray P_2 extractant than by using the Bray P_1 (*10, 11*) or the sodium bicarbonate extractants used on temperate-region soils.

Most Sierra Leone soils, unless recently limed, are quite acid, having pH's below 4.8. They are very low in exchangeable calcium and magnesium, and they are high in exchangeable aluminum. Most of the soils need to be limed, both to increase the pH and convert exchangeable aluminum to the less toxic aluminum oxide gels and to supply a source of calcium and magnesium for plant nutrition. Generally, any soil with a pH below 4.8 or an exchangeable Ca + Mg to Ca + Mg + Al ratio below 0.150 may be suspected of being aluminum-toxic to many crops (see Section 4:4). If available, dolomitic limestone may be used to correct both the low pH and calcium and magnesium deficiencies; otherwise, magnesium sulfate is usually required with regular limestone. Slight overliming of the surface plow layer to around pH 6.0 is often beneficial because it helps correct the low calcium and magnesium levels found in the lower B horizons and lessens the adverse effects of exchangeable aluminum. Excess liming, however, that would raise the pH to 7.0 or over should be avoided.

The steep upland soils are susceptible to severe soil erosion, a danger accentuated by mechanical cultivation, especially plowing. Because the root stalks from the "slash and burn" system are left in the field, the erosion hazard is reduced, but these root stalks also make mechanical operations of all kinds impossible. Drill seeding, mechanical cultivation, and combine harvesting can not be done, thus barring the improved production possible through good tillage. Methods of improving production on the strongly sloping upland soils are essentially limited to increased usage of fertilizers and improved seed and to such improvements in seedbed preparations as are possible with more careful use of native hand tools. The full benefits of mechanical tillage can be directed toward increased production on the gently sloping soils on colluvial footslopes and terraces, and it is on these better soils that agricultural development should be emphasized.

5:4:2. Poorly drained soils without excess sulfur

Along the major streams, in the bolilands and inland valleys, and along the coast are poorly drained soils highly suited to swamp (paddy) and lowland rice production. These soils differ from the tidal swamp soils, Sulfaquents and Sulfaquepts, in that they are essentially free of sulfur and they become oxidized to some extent during the dry season. During the wet season they are less intensely reduced (with an Eh seldom below −0.20 v) than the tidal swamps (usually with an Eh below −0.30 v), and upon drying there is no, or only a very slight, drop in the soil pH. These soils are fairly high in soil organic matter and often do not respond significantly to nitrogen fertilizer during the first year of cultivation. They are acid (pH usually below 4.8), have low levels of exchangeable calcium and magnesium, and are high in exchangeable aluminum. Except for nitrogen, recommended fertilizer usage is essentially the same as that suggested for the upland and better-drained terrace soils. Similarly, the more acid Bray P_2 extractant is necessary to determine the level of available phosphorus in these soils; as with the well-drained soils, field soil samples may be dried before being subject to chemical analysis.

The poorly drained, sulfur-free soils are used almost exclusively for swamp (paddy) and lowland rice production. Their proper management should include some water control, where possible, through levee and dike construction. Nitrogen fertilizer practices are important; rice prefers nitrogen in the ammonium form. Only two nitrogen forms are acceptable for rice on these soils: ammonium forms, such as ammonium sulfate or ammonium phosphates, and urea, which hydrolyzes to ammonium carbonate. The nitrogen fertilizers should be worked into the surface soil to assure the adsorption of the ammonium onto the soil colloids. The soils must then be flooded within 24 to 48 hours after application to minimize oxidation of ammonium to nitrate forms. Adding the ammonium nitrogen fertilizers to the flood or paddy waters is not efficient because the renewal rainwater is well aerated and permits some oxidation of ammonium to nitrates before the waters become anaerobic.

5:4:3. Tidal swamp soils high in sulfur

The tidal swamp soils differ from other poorly drained soils in that they are flooded daily at high tide by brackish seawater during the dry season. They are high in sulfur, which accumulates as sulfates from the seawater; the sulfates are then reduced to sulfides and retained in the soil (see Section 4:6). These soils also accumulate salts during the dry season, becoming saline enough that some degree of weed control is achieved. These salts must be washed out at the beginning of each wet season by natural rainwater before rice can be seeded. During the rainy season the heavy discharge of fresh runoff water prevents the inland movement of brackish seawater, even at high tide, and the soil returns to a lower salt status. These soils are waterlogged the entire year and, unlike the poorly drained soils away from the coast, normally do not pass through a period of oxidation during the dry season.

The tidal swamp soils are highly reduced (*74, 42, 43*), usually having an Eh of −0.30 v or less throughout the year. The exchangeable base content is partially renewed from the brackish seawater during the dry season, so that even after the free salts are washed out the pH remains in the 5.5 to 6.0 range. These soils are quite high in exchangeable manganous manganese and ferrous iron, which tend to react with any added phosphate fertilizers (*38, 41*). Lime is seldom used on these soils, although some may be relatively low in exchangeable calcium and magnesium and thus show a preferential response to regular superphosphate and basic slag (*82*) as compared with triple superphosphate. The tidal swamp soils are relatively high in exchangeable potassium and seldom show a crop response to potash fertilizer.

Conventional methods of soil analysis and handling of field samples are unsatisfactory for tidal swamp soil samples. On drying, the soil becomes partially oxidized with the resulting oxidation of sulfides to sulfates and the formation of sulfuric acid. As a result, the pH of a dried sample may be 2 or 3 pH units more acid than the actual field condition. Phosphorus becomes tied up as unavailable iron and manganese phosphates when the iron and manganese are oxidized on drying. For measurements to be meaningful, the soil sample must be preserved wet, either under nitrogen gas or something like toluene, to prevent bacterial oxidation. Even with these precautions, it is doubtful whether measurements of pH, available phosphorus, and Eh on the wet soil have much meaning. Total analyses and exchangeable cations can be determined accurately, but the basic correlations of such results with rice growth have not been successful.

Water control is the most important single factor in the management of the tidal swamp soils. Because these soils are flooded only at high tide, empoldering and diking can keep the water at the low-tide water levels. This is especially important during the seedling-transplant and crop-establishing period. Only ammonium and urea nitrogen fertilizers should be used. Flooding immediately after nitrogen applications is easily accomplished. Split nitrogen applications (*82*) are generally better than a single application at the time of transplanting.

5:5. MANAGEMENT OF SELECTED CROPS

Crop production is greatly influenced by climate. The dry season is shortest in the eastern sections of Sierra Leone, with the result that this area is best suited to plantation crops such as cocoa, coffee, bananas, and oil palm. Most citrus crops, which go through an annual dormancy period, can be grown in areas where the dry season is more intense. The amount of sunlight (Appendix A) is sometimes a limiting factor in production, even during the dry season; thus, sugar cane, for example, is considered a marginal crop in Sierra Leone because of inadequate sunlight.

Most of the soils in Sierra Leone tend to be highly acid, with pH below 5; they are very low in exchangeable calcium and magnesium and may frequently contain toxic levels of exchangeable aluminum (see Section 4:4). During the first year out of bush fallow, the soils generally are not highly responsive to potassium and phosphorus because of the ash residue. However, much of the nitrogen in the bush vegetation is lost during the burning, so that where good rice stands are obtained nitrogen deficiencies may occur. The success of continuous cultivation on the nearly level nonerosive soils becomes highly dependent on fertilizer use after the first year out of fallow (*7, 8*).

The principal crops grown in Sierra Leone are rice, cassava, maize, groundnuts, cocoa, oil palm, coffee, and citrus. The acreages of various crops and the percentages of farmers growing them for off-farm sale are shown in Table 12. Because most farmers grow mixed crops, the acreages shown total more than the approximate 1,000,000 acres actually being farmed annually. Recent crop introductions include vegetables, fiber crops, and pasture grasses for animal feed. Farmer interest in growing these new crops is increasing.

Table 12. Percent of landholders growing and selling, and total acreage in pure and mixed stands of, the more important crops grown in Sierra Leone (*14*)

Crop	Percent growing	Percent selling	Total acres
Rice	86.3	18.1	741,000
Cassava	62.3	6.2	374,600
Okra	53.2	4.0	190,400
Maize (corn)	46.1	4.2	192,300
Pepper	41.7	6.1	68,000
Kola nuts	40.4	12.1	57,700
Jackatae	40.4	2.5	39,100
Bananas	38.5	7.6	23,000
Groundnuts	34.2	10.5	47,400
Pumpkin	33.8	1.9	29,200
Cocoa	33.2	17.3	66,400
Benniseed	33.2	5.2	14,800
Native spinach (plasas)	32.8	2.2	28,000
Tomatoes	31.7	3.8	41,900
Guinea corn	31.6	1.0	160,500
Eggplant	31.2	2.8	16,900
Potatoes	30.8	1.8	23,700
Palm kernels	26.1	20.4	37,800
Coffee	21.2	9.6	90,400

5:5:1. Rice

Rice is the most important food crop grown in Sierra Leone. Traditionally, it is grown on the sloping uplands, where shifting cultivation is more easily practiced under native management systems. On the more level and productive terraces, alluvial floodplains, and swamps, the sod of the tall native grass is very difficult to destroy with conventional native hand tools; therefore, development of these areas for rice production depends to some degree upon mechanization. The management suggestions given assume the use of some degree of mechanization, such as the plow or cultivator, to permit more adequate tillage of these better soils than is possible with native hand tools.

If minimum mechanization is available, rice production is ideally suited to the coastal plains, river terraces, and bolilands; it can also be grown on the upland sloping areas under bush-fallow systems. Many of the colluvial footslopes and terraces are well drained and are suitable for mixed crop culture, although pure stands are probably more profitable under mechanical agriculture. The more poorly drained soils are adapted to swamp or lowland rice, but mixed cropping is seldom practiced on these areas. The distribution of pure and mixed stands is approximately as follows:

Upland rice	Pure stand	49,200 acres
	Mixed stands	540,000 acres
Swamp rice	Pure stand	142,000 acres
	Mixed stands	9,200 acres

The bolilands, stream terraces, and some inland valley swamps occur in large enough tracts to be suited to large-

Table 13. Response of rice (kg/ha) to N, P, K, and lime fertilization at various locations, 1965-1967

Location	Treatments[a]				
	NPKL[b]	−P	−K	−L	None
Rokupr (tidal swamp)	7,100	5,800	6,400	6,300	3,600
Rokupr (upland)	6,400	6,200	6,400	5,900	3,100
Kontabe	4,800	3,500	4,200	4,100	1,900
Njala (lower nursery)	4,600	3,900	4,200	...	...
Sama	4,200	3,900	3,800	3,700	2,100
Kenema (farm field)	3,500	3,800	3,500	3,500	...
Kontabe	3,800	2,500	3,700	2,600	1,800
Njala (upland)	3,400	3,100	3,000	2,700	2,100
Average	4,725	4,088	4,400	4,114	2,433

[a] All rates relatively high and adequate.
[b] NPKL = nitrogen, phosphorus, potassium, lime, and magnesium sulfate.

scale, mechanized rice production. Swamp, floating, and lowland rice yields are usually higher than upland rice yields (*79, 81*), especially under shifting cultivation. Practically all upland rice, and probably as much as 60 percent of the lowland rice, is broadcast-seeded directly on the soil. Approximately 40 percent of the swamp rice, including much of that grown in tidal swamps, is established by seedling transplants. Floating rice is usually broadcast-seeded. Practically all rice is hand harvested. Minimum mechanization of rice production, therefore, need involve only plowing and preparing the better soils for rice seeding.

Rice responds especially well to nitrogen and phosphorus fertilization. Potash responses are often small during the first year after fallow but become increasingly important with continued cultivation. Numerous studies (*18, 20, 82*) have documented responses of rice to fertilizers. The data in Table 13 support similar studies and were used to establish the soil test calibrations and fertilizer recommendations for phosphorus and potassium (Table 14).

Limestone and magnesium sulfate are also required for good rice yields (*18, 82*). Dolomitic limestone is highly desirable when available. Most soils are very deficient in available or exchangeable calcium and magnesium and high in exchangeable aluminum (*31*). Adding limestone and magnesium sulfate corrects the calcium and magnesium deficiencies and decreases the probability of aluminum toxicity. Aluminum toxicity for rice should be suspected whenever the exchangeable Ca + Mg to Ca + Mg + Al ratio approaches 0.100 (see Section 4:4). For rice, soils need not be limed to a pH above 5.6 to 5.8 for good yields. Because of their high calcium contents, phosphate fertilizers such as regular superphosphate (20-percent P_2O_5) and basic slag are generally superior to triple superphosphate (45-percent P_2O_5) for rice on low pH soils (*82*). Only ammonium and urea (*29*) nitrogen fertilizers should be used on swamp and lowland rice. Any nitrogen fertilizer is suitable for rice on the well-drained soils.

Table 14. Soil test calibration for rice

Percent sufficiency	Phosphorus[a]		Potassium[b]	
	Soil test values (ppm)	Fert. req. (kg P/ha)	Soil test values (ppm)	Fert. req. (kg K/ha)
50	3	25	20	180
75	6	12	40	90
87	9	6	60	45
93	12	3	80	25
96	15	0	100	0

[a] According to Bray P_2 soil test (*10, 11*).
[b] According to Bray soil test (*10*).

5:5:2. Maize

Maize production in Sierra Leone is steadily increasing and, as the livestock industry develops, the demand for maize will increase further. With proper management and fertilizer use, maize can be grown on any of the more productive soils that are adequately drained. Maize cannot be grown on inadequately drained soils nor does it generally do well in a mixed cropping system. It cannot withstand shading, such as occurs when the rice in a mixed culture system grows faster or becomes taller than the maize. Maize is usually grown either during the early (seeded in May) or late (seeded in September) part of the rainy season (*9, 21*). If irrigation water is available, the seeding can be delayed to October, or the crop can be grown entirely during the dry season (January to April).

Fertilizer and soil fertility requirements for maize are high. Soil phosphorus should be around 10 to 15 ppm (Bray P_2 test levels), and the potassium levels should be over 100 ppm. Good yields on suitable soils and with pure stands will require 100 to 120 kg/ha of nitrogen, preferably applied in two or three split applications during the growing season. The pH should be around 6.0 and magnesium sulfate should be added. If available, dolomitic limestone may be used instead of lime and magnesium sulfate. Maize is somewhat sensitive to aluminum toxicity. If maize plants contain more than 500 ppm of aluminum or if the exchangeable Ca + Mg to Ca + Mg + Al ratio in the soil drops below 0.150, aluminum toxicity should be suspected (see Section 4:4). Insufficient research has been conducted in Sierra Leone to properly correlate and calibrate soil tests with maize response to fertilizer use, but the fertilizer recommendations given in Table 15 are thought to be reasonable interpretations, based upon crop requirements and known characteristics of the soils suggested for maize production.

5:5:3. Plantation crops

Plantation crops such as oil palm (*78*), coffee, cocoa, and rubber are being grown on a wide variety of Sierra Leone soils. Generally, the limitation to high plantation production is not a lack of suitable soils but rather the climate. The dry season is very intense: total rainfall during December, January, and February seldom exceeds

Table 15. Suggested rates (kg/ha) of fertilizer use for some common crops when more definite soil test data are not available[a]

Crop	N	P	K	Mg	Lime ($CaCO_3$)
Rice	45	20	40	30	4,000
Cassava	35	15	45	30	4,000
Corn	80	20	50	30	4,000
Groundnuts	0	10	35	30	4,000
Oil palm	65	15	45	30	4,000
Soybeans	0	20	50	30	4,000
Pineapple	80	10	60	30	4,000
Bananas	40	10	50	30	4,000
Coffee	20	10	35	30	4,000
Citrus	50	10	50	30	4,000
Vegetables	50[b]	15	40	30	4,000

[a] These suggested rates are conservative and too low for maximum crop yields.
[b] No nitrogen should be used on beans or peas, but they should be inoculated.

4 or 5 inches (Appendix A). Therefore, without irrigation, crops such as oil palm, coffee, cocoa, and rubber make no significant growth for three to five months of the year, especially on upland soils, and cannot be produced competitively for the world market. While the well-drained soils on colluvial footslopes and terraces are more desirable than the upland soils for plantation crops, even these probably cannot retain enough extra moisture to support profitable production without dry season irrigation. More plantations should be established on the well-drained, better soils where irrigation is possible.

Citrus fruits (oranges, grapefruit, and tangerines) have potential for development in Sierra Leone. Since their "dormancy" can be coordinated with the dry season, they produce relatively better than coffee or cocoa. Again, the well-drained soils on colluvial footslopes and terraces are more desirable than the upland soils for citrus production, but with moderate fertilization (Table 15) citrus can produce surprisingly well on the upland soils. Copper deficiency symptoms are visible on citrus fruit in all parts of Sierra Leone, and citrus and bananas will respond to copper leaf sprays.

5:5:4. Other crops

A wide variety of crops including vegetables (*34*), pineapple (*33*), soybeans (*45*), cocoyam (*30*), sweet potatoes (*32*), ginger, and cassava are grown in Sierra Leone, mostly on the upland soils in mixed culture with rice. Generally, these upland soils, where bush-fallow systems are being followed, are not the best soils for these crops. The upland soils are highly infertile, usually gravelly, and extremely droughty during the dry season. The deeper, well-drained soils on colluvial footslopes and terraces are more suited to these crops and, when fertilized (Table 15), produce quite good crop yields. None of these crops have been studied in sufficient detail to provide soil test correlations for fertilizer recommendations.

LITERATURE CITED

1. Alexander, L. T., and J. G. Cady. 1962. Genesis and hardening of laterite in soils. U.S. Dept. Agr. Tech. Bul. 1282. 90 p.
2. Aubert, G. 1965. Classifications des sols. *Cahiers ORSTOM-Série Pédologie,* 1965, III, No. 3: 269-288.
3. Aubert, G., and P. Ségalen. 1966. Projet de classification des sols ferrallitiques. *ORSTOM.* 18 p.
4. Bartrum, P. C. 1952. *Statistics illustrating the climate of Sierra Leone.* Freetown.
5. Black, C. A. (ed.). 1965. Methods of soil analysis. *Agronomy* 9, Parts 1 and 2. Amer. Soc. Agron. 1,572 p.
6. Bookers Agricultural and Technical Services, Ltd., and Sir Alexander Gibb and Partners. 1967. *Torma Bum Sugar Project, Sierra Leone.* Dept. of Trade, Industry, and Agriculture, Sierra Leone. 78 p.
7. Brams, E. A. 1971. Continuous cultivation of West African soils: Organic matter diminution and effects of applied lime and phosphorus. *Plant and Soil* 35: 401-414.
8. Brams, E. A., *et al.* 1969. *Summary of agronomic experiments in soils at Njala University College, University of Sierra Leone, 1968-69.* 34 p.
9. Brams, E., and R. Weibel. 1971. Maize as a second crop for the uplands of Sierra Leone, West Africa. Bul. No. 1, Prairie View A. & M. College, Texas. 17 p.
10. Bray, R. H. 1948. Correlation of soil tests with crop response to added fertilizers and with fertilizer requirement. *Diagnostic techniques for soils and crops.* American Potash Institute. Washington, D.C. Pp. 53-86.
11. Bray, R. H., and L. T. Kurtz. 1945. Determination of total, organic, and available forms of phosphate in soils. *Soil Sci.* 59: 39-45.
12. Breteler, H. 1969. Soil morphological properties as indicators of waterlogging in soils around the Njala University College, Sierra Leone. Thesis for the Ir. (M.Sc.) degree, Agricultural University of Wageningen, The Netherlands. 29 p.
13. Brewer, R., and J. R. Sleeman. 1964. Glaebules: their definition, classification, and interpretation. *Jour. Soil Sci.* 15: 66-78.
14. Central Statistics Office, Freetown. 1967. *Agricultural statistical survey of Sierra Leone, 1965-66.* 51 p.
15. Chavengsaksongkram, Chusak. 1972. A unified soil sulfur fractionation scheme and an investigation of the sulfur forms in acid sulfate soils. Thesis for the Ph.D. degree, University of Illinois at Urbana-Champaign. 161 p.
16. Clarke, J. I. (ed.). 1966. *Sierra Leone in maps.* University of London Press, Ltd. 120 p.
17. Cole, N. H. A. 1968. *The vegetation of Sierra Leone.* Njala University College, University of Sierra Leone. 198 p.
18. Das Gupta, D. K. 1969. The response of rice varieties to applied nitrogen under swamp cultivation in Sierra Leone, I — Wet season. *Trop. Agr., Trin.* 46: 311-323.
19. Das Gupta, D. K. 1970. Effects of Cycocel on lodging and grain yield of upland and swamp rice in Sierra Leone. *Exp. Agr.* 7: 157-160.
20. Das Gupta, D. K. 1971. Effect of levels and time of nitrogen application and interaction between phosphorus and nitrogen and grain yield of rice varieties under tidal man-

grove swamp cultivation in Sierra Leone. *African Soils* 16: 59-67.

21. Das Gupta, D. K., E. R. Terry, R. T. Odell, and M. T. Dahniya. 1972. Growing maize in Sierra Leone. Cir. No. 5, Njala University College, University of Sierra Leone. 17 p.

22. Department of Geography and Environmental Studies, Njala University College, University of Sierra Leone. *Njala weather.* Monthly and annual summaries 1966, 1967, 1968, 1969, 1971, and 1972.

23. Dijkerman, J. C. 1969. Soil resources of Sierra Leone, West Africa. *African Soils* 14: 185-206.

24. Dijkerman, J. C., and H. Breteler. 1969. *Soil survey of the oil palm station and the northwest extension of the Njala University College Farm.* Njala University College, University of Sierra Leone. 90 p.

25. Dijkerman, J. C., and D. H. Westerveld. 1969. *Reconnaissance soil survey of the lower Sewa River floodplain near Torma Bum, Sierra Leone, West Africa.* Njala University College, University of Sierra Leone. 87 p. plus chart.

26. Dixey, F. 1922. The physiography of Sierra Leone. *Geog. Jour.* 60: 41-65.

27. Dixey, F. 1925. The geology of Sierra Leone. *Quart. Jour. Geol. Soc. Lond.* 81: 195-220.

28. Dudal, R. 1968. Definitions of soil units for the soil map of the world. Food and Agr. Org. of the United Nations, World Soil Resources Report 33. 73 p. plus 4 p. Addendum. Also (1970), Key to soil units for the soil map of the world. 16 p.

29. Enyi, B. A. C. 1965. The efficiency of urea as a fertilizer under tropical conditions. *Plant and Soil* 23: 385-396.

30. Enyi, B. A. C. 1967. Effects of spacing, set size, ridging, and mulching on the development and yield of cocoyam (*Xanthosoma sagittifolium* Schott). *Trop. Agr., Trin.* 44: 53-60.

31. Gbani, A. B. 1972. The effect of soluble aluminum on rice (*Oriza sativa*). Thesis for the M.S. degree, University of Illinois at Urbana-Champaign. 70 p.

32. Godfrey-Sam-Aggrey, W., and H. S. Bundu. 1971. Growing sweet potatoes for tubers and leaves. Cir. No. 2, Njala University College, University of Sierra Leone. 6 p.

33. Godfrey-Sam-Aggrey, W., and H. S. Bundu. 1971. Growing and fertilizing Smooth Cayenne pineapples in Sierra Leone for fresh fruit market. Cir. No. 4, Njala University College, University of Sierra Leone. 11 p.

34. Godfrey-Sam-Aggrey, W., and B. J. Williams. 1972. Upland soils of Sierra Leone for selected vegetable crops. *World Crops* 24: 30-34.

35. Gregory, S. 1965. Rainfall over Sierra Leone. University of Liverpool, Department of Geography, Research Papers No. 2.

36. Hart, M. G. R. 1963. Observations on the source of acid in empoldered mangrove soils: II. Oxidation of soil polysulphides. *Plant and Soil* 19: 106-114.

37. Hart, M. G. R., A. J. Carpenter, and J. W. O. Jeffery. 1963. Problems in reclaiming saline mangrove soils in Sierra Leone. *L'Agronomie Tropicale* 18: 800-802.

38. Hesse, P. R. 1963. Phosphorus relationships in a mangrove-swamp mud with particular reference to aluminum toxicity. *Plant and Soil* 19: 205-218.

39. Hesse, P. R., and J. W. O. Jeffery. 1963. Some properties of Sierra Leone mangrove soils. *L'Agronomie Tropicale* 18: 803-805.

40. Jackson, M. L. 1956. *Soil chemical analysis — advanced course.* University of Wisconsin, Madison. 991 p.

41. Jeffery, J. W. O. 1960. Iron and the pH of waterlogged soils with particular reference to paddy. *Jour. Soil Sci.* 11: 140-148.

42. Jeffery, J. W. O. 1961. Defining the state of reduction of paddy soil. *Jour. Soil Sci.* 12: 172-179.

43. Jeffery, J. W. O. 1961. Measuring the state of reduction of a waterlogged soil. *Jour. Soil Sci.* 12: 317-325.

44. Jordens, E. R. 1972. Chemical and micro-morphological study of the genesis of a Typic Plinthaquult of Sierra Leone, West Africa. Thesis for the Ir. (M.Sc.) degree, Agricultural University of Wageningen, The Netherlands. 74 p.

45. Kamara, S. B. 1973. Preliminary soybean variety trials, with two levels of inoculation, in Sierra Leone. *Sierra Leone Agr. Jour.* 2, No. 2: 9-13.

46. Klingebiel, A. A., and P. H. Montgomery. 1961. Land-capability classification. U. S. Dept. Agr. Handbook 210. 21 p.

47. Lucas, J. 1962. *The transformation of clay minerals during sedimentation, a study of Triassic clays.* University of Strasbourg. Translated from French (1968) for U.S. Dept. Agr. and Nat. Sci. Foundation, Washington, D.C. 205 p.

48. Maignien, R. 1966. Review of research on laterites. UNESCO Natural Resources Research IV. 148 p.

49. Martin, F. J. 1938. *A preliminary survey of the vegetation of Sierra Leone.* Freetown.

50. McKenzie, Eli, Jr. 1971. Phosphorus fertility of some Sierra Leone soils. Thesis for the M.S. degree, University of Illinois at Urbana-Champaign. 112 p.

51. Miedema, R. 1971. Comparison between the chemical and physical properties of termite mounds and surrounding soils, with special reference to *Macrotermes* spp. mounds. Thesis for the Ir. (M.Sc.) degree, Agricultural University of Wageningen, The Netherlands. 115 p.

52. Mohr, E. C. J., F. A. van Baren, and J. van Schuylenborgh. 1972. *Tropical soils.* 3rd ed. Mouton-Ichtiar Baru-van Hoeve, The Hague. 481 p.

53. Mokwunye, A. U. 1972. Studies on the chemistry of soil magnesium. Thesis for the Ph.D. degree, University of Illinois at Urbana-Champaign. 140 p.

54. Mokwunye, A. U., and S. W. Melsted. 1972. Magnesium forms in selected temperate and tropical soils. *Soil Sci. Soc. Amer. Proc.* 36:762-764.

55. Mokwunye, A. U., and S. W. Melsted. 1973. Magnesium fixation and release in soils of temperate and tropical regions. *Soil Sci.* 116:359-362.

56. Nye, P. H. 1954. Some soil-forming processes in the humid tropics. I: A field study of a catena in the West African forest. *Jour. Soil Sci.* 5:7-21.

57. Nye, P. H. 1955. Some soil-forming processes in the humid tropics. IV: The action of the soil fauna. *Jour. Soil Sci.* 6: 73-83.

58. Nye, P. H., and D. J. Greenland. 1960. *The soil under shifting cultivation.* Commonwealth Bureau of Soils, Harpenden. Tech. Com. No. 51. 156 p.

59. Odell, R. T., and J. C. Dijkerman. 1967. *Properties, classification, and use of tropical soils, with special reference to those in Sierra Leone.* Njala University College, University of Sierra Leone. 137 p.

60. Papadakis, J. 1966. *Climates of the world and their agricultural potentialities.* Buenos Aires, Argentina.

61. Papadakis, J. 1966. *Crop ecological survey in West Africa.* F.A.O. report PL/FCC/2, Rome. Vols. I and II, 103 p.

62. Pollet, J. D. 1951. The geology and mineral resources of Sierra Leone. *Colonial Geology and Mineral Resources* 2: 3-28.

63. Scheltema, W. 1964. The kawfoetoe occurrence in Suriname. Suriname Soil Survey Department Report 16. 40 p. (in Dutch).

64. Sivarajasingham, S. 1968. *Soil and land-use survey in the Eastern Province, Sierra Leone.* F.A.O. report TA 2584, Rome. 73 p. and map.

65. Sivarajasingham, S., L. T. Alexander, J. G. Cady, and M. G. Cline. 1962. Laterite. *Advances in Agronomy* (A. G. Norman, ed.) Vol. 14: 1-60.

66. Stark, J. 1968. *Soil and land-use survey of part of the Eastern Province of Sierra Leone.* F.A.O. report TA 2574, Rome. 55 p. and maps.

67. Soil Science Society of America. 1970. *Glossary of soil science terms.* 27 p.

68. Soil Survey Staff. 1951, with 1962 sup. *Soil survey manual.* U.S. Dept. Agr. Handbook 18. 503 p.

69. Soil Survey Staff. 1960, with 1967 Supplement. *Soil classification, a comprehensive system;* and *Soil Taxonomy,* 1970. U.S. Dept. Agr., Washington, D.C.

70. Stobbs, A. R. 1963. *The soils and geography of the Boliland Region of Sierra Leone.* Government of Sierra Leone, Freetown. 45 p. and maps.

71. Stoops, G. 1967. Le profil d'alteration au Bas-Congo (Kinshasa). *Pédologie* XVII 1: 60-105.

72. Surveys and Lands Division, Sierra Leone. 1966. *Atlas of Sierra Leone.* Edward Stanford, Ltd. Longacre, London.

73. Tomlinson, T. E. 1957. Relationships between mangrove vegetation, soil texture, and reaction of surface soil after empoldering saline swamps in Sierra Leone. *Trop. Agr., Trin.* 34: 41-50.

74. Tomlinson, T. E. 1957. Changes in sulphide-containing mangrove soil on drying and their effect upon the suitability of the soil for the growth of rice. *Empire Jour. Exp. Agr.* 25: 108-118.

75. van Vuure, W., and R. Miedema. 1973. *Soil survey of the Makeni area, Northern Province, Sierra Leone.* Njala University College, University of Sierra Leone. 104 p., maps.

76. van Vuure, W., R. T. Odell, and P. M. Sutton. 1973. *Soil survey of the Njala area, Sierra Leone.* Njala University College, University of Sierra Leone, Bul. 3. 117 p., maps.

77. Waldock, E. A., E. S. Capstick, and A. J. Browning. 1951. Soil conservation and land use in Sierra Leone. *Sessional paper* No. 1. 124 p.

78. Walker, W. M., and S. W. Melsted. 1971. Effect of N, P, Mg, and K, and soils upon oil palm yields in Sierra Leone. *Trop. Agr., Trin.* 48: 237-243.

79. *West African Rice Research Station Annual Report 1964-65.* 1966. West African Rice Research Station, Rokupr, Sierra Leone. 44 p.

80. Westerveld, D. H. 1969. Morphological and mineralogical differences between two types of iron concretions in a soil of Sierra Leone, West Africa. Thesis for the Ir. (M.Sc.) degree, Agricultural University of Wageningen, The Netherlands. 25 p.

81. Will, H. 1971. Two new rice varieties for Sierra Leone. Bul. No. 1, Njala University College, University of Sierra Leone. 10 p.

82. Will, H., and R. A. D. Jones. 1970. Three and a half decades of rice research at the Rice Research Station, Rokupr, Sierra Leone. Njala University College, University of Sierra Leone. 64 p. mimeo.

83. Wright, E. H. M., and M. N. Fawty. 1971. Physical and physico-chemical characteristics of some Sierra Leone soils. *African Soils* 16: 5-30.

APPENDIX A. CLIMATIC DATA FOR SELECTED STATIONS IN SIERRA LEONE

Mean monthly and annual rainfall

Station	Years	J	F	M	A	M	J	J	A	S	O	N	D	Annual total
							Inches							
Batkanu	1926-50	0.2	0.2	1.1	3.2	8.8	15.6	17.1	19.5	18.0	19.0	5.9	0.7	109.3
Bonthe	20	0.7	1.0	0.6	4.4	10.5	22.5	34.7	29.7	24.2	13.8	7.0	2.6	151.7
Daru	About 20	0.4	1.3	4.1	6.9	10.7	12.1	12.0	14.4	16.5	12.5	8.0	2.1	101.0
Freetown (Falconbridge Point)	1939-48	0.3	0.1	0.6	2.2	5.6	13.2	36.3	37.1	24.2	11.3	5.0	1.9	137.8
Makeni	1934-68	0.3	0.3	1.3	3.5	8.8	15.2	19.4	25.2	21.7	16.5	8.0	1.1	121.3
Marampa	1941-50	0.2	0.1	0.7	3.1	7.0	10.8	17.6	22.5	17.6	16.1	6.9	0.9	103.5
Njala	1926-62	0.2	0.7	3.3	4.9	9.7	14.4	16.0	19.9	17.2	13.4	7.1	1.5	108.3
Rokupr	1934-64	0.2	0.1	0.5	2.2	7.0	14.8	23.6	29.2	19.6	14.5	6.2	0.7	118.6
Torma Bum	1958-66	0.9	1.2	2.1	4.6	11.5	20.1	28.4	28.6	22.6	11.4	7.6	1.6	140.6
							Millimeters							
Batkanu	1926-50	4	6	27	82	224	397	434	494	457	482	151	18	2,776
Bonthe	20	17	25	16	112	267	572	881	754	615	350	178	66	3,853
Daru	About 20	9	34	104	175	272	308	306	366	419	318	202	54	2,567
Freetown (Falconbridge Point)	1939-48	8	2	14	56	141	336	923	941	615	288	126	49	3,499
Makeni	1934-68	6	8	33	90	224	387	491	641	552	418	204	27	3,081
Marampa	1941-50	6	3	17	80	177	274	446	573	448	408	175	22	2,629
Njala	1926-62	6	17	83	125	248	365	406	506	436	339	180	39	2,750
Rokupr	1934-64	5	1	12	56	178	375	599	741	498	369	158	19	3,011
Torma Bum	1958-66	23	29	54	117	291	511	722	726	574	290	193	41	3,571

Mean number of days with rainfall greater than stated amounts

Station	Years	J	F	M	A	M	J	J	A	S	O	N	D	Annual total
							Days							
Makeni	1936-50													
	> 0.01 in.	0.4	0.9	4	7	15	22	26	28	27	26	14	2	172
	> 0.40 in.	0.1	0.1	1	2	8	11	13	16	15	14	6	0.7	87
Njala	1936-50													
	> 0.01 in.	0.6	1	7	9	16	22	26	26	26	24	14	4	176
	> 0.40 in.	0	0.3	0.7	3	8	11	13	16	12	11	6	1	82
	> 1.0 in.	0	0	0.2	1	3	3	5	8	6	4	2	0.5	33

Minimum and maximum monthly rainfall and greatest daily rainfall per month

Station	Years	Item	J	F	M	A	M	J	J	A	S	O	N	D
							Inches							
Batkanu	1926-50	min.	0	0	0	0	3.7	12.4	12.4	11.8	11.8	7.5	1.5	0
		max.	1.8	2.3	3.6	7.0	17.4	25.1	25.0	28.4	29.1	21.9	11.4	2.6
Bonthe	1939-48	min.	0	0	0	2.6	5.5	16.1	20.5	18.7	15.8	9.3	2.3	0.9
		max.	0.5	1.2	3.5	9.1	16.8	27.1	57.5	65.4	34.5	24.0	11.7	5.4
		gr./day	0.4	0.7	1.1	2.6	3.8	4.4	9.5	11.7	9.0	6.0	2.2	3.0
Freetown (Falconbridge Point)	1939-48	min.	0	0	tr.	0.1	2.7	8.5	25.8	25.7	15.1	6.6	0.8	0.1
		max.	1.8	0.2	3.5	4.8	8.9	23.6	49.5	49.3	32.5	18.0	6.7	3.7
		gr./day	1.7	0.2	1.8	2.4	3.4	4.0	7.5	8.4	9.0	7.5	3.5	3.4
Makeni	1939-48	min.	0	0	0	2.6	3.4	9.4	14.4	20.1	14.7	10.6	1.7	0.1
		max.	1.0	0.6	2.2	6.4	13.2	24.1	26.6	33.6	30.6	24.0	9.6	3.9
		gr./day	1.0	0.6	1.2	1.8	5.2	4.6	4.1	5.7	4.6	4.2	2.6	3.2
Torma Bum	1956-66	min.	0.1	0	0.1	0.6	9.4	12.0	7.0	11.4	17.0	6.8	2.1	0
		max.	2.7	4.5	6.3	14.1	14.0	34.9	45.7	37.3	33.2	27.5	15.3	5.7
							Millimeters							
Batkanu	1926-50	min.	0	0	0	0	94	316	316	299	299	191	38	0
		max.	47	58	92	177	441	639	635	722	739	556	290	66
Bonthe	1939-48	min.	0	0	0	67	140	409	521	474	402	237	58	23
		max.	12	29	89	231	426	688	1,496	1,661	876	610	298	138
		gr./day	9	18	29	67	97	110	241	297	229	153	56	75
Freetown (Falconbridge Point)	1939-48	min.	0	0	tr.	3	69	216	655	653	384	169	19	2
		max.	45	6	89	121	227	600	1,258	1,253	826	457	170	94
		gr./day	43	5	46	62	86	102	190	213	228	191	89	86
Makeni	1939-48	min.	0	0	0	66	86	238	365	510	373	269	43	1
		max.	25	14	55	163	335	611	677	853	777	609	244	100
		gr./day	25	14	32	47	133	118	104	146	116	107	66	80
Torma Bum	1956-66	min.	1	0	1	2	238	305	176	290	431	173	53	0
		max.	68	115	160	357	356	887	1,161	948	842	699	388	146

Average minimum, mean, and maximum monthly and annual temperatures, °F

Station	Years	Item	J	F	M	A	M	J	J	A	S	O	N	D	Ann. ave.
Batkanu	1933-42	min.	68	72	73	73	73	72	72	72	72	72	72	69	71.7
		mean	81	84	86	85	84	80	79	78	80	81	81	80	81.6
		max.	94	97	99	97	92	89	85	83	88	91	91	91	91.5
Bonthe	?	min.	74	75	75	76	75	74	73	73	73	74	75	74	74.3
		mean	80	82	82	83	82	80	77	77	78	80	80	80	80.1
		max.	87	89	90	90	89	85	82	81	83	86	87	86	86.3
Daru	About 20	min.	68	68	70	71	72	71	71	71	70	70	70	68	70.0
		mean	78	82	83	83	82	81	78	77	80	80	80	79	80.3
		max.	90	95	94	93	92	89	85	83	87	90	90	88	89.7
Freetown (Hill Station)	10	min.	75	77	78	78	77	75	74	74	75	75	76	76	75.8
		mean	80	81	82	82	82	80	78	77	79	79	80	80	80.0
		max.	85	85	86	86	86	85	83	82	83	85	85	85	84.7
Makeni	1942-50	min.	65	68	71	73	73	73	72	72	72	72	72	69	71.0
		mean	79	82	84	84	83	81	79	78	80	80	81	79	80.8
		max.	92	95	97	95	92	89	85	83	87	89	90	90	90.3
Marampa	1941-50	min.	68	69	72	72	73	72	71	71	72	71	71	70	71.0
		mean	79	81	83	83	82	80	78	77	79	80	80	80	80.2
		max.	90	93	95	94	92	89	85	82	86	89	89	88	89.2
Musaia	?	min.	57	62	68	71	71	70	69	69	69	68	67	59	66.7
		mean	74	78	82	82	81	79	77	77	78	78	76	74	78.0
		max.	92	95	96	95	91	87	85	83	86	87	88	89	89.5
Njala	1926-62	min.	68	70	70	71	72	71	71	71	71	71	70	68	70.3
		mean	78	81	82	82	81	79	77	77	78	79	79	78	79.3
		max.	89	93	94	93	90	88	83	82	85	88	88	87	88.3
Rokupr	1939-64	min.	68	70	71	73	74	72	72	72	72	72	72	69	71.4
		mean	79	82	83	83	83	81	79	78	80	81	81	81	80.9
		max.	91	93	93	93	91	88	84	82	85	88	89	89	88.7
Torma Bum	1966	min.	68	71	72	73	72	72	72	72	72	72	71	70	71.4
		mean	79	82	83	82	81	80	77	77	78	79	79	79	79.6
		max.	89	93	93	91	90	87	83	81	84	85	87	87	87.5

Extreme minimum and maximum values recorded

Makeni, 1942-50: 50°F (9.9°C) to 103°F (39.5°C); Njala, 1926-62: 55°F (12.8°C) to 103°F (39.5°C); Rokupr, 1939-64: 50°F (9.9°C) to 103°F (39.5°C)

Average minimum, mean, and maximum monthly and annual temperatures, °C

Station	Years	Item	J	F	M	A	M	J	J	A	S	O	N	D	Ann. ave.
Batkanu	1933-42	min.	20	22	23	23	23	22	22	22	22	22	22	21	22.0
		mean	27	29	30	29	29	27	26	26	27	27	27	27	27.6
		max.	34	36	37	36	33	32	29	28	31	33	33	33	32.9
Bonthe	?	min.	23	24	24	24	24	23	23	23	23	23	24	23	23.5
		mean	27	28	28	28	28	27	25	25	26	27	27	27	26.9
		max.	31	32	32	32	32	29	28	27	28	30	31	30	30.2
Daru	About 20	min.	20	20	21	22	22	22	22	22	21	21	21	20	21.1
		mean	26	28	28	28	28	27	26	25	27	27	27	26	26.9
		max.	32	35	34	34	33	32	29	28	31	32	32	31	31.9
Freetown (Hill Station)	10	min.	24	25	26	26	25	24	23	23	24	24	24	24	24.4
		mean	27	27	28	28	28	27	26	25	26	26	27	27	26.8
		max.	29	29	30	30	30	29	28	28	28	29	29	29	29.0
Makeni	1942-50	min.	18	20	22	23	23	23	22	22	22	22	22	21	21.7
		mean	26	28	29	29	28	27	26	26	27	27	27	26	27.2
		max.	33	35	36	35	33	32	29	28	31	32	32	32	32.4
Marampa	1941-50	min.	20	21	22	22	23	22	22	22	22	22	22	21	21.7
		mean	26	27	28	28	28	27	26	25	26	27	27	27	26.8
		max.	32	34	35	34	33	32	29	28	30	32	32	31	31.8
Musaia	?	min.	14	17	20	22	22	21	21	21	21	20	20	15	19.5
		mean	23	26	28	28	27	26	25	25	26	26	24	23	25.5
		max.	33	35	36	35	33	31	29	28	30	31	31	32	32.0
Njala	1926-62	min.	20	21	21	22	22	22	22	22	22	22	21	20	21.3
		mean	26	27	28	28	27	26	25	25	26	26	26	25	26.3
		max.	32	34	34	34	32	31	28	28	29	31	31	31	31.3
Rokupr	1939-64	min.	20	21	22	23	23	22	22	22	22	22	22	21	21.9
		mean	26	28	28	28	28	27	26	26	27	27	27	27	27.1
		max.	33	34	34	34	33	31	29	28	29	31	32	32	31.7
Torma Bum	1966	min.	20	22	22	23	22	22	22	22	22	22	22	21	21.8
		mean	26	28	28	28	27	27	25	25	26	26	26	26	26.5
		max.	32	34	34	33	32	31	28	27	29	29	31	31	30.9

Mean daily range in temperature by months and annual average

Station	Years	J	F	M	A	M	J	J	A	S	O	N	D	Ann. ave.
						°Fahrenheit								
Batkanu	1933-42	26	26	27	24	20	17	12	11	16	20	19	22	20.0
Makeni	1942-50	27	27	25	22	19	17	13	11	15	18	18	21	19.4
Marampa	1941-50	22	24	23	21	19	17	13	11	15	18	18	19	18.3
Njala	1926-62	22	24	24	21	18	16	12	11	14	17	18	19	18.0
						°Centigrade								
Batkanu	1933-42	14	14	14	13	10	10	7	6	9	11	11	12	10.9
Makeni	1942-50	15	15	14	12	10	9	7	6	9	10	10	11	10.7
Marampa	1941-50	12	13	13	12	10	10	7	6	8	10	10	10	10.1
Njala	1926-62	12	13	13	12	10	9	6	6	7	9	10	11	9.8

Humidity, sunshine, and cloudiness by months and for the year

Station	Years	Time	J	F	M	A	M	J	J	A	S	O	N	D	
			Average percent relative humidity at 0900 and 1500 hours												Ann. ave.
Daru	About 20	1500	49	41	48	58	65	67	75	78	71	66	64	60	61.8
Njala	1949-58	0900	95	92	90	88	88	93	94	95	95	94	94	95	92.8
		1500	54	50	52	62	64	76	83	86	80	74	68	65	67.8
Rokupr	1949-64	0900	88	88	84	82	84	89	92	92	91	88	88	86	87.7
		1500	53	49	53	56	66	73	80	83	79	71	68	56	65.6
Torma Bum	1966	0900	96	91	85	85	90	92	93	95	92	92	91	95	91.4
		1500	60	60	55	61	69	76	85	85	83	76	72	71	71.1
			Extreme percent relative humidity values recorded												
Rokupr	1949-64	max.	100	100	100	100	100	100	100	100	100	100	100	100	
		min.	15	13	23	28	31	53	59	53	51	41	37	10	
			Total hours of sunshine												Ann. total
Bonthe[a]	10		214	202	195	180	171	126	74	50	102	164	180	195	1,853
Freetown[a]	10		251	235	242	207	195	165	93	74	123	189	198	214	2,186
Njala[a]	10		226	213	198	174	189	159	96	62	90	186	186	199	1,978
Rokupr	20		249	228	242	208	192	159	101	65	122	193	199	224	2,182
Torma Bum	1966		199	182	194	149	185	126	92	56	71	144	160	190	1,748
			Cloudiness (in tenths)												Ann. ave.
Bonthe[a]	10		4.3	3.8	5.3	6.0	7.3	8.0	9.0	9.2	8.4	7.5	6.7	5.0	6.7
Daru[a]	7		3.7	3.2	5.5	6.6	7.5	7.8	8.8	9.3	8.5	8.0	7.2	5.6	6.8
Freetown[a]	10		3.5	3.1	4.4	5.6	6.5	6.7	8.8	9.4	8.8	7.8	6.7	5.0	6.4
Makeni	7		3.5	3.1	4.8	6.3	7.3	8.0	8.9	9.2	8.6	8.2	7.2	4.6	6.6
			Average number of cloudy days (>7.5 tenths)												Ann. total
Makeni			2	1	4	9	15	22	29	30	27	24	14	5	182

[a]After *Atlas of Sierra Leone* (72)

Potential evapotranspiration by months and for the year

Station	Years	J	F	M	A	M	J	J	A	S	O	N	D	Ann. total
Potential evapotranspiration (inches) calculated by formula of Papadakis (60): $E = 7.5\left(e_{ma} - e_{mi-3.6\ °F}\right)$														
Batkanu	1933-42	7.5	7.9	8.7	7.8	6.0	5.0	3.8	3.2	4.7	5.7	5.7	6.3	72.3
Bonthe	?	4.1	4.6	4.8	4.6	4.6	3.5	2.9	2.6	3.1	4.1	4.3	4.1	47.3
Daru	About 20	6.0	7.8	7.1	6.7	6.1	5.3	4.1	3.5	4.8	5.7	5.7	5.4	68.2
Freetown (Hill Sta.)	10	3.3	2.9	3.0	3.0	3.3	3.3	2.9	2.7	2.7	3.3	3.1	3.1	36.6
Makeni	1942-50	7.3	7.8	8.1	7.0	6.0	4.9	3.8	3.2	4.4	5.0	5.3	5.9	68.7
Marampa	1941-50	6.0	7.0	7.1	6.7	6.0	5.0	4.1	3.3	4.2	5.3	5.3	5.1	65.1
Musaia	?	8.3	8.7	8.3	7.4	6.0	4.8	4.4	3.8	4.5	5.1	5.6	7.0	73.9
Njala	1926-62	6.0	7.0	7.2	6.6	5.5	4.8	3.6	3.3	4.0	4.9	5.0	5.2	63.1
Rokupr	1939-64	6.4	6.8	6.7	6.3	5.4	4.7	3.5	3.0	3.8	4.7	5.0	5.6	61.9
Torma Bum	1966	5.7	6.7	6.4	5.6	5.3	4.4	3.2	2.7	3.5	3.8	4.7	4.8	56.8
Potential evapotranspiration (mm) calculated by formula of Papadakis (60): $E = 5.625\left(e_{ma} - e_{mi-2\ °C}\right)$														
Batkanu	1933-42	190	201	221	198	152	127	97	81	119	145	145	160	1,836
Bonthe	?	104	117	122	117	117	89	74	66	79	104	109	104	1,202
Daru	About 20	152	198	180	170	155	135	104	89	122	145	145	137	1,732
Freetown (Hill Sta.)	10	84	74	76	76	84	84	74	68	68	84	79	79	930
Makeni	1942-50	185	198	206	178	152	124	97	81	112	127	135	150	1,745
Marampa	1941-50	152	178	180	170	152	127	104	84	107	135	135	130	1,654
Musaia	?	211	221	211	188	152	122	112	96	114	130	142	178	1,877
Njala	1926-62	152	178	183	168	140	122	91	84	102	124	127	132	1,603
Rokupr	1939-64	163	173	170	160	137	119	89	76	97	119	127	142	1,572
Torma Bum	1966	145	170	163	142	135	112	81	69	89	96	119	122	1,443

Open-pan and Piche evaporation by months and for the year

Station	Years	J	F	M	A	M	J	J	A	S	O	N	D	Annual total
						Open-pan evaporation (inches)								
Njala	1971	5.0	6.2	8.2	6.0	5.2	5.4	4.1	...	...	6.0	3.8	3.9	
	1972	4.5	8.1	9.7	6.5	5.9	5.4	...	...	...	...	...	...	
Torma Bum	1966	...	4.5	5.3	4.8	4.3	3.6	...	...	...	...	3.3	3.4	
						Piche evaporation (inches)								
Makeni	1968	...	...	...	...	2.9	1.7	1.8	1.2	1.4	1.7	1.4	1.4	
	1969	2.2	3.8	4.3	2.8	2.3	1.8	1.1	...	...	...	...	...	
Njala	1971	4.9	5.4	7.6	4.5	...	2.8	2.6	1.8	1.9	3.2	3.0	1.8	
	1972	3.5	5.6	6.4	4.1	3.1	2.4	...	...	...	...	...	...	
Torma Bum	1966	3.1	4.2	4.9	3.5	2.8	1.8	1.6	1.3	1.5	1.7	2.0	2.1	30.5
						Open-pan evaporation (mm)								
Njala	1971	127	158	208	152	132	137	104	...	...	152	96	99	
	1972	114	206	246	165	150	137	...	...	...	...	...	...	
Torma Bum	1966	...	114	135	122	109	91	...	...	...	...	84	86	
						Piche evaporation (mm)								
Makeni	1968	...	...	...	...	74	43	46	30	36	43	36	36	
	1969	56	96	109	71	58	46	28	...	...	...	...	...	
Njala	1971	124	137	192	114	...	71	66	45	48	82	77	45	
	1972	89	143	162	104	78	61	...	...	...	...	...	...	
Torma Bum	1966	78	106	124	90	71	45	40	32	39	43	51	53	772

Mean monthly soil temperature at Njala University College *(22)*, compared with mean monthly minimum and maximum air temperatures

Period	1966, at 12 inches depth				1967, at 6 inches depth				1968, at 6 inches depth			
	0900 hours		1500 hours		0900 hours		1500 hours		0900 hours		1500 hours	
	Soil	Air, min.	Soil	Air, max.	Soil	Air, min.	Soil	Air, max.	Soil	Air, min.	Soil	Air, max.
						°Fahrenheit						
January	81	66	88	90	81	66	87	91	79	69	88	91
February	85	68	95	94	83	68	89	92	83	71	92	91
March	...	71	...	95	85	70	93	96	84	71	93	94
April	82	72	88	92	86	72	94	95	85	72	93	95
May	84	73	90	92	85	72	91	91	82	71	88	89
June	81	71	86	87	78	71	85	88	81	73	86	87
July	81	73	85	86	79	71	87	84	80	73	84	86
August	79	72	83	84	81	71	88	82	79	72	84	83
September	79	71	84	85	80	72	85	85	80	73	84	89
October	81	72	86	88	79	72	83	88	81	73	86	87
November	81	70	85	88	78	73	81	88	81	72	85	87
December	79	69	85	89	80	69	83	89	81	...	83	87
Ann. ave.	81	71	87	89	81	71	87	89	81	72	87	89
						°Centigrade						
January	27	19	31	32	27	19	31	33	26	21	31	33
February	29	20	35	34	28	20	32	33	28	22	33	33
March	...	22	...	35	29	21	34	36	29	22	34	34
April	28	22	31	33	30	22	34	35	29	22	34	35
May	29	23	32	33	29	22	33	33	28	22	31	32
June	27	22	30	31	26	22	29	31	27	23	30	31
July	27	23	29	30	26	22	31	29	27	23	29	30
August	26	22	28	29	27	22	31	28	26	22	29	28
September	26	22	29	29	27	22	29	29	27	23	29	32
October	27	22	30	31	26	22	28	31	27	23	30	31
November	27	21	29	31	26	23	27	31	27	22	29	31
December	26	21	29	32	27	21	28	32	27	...	28	31
Ann. ave.	27	22	30	32	27	22	31	32	27	22	31	32

APPENDIX B. DESCRIPTIONS AND ANALYTICAL DATA FOR SELECTED SOIL PROFILES

In this Appendix, descriptions and other data are given for 44 soil profiles. These profiles were analyzed in laboratories of the Agronomy Department, University of Illinois at Urbana-Champaign, Illinois, U.S.A., except for the bulk density measurements, which were made by the clod method at Njala University College. The soil descriptions were written using terminology in the *Soil Survey Manual* (*68*) and *Glossary* (*67*). The colors are for the moist soil unless stated otherwise.

The analytical methods used were essentially those published in "Methods of Soil Analysis," edited by C. A. Black and published in 1965 by the American Society of Agronomy, Madison, Wisconsin, U.S.A. (*5*). Particle-size analyses were done by the sieve and pipette method. Organic carbon was determined by the Walkley-Black wet oxidation method. Cation-exchange capacity was determined by ammonium saturation. Exchangeable bases were removed by leaching with 1N neutral ammonium acetate; calcium and magnesium were measured by EDTA titration, and potassium and sodium by flame photometry. Exchangeable aluminum was removed by leaching with 1N KCl, then measured by emission spectroscopy. The pH was determined potentiometrically with a glass electrode in a 1:1 ratio of soil with water and also in a 1:1 ratio of soil with 1N KCl. Soil test P_1 was determined by extraction with 0.03N NH_4F in 0.025N HCl, and P_2 with 0.03N NH_4F in 0.1N HCl. Soil-test available K was extracted with 23-percent $NaNO_3$ and determined by the sodium cobaltinitrite turbidometric method. Total phosphorus was determined by perchloric acid digestion. Total analyses of the total soil for calcium, iron, and potassium were by X-ray spectroscopy on ground, pressed samples, using National Bureau of Standard samples as standards.

Profile 144801A, Baoma sandy clay loam
Description after Sivarajasingham *(64)*

Location	On the right-hand side of the road from Daru Junction to Moa Barracks, about 150 feet (46 m) past the Girls' School at the first bend of the road to the left.
Physiography	Undulating upland.
Relief	Upper gentle slope.
Vegetation	Cocoa 7 to 15 years old in very poor health, poor management, inadequate shade, open stand, and heavy weed growth; few tall trees of the former secondary forest remain.
Drainage	Well drained.
Parent material	A thick layer of locally transported material derived from laterite crust and partially weathered and fresh rock of a previous landscape.
A_1 0-5 inches 0-13 cm Lab. No. S28572	Dusky red (2.5YR 3/2); sandy clay loam; moderate fine subangular blocky; light and porous; soft, slightly sticky, slightly plastic; many fine and medium roots; clear, smooth boundary to horizon below.
B_{2t} 5-23 inches 13-58 cm Lab. No. S28571	Red (10R 4/6) to dark red (10R 3/6); clay; less than 5% hardened plinthite glaebules of the kind in the layer below; moderate medium and fine subangular blocky; porous; friable, slightly sticky, and slightly plastic; common fine and medium roots; abrupt, smooth boundary to horizon below.
IIB_{31} 23-43 inches 58-109 cm Lab. No. S28570	Main gravel layer; red (10R 4/6); gravelly clay; 40% black-coated and uncoated, medium, round, black, dense hardened plinthite glaebules, and 10% coarse, dense, very hard, fresh rock pebbles; moderate fine subangular blocky; porous; friable, slightly sticky, slightly plastic; few fine roots; diffuse, smooth boundary to horizon below.
IIB_{32} 43-67 inches 109-170 cm Lab. No. S28569	Red (10R 4/6); gravelly clay; 40% hardened plinthite glaebules as in IIB_{31} but finer in size; moderate fine subangular blocky; slightly porous; friable, slightly sticky, slightly plastic; no roots.
Diagnostic horizons	Ochric epipedon, 0-5 inches (0-13 cm). Argillic horizon, 5-67 inches (13-170 cm) probable, but not fully documented.

Profile 144801A, Baoma sandy clay loam

Classification: Typic Paleudult (or Tropeptic Haplorthox)

Illinois Lab. No.	S28572	S28571	S28570	S28569
Depth of horizon (inches)	0-5	5-23	23-43	43-67
Horizon	A_1	B_{2t}	IIB_{31}	IIB_{32}
Percent of entire sample > 2.0 mm . .	14.4	17.3	50[a]	40[a]
Particle-size distribution of < 2 mm (%):				
Very coarse sand 2.0-1.0 mm. . . .	6.6	4.9	3.3	4.0
Coarse sand 1.0-.5 mm	8.0	5.3	5.5	5.9
Medium sand .5-.25 mm. . . .	9.9	6.8	4.7	5.0
Fine sand .25-.1 mm	19.7	14.3	8.6	8.6
Very fine sand .1-.05 mm. . . .	8.7	8.4	7.3	6.2
Total sand 2.0-.05 mm. . . .	52.5	39.4	28.6	29.3
Total silt .05-.002 mm . . .	13.4	13.9	15.0	15.0
Total clay < .002 mm . . .	34.1	46.7	56.4	55.7
Water-dispersible clay < .002 mm. . .	6.9	0.9	0.5	0.4
Bulk density.	1.2	1.3	1.5	1.5
Moisture: 1/3 atmos. (%)	19.2	22.2	24.9	25.8
15 atmos. (%)	14.2	16.7	20.0	21.2
Avail. moist.-hold. capacity[b]	0.05	0.06	0.03	0.04
Organic carbon (%).	2.43	0.81	0.53	0.24
Exchangeable cations (me/100g soil):				
Ca.	0.21	0.05	0.23	0.36
Mg.	0.23	0.26	0.26	0.34
K	0.06	0.05	0.05	0.04
Na.	0.02	0.03	0.07	0.04
Al.	1.33	0.63	0.12	0.16
Cation-exch. capacity (me/100g) . . .	11.93	7.29	6.50	5.36
Base saturation (%)	4.4	5.3	9.4	14.6
pH H_2O	4.6	4.8	5.0	5.2
pH KCl	3.8	4.2	4.6	5.0
Soil tests:				
K (lbs/A)	45	4	9	10
P_1 (lbs/A)	45	21	32	27
P_2 (lbs/A)	60	34	56	49
Total P (ppm)	2,070	1,970	2,770	2,760
Total CaO(%)	0.128	0.095	0.099	0.099
Total Fe_2O_3(%)	16.40	17.17	18.13	18.96
Total K_2O(%)	0.204	0.197	0.219	0.203

[a] Volume percent of total sample estimated in the field.
[b] Inches of available moisture-holding capacity per inch of soil, adjusted for the amount of > 2.0 mm material.

Profile N39, Bonjema loam

Described by J. C. Dijkerman on March 28, 1966

Location	On proposed new experimental farm northwest of Njala University College Campu a few feet west of path from Bonjema to Belebu; 301 feet (92 m) north of the junction of this path with path towards Gbesebu.
Physiography	Colluvial footslope or upper river terrace.
Relief	Lower part of a straight 2- to 3-percent slope.
Vegetation	Secondary farm bush.
Drainage	Imperfectly drained.
Parent material	Gravel-free colluvium, over gravelly colluvium, over residual material.
A_1 0-4 inches 0-10 cm Lab. No. S28651	Dark grayish brown (10YR 4/2); loam; weak medium subangular blocky, breaking to moderate coarse to fine granular; friable; many medium and fine and few coarse roots; many pores of all sizes; gradual, smooth boundary to horizon below.
A_3 4-16 inches 10-41 cm Lab. No. S29739	Brown (10YR 5/3) with few fine distinct yellowish-red (5YR 5/8) and light brownish-gray (10YR 6/2) mottles; loam; very weak medium subangular blocky, breaking to weak coarse to fine granular; friable; common medium and fine roots; many pores of all sizes; gradual, smooth boundary to horizon below.
B_{1t} 16-25 inches 41-63 cm Lab. No. S28652	Yellowish brown (10YR 5/4) with common fine distinct yellowish-red (5YR 5/8) and light brownish-gray (10YR 6/2) mottles; loam; very weak medium subangular blocky, breaking to weak coarse to fine granular; firm in place but friable t crush; common medium and fine roots; many pores of all sizes; abrupt, smooth boundary to horizon below.
IIB_{21} 25-33 inches 63-84 cm Lab. No. S28653	Yellowish brown to pale brown (10YR 5/4-6/3) with many prominent medium red (2.5YR 4/8) mottles, most of which are slightly hard to crush; gravelly (50% by volume) clay loam; the gravels form a stone line and consist mainly of quartz pebbles (35%) and dense, irregular, red (10YR 4/4-4/6) hardened plinthite glaebules (15%) 1/4" to 1/2" in diameter; massive to weak medium an fine angular blocky; firm; few medium and fine roots; common medium and fine pores; clear, smooth boundary to horizon below.
$IIIB_{22}$ 33-57 inches 84-145 cm Lab. No. S29740	Forty percent prominent fine, medium, and coarse light brownish-gray to pale brown (10YR 6/2-6/3) soft mottles, and 60% prominent fine, medium, and coarse red (10R 4/8) mottles, most of which are slightly hard to crush; gravelly (30% by volume) clay loam; gravels are irregular, nondense, red (10R 4/8) hardened plinthite glaebules, 1/4" to 3/4" in diameter; moderate medium to very fine angular blocky; firm; few medium and fine roots; common medium and fine pores; diffuse, smooth boundary to horizon below.
$IIIB_{23}$ 57-70 inches 145-178 cm Lab. No. S28654	Forty percent prominent fine, medium, and coarse light gray (10YR 6/1) soft mottles, and 60% prominent fine, medium, and coarse red (2.5YR 5/8, 10R 4/8) mottles, most of which are slightly hard or hard to crush; gravelly (20% by volume) clay; gravels are irregular, nondense, red (2.5YR 5/8, 10R 4/8) hardened plinthite glaebules, 1/4" to 3/4" in diameter; strong medium to very fine angular blocky; firm; few medium and fine roots; common medium and fine pores. Augering to a depth of 125 inches (318 cm) revealed light gray (10YR 6/1-7/1) and white (10YR 8/1) colors, with red (10R 4/8) and strong brown (7.5YR 5/8) mottles; small pieces of weathered siltstone occurred below 100 inches (254 cm).
Diagnostic horizons	Ochric epipedon, 0-16 inches (0-41 cm). Argillic horizon, 16-70 inches (41-178 cm) probable, but not fully documented

Profile N39, Bonjema loam

Classification: Plinthic Paleudult (or "Plinthic" Udoxic Dystropept)

Illinois Lab. No.	S28651	S29739	S28652	S28653	S29740	S28654
Depth of horizon (inches)	0-4	4-16	16-25	25-33	33-57	57-70
Horizon	A_1	A_3	B_{1t}	IIB_{21}	$IIIB_{22}$	$IIIB_{23}$
Percent of entire sample > 2.0 mm . .	<1	4	3	25	38	32
Particle-size distribution of < 2 mm (%):						
Very coarse sand 2.0-1.0 mm. . . .	1.5	0.5	3.9	4.2	0.3	2.4
Coarse sand 1.0-.5 mm	4.3	6.5	5.8	5.1	6.1	2.9
Medium sand .5-.25 mm. . . .	8.1	8.3	6.4	5.3	5.6	2.7
Fine sand .25-.1 mm	19.3	19.5	16.6	11.9	9.8	5.5
Very fine sand .1-.05 mm. . . .	15.1	16.2	12.4	9.0	8.6	6.0
Total sand 2.0-.05 mm. . . .	48.3	51.0	45.1	35.5	30.4	19.5
Total silt .05-.002 mm . . .	38.7	32.6	32.5	32.5	30.2	34.0
Total clay <.002 mm . . .	13.0	16.4	22.4	32.0	39.4	46.5
Water-dispersible clay <.002 mm . . .	5.4	11.0	19.9	28.6	13.9	4.6
Moisture: 1/3 atmos. (%)	21.5	17.9	17.7	20.9	26.2	28.6
15 atmos. (%)	6.6	6.5	9.2	12.7	15.6	18.1
Organic carbon (%).	2.36	0.57	0.41	0.38	0.33	0.24
Exchangeable cations (me/100g soil):						
Ca.	1.07	0.18	0.03	0.03	0.26	0.03
Mg.	0.29	0.13	0.15	0.20	0.05	0.27
K	0.22	0.02	0.05	0.06	0.04	0.07
Na.	0.04	0.04	0.02	0.02	0.04	0.02
Al.	0.84	1.02	2.31	3.51	4.44	10.00
Cation-exch. capacity (me/100g) . . .	8.43	3.93	4.57	6.72	9.86	13.15
Base saturation (%)	19.2	9.4	5.5	4.6	3.9	3.0
pH H_2O	4.6	4.3	4.3	4.4	4.9	4.8
pH KCl.	3.8	3.6	3.4	3.1	3.4	3.3
Soil tests:						
K (lbs/A)	202	43	52	60	65	65
P_1(lbs/A)	18	4	3	2	1	0
P_2(lbs/A)	19	4	3	2	1	1
Total P (ppm)	167	78	78	105	125	125
Total CaO(%).	0.153	...	0.072	0.072	...	0.069
Total Fe_2O_3(%).	1.50	...	3.08	4.90	...	8.52
Total K_2O(%).	0.426	...	0.722	1.070	...	2.250

Profile N105, Bonjema fine sandy loam
Described by D. H. Westerveld on December 28, 1966

Location	Oil Palm Station of Njala University College, adjacent to the south boundary road, 370 feet (113 m) northwest of Kania.
Physiography	Third (upper) terrace of the Taia River.
Relief	Very gentle, straight slope.
Vegetation	Secondary bush.
Drainage	Imperfectly drained.
Parent material	Gravel-free colluvium or alluvium, over colluvial material high in quartz gravel and hardened plinthite glaebules, over residual material weathered from bedrock.
A_1 0-20 inches 0-51 cm Lab. No. S29094	Dark brown (10YR 4/3); fine sandy loam; very weak fine and medium angular to subangular blocky, breaking into weak fine and medium granular; friable; many fine, medium, and coarse pores; many fine, medium, and coarse roots; gradual, smooth boundary to horizon below.
B_{1t} 20-32 inches 51-81 cm Lab. No. S29095	Yellowish brown (10YR 5/4) with few fine faint yellowish-red (5YR 5/8) mottles; sandy clay loam; weak fine, medium, and coarse angular to subangular blocky, breaking into weak to moderate fine and medium granular; friable; many fine, medium, and coarse pores; many fine and medium roots; clear, wavy boundary to horizon below.
IIB_{21} 32-40 inches 81-102 cm Lab. No. S29097	Yellowish brown (10YR 5/4) with common fine and medium faint yellowish-red (5YR 4/8) mottles; gravelly sandy clay loam, with most of the gravel being rounded quartz pieces 1/4" to 1" in diameter (stone line); very weak fine and medium angular to subangular blocky, breaking into weak fine and medium granular; friable; many fine, medium, and coarse pores; common fine and medium roots; clear, wavy boundary to horizon below.
$IIIB_{22}$ 40-50 inches 102-127 cm Lab. No. S29099	Brown to dark brown (10YR 5/3-4/3) with common fine and medium distinct red (2.5YR 4/8) mottles, and few fine and medium faint yellowish-brown (10YR 5/8) mottles; gravelly clay loam; half of the gravel is rounded quartz, and half is red (10R 4/6), round and nodular, 1/4" to 1" in diameter, hardened plinthite glaebules; very weak fine and medium angular to subangular blocky, breaking into fine and medium granular; many fine, medium, and coarse pores; few fine roots; gradual, smooth boundary to horizon below.
$IIIB_{23}$ 50-60 inches 127-153 cm Lab. No. S29101	Light brownish gray (10YR 6/2) with many fine, medium, and coarse prominent red (2.5YR 4/6) mottles, and few fine and medium faint yellowish-brown (10YR 5/8) mottles; gravelly clay loam, with most of the gravel being hardened plinthite glaebules similar to those in the $IIIB_{22}$ horizon; very weak fine and medium angular to subangular blocky, breaking into weak fine and medium granular; firm; many fine, medium, and coarse pores; few fine roots.
Diagnostic horizons	Ochric epipedon, 0-20 inches (0-51 cm). Argillic horizon, 20-60 inches (51-153 cm) probable, but not fully documented.

Profile N105, Bonjema fine sandy loam

Classification: Plinthic Paleudult (or "Plinthic" Udoxic Dystropept)

Illinois Lab. No. Depth of horizon (inches) Horizon	S29094 0-20 A_1	S29095 20-32 B_{1t}	S29097 32-40 IIB_{21}	S29099 40-50 $IIIB_{22}$	S29101 50-60 $IIIB_{23}$
Percent of entire sample > 2.0 mm.	0	0	32.2	29.5	35.5
Particle-size distribution of < 2 mm (%):					
Very coarse sand 2.0-1.0 mm	0.6	2.0	3.4	4.4	3.7
Coarse sand 1.0-.5 mm.	4.0	5.1	4.7	5.0	5.5
Medium sand .5-.25 mm	9.0	7.3	6.3	6.0	5.7
Fine sand .25-.1 mm.	30.2	24.3	19.1	17.1	14.4
Very fine sand .1-.05 mm	18.1	15.4	12.9	11.9	11.0
Total sand 2.0-.05 mm	61.9	54.1	46.4	44.4	40.3
Total silt .05-.002 mm.	26.0	24.9	24.4	24.0	23.0
Total clay < .002 mm.	12.1	21.0	29.2	31.6	36.7
Water-dispersible clay < .002 mm	5.1	16.6	24.7	23.5	5.5
Moisture: 1/3 atmos. (%).	9.6	...	14.2	15.4	17.7
15 atmos. (%).	5.6	...	10.8	12.0	13.6
Organic carbon (%)	1.19	0.44	0.30	0.26	0.14
Exchangeable cations (me/100g soil):					
Ca	0.18	0.10	0.08	0.13	0.18
Mg	0.10	0.10	0.10	0.31	0.10
K.	0.01	0.02	0.01	0.02	0.03
Na	0.06	0.03	0.04	0.03	0.04
Al	1.50	1.55	1.89	2.11	3.44
Cation-exch. capacity (me/100g).	5.79	4.64	5.57	6.14	8.07
Base saturation (%).	6.0	5.4	4.1	8.0	4.3
pH H_2O	4.1	4.4	4.5	4.6	4.5
pH KCl	3.5	...	3.4	3.4	3.3
Soil tests:					
K (lbs/A).	56	39	35	43	48
P_1(lbs/A).	11	3	2	2	3
P_2 lbs/A).	15	5	4	4	5
Total P (ppm).	137	...	110	140	...
Total CaO(%).	0.080	0.074	0.073	0.073	0.075
Total Fe_2O_3(%).	1.01	1.51	2.68	3.74	4.52
Total K_2O(%).	0.29	0.42	0.58	0.64	...

Profile P60, Bosor fine sandy loam

Described by R. Miedema on April 30, 1968

Location	Topographic map of Sierra Leone, scale 1:50,000, sheet 43, coordinates $HE22_3$-85_9; along the path from Mabanta to Bosor, near augerhole 12.
Physiography	Flat summit of a low hill, on an old tributary terrace.
Relief	Slope, 0 to 3 percent.
Vegetation	Short bush, 2 to 4 years old, with many wild oil palms.
Drainage	Well drained.
Parent material	Gravel-free alluvium or colluvium, over weathering products of Precambrian granite and acid gneiss.
A_{11} 0-9 inches 0-24 cm Lab. No. S29827	Very dark grayish brown (10YR 3/2); fine sandy loam; weak fine and medium subangular blocky with many crumbs; friable; many macro- and mesopores; few medium distinct charcoal mottles; common coarse, many medium and fine roots; much ant and termite activity; clear, smooth boundary to horizon below.
A_{12} 9-18 inches 24-45 cm Lab. No. S29828	Dark brown (10YR 3/3); fine sandy clay loam; weak fine and medium subangular blocky with many crumbs; friable; common macro- and many mesopores; common medium distinct charcoal mottles; many coarse, medium, and fine roots; much ant and termite activity; clear, smooth boundary to horizon below.
B_{21} 18-24 inches 45-60 cm Lab. No. S29829	Dark brown to brown (7.5YR 4/4); fine sandy clay loam; weak fine, medium, and coarse subangular to angular blocky; friable; many macro- and mesopores; few medium distinct charcoal mottles; common coarse and medium, many fine roots; much ant and termite activity; gradual, smooth boundary to horizon below.
B_{22} 24-43 inches 60-108 cm Lab. No. S29830	Yellowish red to strong brown (5YR 5/8-7.5YR 5/8); fine sandy clay loam; weak fine and medium subangular blocky; friable; common macro- and many mesopores; few coarse, common medium and fine roots; common ant and termite activity; abrupt, smooth boundary to horizon below.
IIB_{23} 43-51 inches 108-130 cm Lab. No. S29831	Yellowish red to strong brown (5YR 5/8-7.5YR 5/6); gravelly sandy clay loam; weak fine and medium subangular blocky; friable; common macro- and many mesopores; common fine roots; low ant and termite activity; 50% gravel (approximately 25% fine and medium angular quartz gravel, and 25% fine, medium, and coarse, hardened plinthite glaebules).
Diagnostic horizons	Umbric epipedon, 0-18 inches (0-45 cm). Argillic horizon, 43-51 inches (108-130 cm) probable, but not fully documented.

Profile P60, Bosor fine sandy loam

Classification: Orthoxic Palehumult (or Udoxic Dystropept)

Illinois Lab. No.	S29827	S29828	S29829	S29830	S29831
Depth of horizon (inches)	0-9	9-18	18-24	24-43	43-51
Horizon	A_{11}	A_{12}	B_{21}	B_{22}	IIB_{23}
Percent of entire sample > 2.0 mm . . .	0	0	0	0	50.4
Particle-size distribution of < 2 mm (%):					
Very coarse sand 2.0-1.0 mm	3.6	3.8	6.6	6.2	7.6
Coarse sand 1.0-.5 mm.	8.6	7.5	8.4	7.0	7.1
Medium sand .5-.25 mm	15.7	13.3	11.7	10.3	9.1
Fine sand .25-.1 mm.	28.8	25.3	22.6	22.0	17.6
Very fine sand .1-.05 mm	12.9	13.1	12.7	13.4	12.4
Total sand 2.0-.05 mm	69.6	63.0	62.0	58.9	53.8
Total silt .05-.002 mm.	13.1	12.5	13.4	13.3	14.1
Total clay < .002 mm.	17.3	24.5	24.6	27.8	32.1
Water-dispersible clay < .002 mm. . . .	3.8	6.6	10.2	11.0	4.8
Bulk density.	1.2	1.2	1.3	1.3	1.4
Moisture: 1/3 atmos. (%)	12.1	13.6	13.2	13.8	16.2
15 atmos. (%)	8.5	10.0	9.6	10.4	12.3
Avail. moist.-hold. capacity[a]	0.04	0.04	0.05	0.04	0.02
Organic carbon (%).	2.34	1.40	0.86	0.66	0.62
Exchangeable cations (me/100g soil):					
Ca.	0.58	0.11	0.11	0.11	0.11
Mg.	0.16	0.05	0.10	0.26	0.05
K	0.12	0.01	0.01	0.02	0.03
Na[b]	0.13	0.03	0.03	0.04	0.05
Al.	0.99	1.24	0.91	0.78	0.63
Cation-exch. capacity (me/100g)	7.29	6.14	4.50	4.07	4.85
Base saturation (%)	13.6	3.3	5.6	10.6	4.9
pH H_2O.	4.7	4.7	4.7	4.8	4.8
pH KCl.	4.1	4.1	4.1	4.1	4.1
Soil tests:					
K (lbs/A)	194	74	35	39	56
P_1 (lbs/A)	15	4	3	3	2
Total CaO(%).	0.120	0.078	0.075	0.073	0.076
Total Fe_2O_3(%).	4.96	6.80	6.74	7.28	8.40
Total K_2O(%).	0.402	0.391	0.372	0.387	0.407

[a]Inches of available moisture-holding capacity per inch of soil, adjusted for the amount of > 2.0 mm material.
[b]Estimated values.

Profile T165, Gbamani coarse sand
Described by J. C. Dijkerman on May 26, 1966

Location	Torma Bum soil survey area, 528 feet (161 m) west of Sahun along path to Mani. On aerial photograph 61-SL3-023, pit T165 is 20.4 cm south and 11.5 cm west of the northeast corner mark.
Physiography	Beach ridge about 5 miles north of present coast.
Relief	Convex 2-percent slope on the crest of a ridge about 1/4 mile wide and 10 feet (3 m) higher than the surrounding low area.
Vegetation	Forest with many oil palms and coconut trees.
Drainage	Well drained.
Parent material	Coarse beach sand of Bullom Series.
A_{21} 0-16 inches 0-41 cm Lab. No. S28668	Very dark gray to dark gray (10YR 4/1-3/1); coarse sand with many clean coarse quartz grains; single grain; very friable; many coarse, medium, and fine roots; many medium and fine pores; gradual, smooth boundary to horizon below.
A_{22} 16-41 inches 41-104 cm Lab. No. S28669	Dark gray (10YR 4/1-7.5YR 4/1); coarse sand with many clean coarse quartz grains; single grain; very friable; many medium and fine pores; few medium and fine roots; abrupt, wavy boundary to horizon below.
B_{2h} 41-48 inches 104-122 cm Lab. No. S28670	Dark reddish brown (5YR 2/2); coarse sand; turns white on ignition; massive; firm in place but friable to crush; many medium and fine pores; few medium and fine roots; abrupt, irregular boundary to horizon below with vertical tongues as long as 15 inches extending into the B_{2ir}.
B_{2ir} 48-80 inches 122-203 cm Lab. No. S28671	Yellowish red (5YR 4/6); loamy coarse sand; turns red on ignition; massive; firm to very firm; common medium and fine pores; few medium and fine roots; gradual boundary to horizon below.
C 80-120 inches 203-305 cm Lab. No. S28672	Yellowish brown (10YR 5/4) with common distinct coarse strong brown (7.5YR 5/6) mottles; loamy coarse sand; single grain; very friable; no roots; many fine and medium pores.
Diagnostic horizons	Ochric epipedon, 0-41 inches (0-104 cm). Spodic horizon, 41-80 inches (104-203 cm).

Profile T165, Gbamani coarse sand

Classification: "Arenic" Tropohumod

Illinois Lab. No.	S28668	S28669	S28670	S28671	S28672
Depth of horizon (inches)	0-16	16-41	41-48	48-80	80-120
Horizon	A_{21}	A_{22}	B_{2h}	B_{2ir}	C
Percent of entire sample > 2.0 mm.	0+	0+	0+	0+	0+
Particle-size distribution of < 2 mm (%):					
Very coarse sand 2.0-1.0 mm.	25.4	28.2	29.4	25.6	19.8
Coarse sand 1.0-.5 mm	49.5	45.0	29.4	35.0	26.8
Medium sand .5-.25 mm.	16.3	18.6	20.6	19.0	23.3
Fine sand .25-.1 mm	5.0	3.9	9.8	7.5	12.8
Very fine sand .1-.05 mm.	0.2	0.1	1.0	0.7	1.3
Total sand 2.0-.05 mm.	96.4	95.8	90.2	87.8	84.0
Total silt .05-.002 mm	2.3	2.9	4.2	3.4	4.9
Total clay < .002 mm	1.3	1.3	5.6	8.8	11.1
Water-dispersible clay < .002 mm	0.6	1.7	2.3	1.1	0.6
Bulk density	...	...	1.5	1.7	1.8
Moisture: 1/3 atmos. (%)	1.3	1.5	8.1	5.0	5.0
15 atmos. (%)	0.8	0.6	4.3	3.7	4.0
Avail. moist.-hold. capacity[a].	...	...	0.06	0.02	0.02
Organic carbon (%).	0.28	0.12	2.27	0.46	0.18
Exchangeable cations (me/100g soil):					
Ca	0.03	0.03	0.06	0.06	0.06
Mg	0.03	0	0.06	0.06	0
K.	0.03	0.01	0.03	0.02	0.03
Na	0.03	0.02	0.06	0.05	0.04
Al	3.22	4.89	1.28	0.40	0.62
Cation-exch. capacity (me/100g).	1.29	0.64	9.01	2.93	2.21
Base saturation (%).	9.3	9.4	2.3	6.5	5.9
pH H_2O	4.3	4.5	4.6	5.1	5.2
pH KCl	3.7	4.0	4.0	4.6	4.7
Soil tests:					
K (lbs/A).	35	21	30	21	26
P_1(lbs/A).	7	9	0	26	125
P_2(lbs/A).	7	14	0	39	125
Total P (ppm).	70	...	...	...	...
Total CaO(%)	0.074	0.068	0.084	0.078	0.078
Total Fe_2O_3(%)	0	0	0.30	1.85	0.80
Total K_2O(%)	0.078	0.173	0.281	0.349	0.413

[a]Inches of available moisture-holding capacity per inch of soil.

Profile T187, Gbehan silty clay
Described by J. C. Dijkerman on March 4, 1966

Location	Torma Bum soil survey area, near the former sugar cane experimental plots; 1,954 feet (596 m) west of the former sugar cane office and 2,323 feet (708 m) west of Sewa River. On aerial photograph 53-SL13-036, pit T187 is 13.3 cm west and 10.1 cm south of the northeast corner mark.
Physiography	Basin in the floodplain of Sewa River.
Relief	Concave 1-percent slope in a basin, adjacent to the higher levee on which profile T183, Taso clay, is located.
Vegetation	Short water-loving grasses.
Drainage	Poorly drained.
Parent material	Clayey alluvium.
A_1 0-5 inches 0-13 cm Lab. No. S28664	Black (10YR 2/1); silty clay; moderate fine to very fine granular; friable; many fine and medium pores; many fine and medium roots; clear, smooth boundary to horizon below.
A_{3g} 5-11 inches 13-28 cm Lab. No. S28665	Dark gray (10YR 4/1); clay; strong very coarse prismatic, breaking into strong coarse to medium angular blocks; very firm; few medium and common fine pores; common fine and medium roots; clear, smooth boundary to horizon below.
B_{1g} 11-14 inches 28-35 cm Lab. No. S28666	Light brownish gray (2.5Y 6/2) with common distinct fine and medium strong brown (7.5YR 5/8) mottles; clay; strong very coarse prismatic, breaking into strong coarse to medium angular blocks; very firm; few medium and common fine pores; common fine and medium roots; clear, smooth boundary to horizon below.
B_{21g} 14-23 inches 35-58 cm	Light gray (2.5Y 7/2) with common distinct medium and fine yellowish-red (5YR 5/6) and strong brown (7.5YR 5/6) mottles; clay; strong medium angular blocky; firm in place but friable to crush; many medium and fine pores; few medium and fine roots; gradual, smooth boundary to horizon below.
B_{22g} 23-52 inches 58-132 cm Lab. No. S28667	Light gray (2.5Y 7/2) with many distinct yellowish-red (5YR 5/6) and strong brown (7.5YR 5/6) soft mottles; clay; moderate medium to very fine angular blocky; firm in place but friable to crush; many medium and fine pores; few medium and fine roots.
Diagnostic horizons	Ochric epipedon, 0-11 inches (0-28 cm). Oxic horizon, 23-52 inches (58-132 cm).

Profile T187, Gbehan silty clay

Classification: "Plinthic Tropeptic" Ochraquox

Illinois Lab. No.	S28664	S28665	S28666	S28667
Depth of horizon (inches)	0-5	5-11	11-14	23-52
Horizon	A_1	A_{3g}	B_{1g}	B_{22g}
Percent of entire sample > 2.0 mm.	0	0	0	21
Particle-size distribution of < 2 mm (%):				
Total sand 2.0-.05 mm	1.8	1.1	0.5	2.5
Total silt .05-.002 mm.	43.7	29.5	36.1	33.9
Total clay < .002 mm.	54.5	69.4	63.4	63.6
Water-dispersible clay < .002 mm	15.9	45.0	48.2	1.4
Bulk density	0.8	1.1	1.4	1.4
Moisture: 1/3 atmos. (%).	86.7	48.7	38.6	40.3
15 atmos. (%).	37.1	32.0	25.6	26.8
Avail. moist.-hold. capacity[a].	0.40	0.18	0.18	0.15
Organic carbon (%)	13.48	5.83	0.84	0.33
Exchangeable cations (me/100g soil):				
Ca	0.11	0.03	0.24	1.01
Mg	0.31	0.39	0.91	2.44
K.	0.35	0.10	0.05	0.06
Na	0.15	0.13	0.06	0.07
Al	4.72	6.44	3.33	3.22
Cation-exch. capacity (me/100g).	46.37	30.58	11.29	9.57
Base saturation (%).	2.0	2.1	11.2	37.4
pH H_2O	4.8	4.7	5.0	5.5
pH KCl	4.0	3.7	3.6	4.2
Soil tests:				
K (lbs/A).	158	69	43	56
P_1(lbs/A).	111	14	9	8
P_2(lbs/A).	125	25	10	11
Total P (ppm).	1,550	740	...	...
Total CaO(%)....	0.124	0.104	0.101	0.120
Total Fe_2O_3(%)	1.83	2.50	3.15	5.81
Total K_2O(%)	0.500	1.080	1.270	1.330

[a]Inches of available moisture-holding capacity per inch of soil, adjusted for the amount of > 2.0 mm material.

Profile N125, Gbesebu silty clay
Described by H. Breteler on January 18, 1967

Location	From the extreme southwestern corner of the Oil Palm Station of Njala University College, at the junction of the Kania boundary road and the path along the Taia River near surveyor stone No. PB-B 829, thence 322 feet (98 m) down the steep slope towards the river to pit N125, near the river bank on a natural levee.
Physiography	Natural levee of the Taia River, on the present floodplain or first terrace.
Relief	Nearly level, convex slope.
Vegetation	Old secondary bush with much grass.
Drainage	Moderately well drained; may be flooded for several weeks during the wet season.
Parent material	Clayey alluvium.
A_1 0-4 inches 0-10 cm Lab. No. S29066	Dark brown (10YR 4/3); silty clay; weak very fine and fine subangular blocky, breaking to weak very fine granular; very friable; many fine, medium, and coarse pores; many fine, medium, and coarse roots; clear, smooth boundary to horizon below.
A_3 4-7 inches 10-18 cm Lab. No. S29067	Dark yellowish brown (10YR 4/4); clay; weak very fine and fine angular to subangular blocky, breaking to weak very fine granular; friable; many fine, medium, and coarse pores; many fine, medium, and coarse roots; clear, smooth boundary to horizon below.
B_{21} 7-19 inches 18-48 cm Lab. No. S29068	Strong brown (7.5YR 5/6) with many fine and medium faint yellowish-red (5YR 5/6) mottles; clay; weak very fine and fine blocky, breaking into weak very fine granular; friable; many fine, medium, and coarse pores; common fine, medium, and coarse roots; mica flakes; clear, smooth boundary to horizon below.
B_{22b} 19-25 inches 48-63 cm Lab. No. S29069	Strong brown to yellowish brown (7.5YR-10YR 5/6) with many fine, medium, and coarse faint yellowish-red (5YR 5/6) mottles; this is a buried A horizon with common fine, medium, and coarse charcoal mottles; clay; weak to moderate fine and medium blocky, breaking into weak to moderate very fine and fine granular; firm; many fine, medium, and coarse pores; common fine and medium roots; mica flakes; clear, smooth boundary to horizon below.
B_{23} 25-63 inches 63-160 cm Lab. No. S29070	Strong brown (7.5YR 5/6) with many fine, medium, and coarse faint yellowish-red (5YR 5/6) mottles; clay; weak to moderate fine and medium blocky, breaking into weak to moderate fine granular; firm; many fine, medium, and coarse pores; few fine and medium roots; mica flakes.
Diagnostic horizons	Ochric epipedon, 0-7 inches (0-18 cm). Cambic horizon, 7-63 inches (18-160 cm).

Profile N125, Gbesebu silty clay

Classification: Fluventic Udoxic Dystropept

Illinois Lab. No.	S29066	S29067	S29068	S29069	S29070
Depth of horizon (inches)	0-4	4-7	7-19	19-25	25-63
Horizon	A_1	A_3	B_{21}	B_{22b}	B_{23}
Percent of entire sample > 2.0 mm	0	0	0	0	0
Particle-size distribution of < 2 mm (%):					
Total sand 2.0-.05 mm.	6.5	2.2	0.8	1.6	2.2
Coarse silt .05-.02 mm.	7.3	4.8	4.9	6.3	8.0
Fine silt .02-.002 mm	36.8	33.3	33.1	31.5	31.2
Total silt .05-.002 mm	44.1	38.1	38.0	37.8	39.2
Total clay < .002 mm	49.4	59.7	61.2	60.6	58.6
Water-dispersible clay < .002 mm.	20.4	36.6	34.1	37.2	2.6
Bulk density.	0.9	1.0	1.1	1.1	1.2
Moisture: 1/3 atmos. (%)	47.1	40.8	37.2	36.7	36.9
15 atmos. (%)	25.7	26.4	27.0	27.3	26.4
Avail. moist.-hold. capacity[a]	0.19	0.14	0.11	0.10	0.13
Organic carbon (%).	4.41	2.43	1.00	0.87	0.56
Exchangeable cations (me/100g soil):					
Ca.	0.18	0.13	0.08	0.10	0.15
Mg.	0.22	0.18	0.15	0.33	0.44
K	0.03	0.02	0.02	0.01	0.02
Na.	0.08	0.06	0.06	0.04	0.04
Al.	2.44	2.00	1.78	1.94	1.78
Cation-exch. capacity (me/100g)	18.93	12.65	9.29	9.57	8.86
Base saturation (%)	2.7	3.1	3.3	5.0	7.3
pH H_2O	4.6	4.6	4.8	4.8	4.9
pH KCl	3.8	3.8	3.8	3.7	3.7
Soil tests:					
K (lbs/A).	98	60	39	35	35
P_1 (lbs/A).	28	10	9	9	16
P_2 (lbs/A).	35	14	10	10	26
Total P (ppm)	950	...	...	...	...
Total CaO(%)	0.193	0.150	0.137	0.139	0.137
Total Fe_2O_3(%)	5.84	6.20	7.53	7.08	7.10
Total K_2O(%)	1.37	1.31	1.35	1.34	1.35

[a]Inches of available moisture-holding capacity per inch of soil.

Profile N13, Gbesebu silty clay
Described by H. Breteler on January 5, 1967

Location	On proposed new experimental farm northwest of Njala University College Campus. Pit N13 is on the path from Nyawama toward Taia River, about 48 feet (15 m) before the steep slope starts down to the river. On aerial photograph 39-SL25-083, pit N13 is 12.6 cm west and 7.9 cm south of northeast corner mark.
Physiography	Levee of Taia River on the lowest terrace.
Relief	Nearly level.
Vegetation	Secondary bush.
Drainage	Moderately well drained, but it may be flooded for 1 to 2 weeks at the height of the wet season.
Parent material	Clayey alluvium.
A_1 0-7 inches 0-18 cm Lab. No. S29127	Dark brown (10YR 4/3); silty clay; weak to moderate fine, medium, and coarse angular to subangular blocky, breaking into weak very fine, fine, and medium granular; friable; many fine, medium, and coarse pores; many fine, medium, and coarse roots; clear, smooth boundary to horizon below.
B_{21} 7-42 inches 18-107 cm Lab. No. S29128	Strong brown (7.5YR 5/6); clay with much mica; weak to moderate fine, medium, and coarse angular to subangular blocky, breaking into weak to moderate very fine, fine, and medium granular; friable; many fine, medium, and coarse pores; common fine, medium, and coarse roots; clear, smooth boundary to horizon below.
B_{22} 42-50 inches 107-127 cm Lab. No. S29129	Strong brown (7.5YR 5/6) with many fine and medium faint red (2.5YR 4/6) mottles; clay with much mica; weak to moderate fine, medium, and coarse angular to subangular blocky, breaking into weak to moderate very fine, fine, and medium granular; friable; common fine, medium, and coarse pores; common fine, medium, and coarse roots.
Diagnostic horizons	Ochric epipedon, 0-7 inches (0-18 cm). Cambic horizon, 7-50 inches (18-127 cm).

Profile N13, Gbesebu silty clay

Classification: Fluventic Udoxic Dystropept

Illinois Lab. No.	S29127	S29128	S29129
Depth of horizon (inches)	0-7	7-42	42-50
Horizon	A_1	B_{21}	B_{22}
Percent of entire sample > 2.0 mm.	0	0	0
Particle-size distribution of < 2 mm (%):			
Total sand 2.0-.05 mm.	10.0	6.8	22.2
Coarse silt .05-.02 mm.	10.4	11.7	11.7
Fine silt .02-.002 mm	33.8	27.9	24.1
Total silt .05-.002 mm	44.2	39.6	35.8
Total clay < .002 mm	45.8	53.6	42.0
Water-dispersible clay < .002 mm	10.4	15.2	1.5
Moisture: 1/3 atmos. (%).	45.1	38.3	28.6
15 atmos. (%).	23.3	23.3	15.5
Organic carbon (%)	4.47	1.01	0.42
Exchangeable cations (me/100g soil):			
Ca	1.18	0.10	0.15
Mg	1.25	0.18	0.31
K.	0.82	0.02	0.03
Na	0.25	0.05	0.06
Al	2.11	2.11	1.44
Cation-exch. capacity (me/100g).	19.51	8.64	6.43
Base saturation (%).	17.9	4.1	8.6
pH H_2O	3.9	4.6	4.4
pH KCl	3.7	3.7	3.7
Soil tests:			
K (lbs/A).	92	65	98
P_1(lbs/A).	13	12	12
P_2(lbs/A).	18	18	21
Total P (ppm).	830	...	...
Total CaO(%)	0.276	0.177	0.224
Total Fe_2O_3(%)	6.82	6.84	6.14
Total K_2O(%)	1.54	1.56	1.71

Profile N70, Kania clay loam

Description by J.C. Dijkerman on January 11, 1967

Location
On proposed new experimental farm northwest of Njala University College. Pit N70 is located along traverse one, 739 feet (225 m) east of surveyor's stone SLS 21/64 BP/33. On aerial photograph 39-SL-25-083, pit N70 is 9.8 cm west and 4.6 cm south of northeast corner mark.

Physiography
In shallow drainageway on middle terrace of Taia River.

Relief
Very gentle concave slope, in the center of drainageway.

Vegetation
Tall grass.

Drainage
Imperfectly drained.

Parent material
Gravel-free alluvium.

A_1
0-12 inches
0-30 cm
Lab. No. S29114

Black (10YR 2/1); clay loam; weak fine and medium subangular blocky, breaking into weak very fine and fine granular; firm; many fine, medium, and coarse pores; many fine, medium, and coarse roots; clear, smooth boundary to horizon below.

A_3
12-16 inches
30-41 cm
Lab. No. S29115

Dark grayish brown (10YR 4/2); clay loam; very weak fine, medium, and coarse subangular blocky; firm; many fine and medium pores; common fine and medium roots; clear, smooth boundary to horizon below.

B_{21t}
16-24 inches
41-61 cm
Lab. No. S29116

Yellowish brown (10YR 5/4) with few, medium faint strong brown (7.5YR 5/6) mottles; clay; weak fine and very fine subangular blocky, breaking into very weak fine and very fine granular; firm; many fine and medium pores; common fine and medium roots; clear, smooth boundary to horizon below.

B_{22t}
24-39 inches
61-99 cm
Lab. No. S29117

Pale brown (2.5Y-10YR 6/3) with common medium and distinct red (2.5YR 4/8) mottles; clay; weak fine and very fine subangular blocky, breaking into weak fine and very fine granular; firm; common fine and medium pores; common fine and medium roots; gradual, smooth boundary to horizon below.

B_{23t}
39-56 inches
99-142 cm
Lab. No. S29118

Light brownish gray (2.5Y-10YR 6/2) with many medium and coarse prominent red (2.5Y 4/8) and yellowish-red (5YR 4/8) mottles that are slightly hard to crush; clay; weak to moderate fine and very fine subangular blocky, breaking into weak to moderate fine and very fine granular; friable; few fine and medium pores; few fine roots.

Diagnostic horizons
Umbric epipedon, 0-12 inches (0-30 cm).
Argillic horizon, 16-56 inches (41-142 cm) probable, but not fully documented.

Profile N70, Kania clay loam

Classification: "Plinthic" Orthoxic Palehumult (or Plinthic Aquic Umbriorthox)

Illinois Lab. No.	S29114	S29115	S29116	S29117	S29118
Depth of horizon (inches)	0-12	12-16	16-24	24-39	39-56
Horizon	A_1	A_3	B_{21t}	B_{22t}	B_{23t}
Percent of entire sample > 2.0 mm.	0	0	0	0	0
Particle-size distribution of < 2 mm (%):					
Very coarse sand 2.0-1.0 mm	0.2	0.1	0.2	0.1	1.3
Coarse sand 1.0-.5 mm.	0.4	0.5	0.3	0.3	0.9
Medium sand .5-.25 mm	1.8	1.4	0.9	0.9	0.9
Fine sand .25-.1 mm.	22.1	22.7	14.4	12.8	9.9
Very fine sand .1-.05 mm	18.6	19.0	14.5	13.4	12.1
Total sand 2.0-.05 mm	43.1	43.7	30.3	27.5	25.1
Coarse silt .05-.02 mm	5.2	4.8	4.1	3.9	5.5
Fine silt .02-.002 mm.	18.3	15.9	12.1	12.5	13.5
Total silt .05-.002 mm.	23.5	20.7	16.2	16.4	19.0
Total clay < .002 mm.	33.4	35.6	53.5	56.1	55.9
Water-dispersible clay < .002 mm	15.4	26.4	1.0	0.8	0.7
Bulk density	1.2	1.4	1.4	1.5	1.6
Moisture: 1/3 atmos. (%)	26.5	21.3	25.6	27.0	27.5
15 atmos. (%)	15.2	14.0	18.5	19.4	20.6
Avail. moist.-hold capacity[a]	0.14	0.10	0.10	0.11	0.11
Organic carbon (%)	2.73	0.86	0.62	0.29	0.19
Exchangeable cations (me/100g soil):					
Ca	0.08	0.10	0.10	0.08	0.08
Mg	0.02	0.03	0.10	0.10	0.10
K	0.05	0.04	0.04	0.02	0.05
Na	0.06	0.04	0.05	0.05	0.03
Al	1.33	1.50	1.72	1.78	1.94
Cation-exch. capacity (me/100g)	11.07	4.21	6.36	6.79	7.00
Base saturation (%)	1.9	5.0	4.6	3.7	3.7
pH H_2O	5.0	4.7	4.8	5.0	5.0
pH KCl	4.2	3.9	3.9	3.8	3.8
Soil tests:					
K (lbs/A)	65	48	43	48	48
P_1 (lbs/A)	19	5	4	4	4
P_2 (lbs/A)	22	5	4	4	3
Total P (ppm)	340	...	...	...	...
Total CaO (%)	0.084	0.076	0.074	0.072	0.070
Total Fe_2O_3 (%)	1.50	1.60	2.48	3.04	4.26
Total K_2O (%)	0.84	0.90	0.89	0.91	0.94

[a]Inches of available moisture-holding capacity per inch of soil.

Profile 145041, Keya loamy coarse sand
Description after Sivarajasingham (*64*)

Location	In the second swamp from Tundula on the new road to Baoma and Segbwema.
Physiography	Bottomland (swamp).
Relief	Nearly level.
Vegetation	It was in swamp rice in 1965, and during 1966 it was under grass. Many of the cut raphia palms have grown to a height of about 6 feet (2 m).
Drainage	Very poorly drained. Water table was 38 inches (96 cm) below the surface on April 20, 1966.
Parent material	Valley fill over residuum from quartz-rich granitic bedrock.
A_{11} 0-5 inches 0-13 cm	Grayish brown to dark grayish brown (2.5Y 5/2-4/2); loamy coarse sand; loose; structureless; few fine roots; presumably a layer of recent deposition; abrupt, smooth boundary to horizon below.
A_{12} 5-11 inches 13-28 cm Lab. No. S28548	Grayish brown to dark grayish brown (2.5Y 5/2-4/2); coarse sand; loose to soft; structureless, but held together by many fine roots; abrupt, smooth boundary to horizon below.
IIA_{13} 11-13 inches 28-33 cm	Grayish brown to dark grayish brown (2.5Y 5/2-4/2); loamy coarse sand; loose; structureless; many fine and medium roots of raphia palms; almost all the medium-sized roots are growing horizontally; abrupt, smooth boundary to horizon below.
$IIIA_{14}$ 13-21 inches 33-53 cm	Grayish brown to dark grayish brown (2.5Y 5/2-4/2); loamy coarse sand; loose; structureless; common fine and medium roots of raphia palm with most of the roots extending downward; gradual, wavy boundary to horizon below.
$IIIC_{1g}$ 21-33 inches 53-84 cm Lab. No. S28549	White (N 8/) with grayish-brown (2.5Y 5/2) common coarse distinct mottles, presumably because of mixing from the A_1 materials; coarse sandy loam; many fine and medium raphia palm roots growing downward; much coarse quartz gravel in the first 3 inches; the 21- to 24-inch layer is like a stone line; diffuse, irregular boundary to horizon below.
IVC_{2g} 33-48 inches 84-122 cm	White (N 8/) and greenish blue; common, very coarse, distinct patches of soft disintegrated quartz-rich rock with greenish color due to a powdery greenish-black mineral like chlorite, probably derived from mica and hornblende; many fine micaceous particles and white powdery feldspar grains; loam; common medium raphia palm roots growing downward.
IVC_{3g} 48-60 inches 122-153 cm	Same as IVC_{2g}, but sandy loam instead of loam.
Diagnostic horizon	Ochric epipedon, 0-21 inches (0-53 cm).

Profile 145041, Keya loamy coarse sand

Classification: Fluventic Tropaquent

Illinois Lab. No.	S28548	S28549
Depth of horizon (inches)	5-11	21-33
Horizon	A_{12}	$IIIC_{1g}$
Percent of entire sample > 2.0 mm.	6.6	8.7
Particle-size distribution of < 2 mm (%):		
Very coarse sand 2.0-1.0 mm	7.5	13.6
Coarse sand 1.0-.5 mm.	31.6	24.3
Medium sand .5-.25 mm	26.5	12.6
Fine sand .25-.1 mm.	23.6	10.5
Very fine sand .1-.05 mm	4.7	6.3
Total sand 2.0-.05 mm	94.1	67.4
Total silt .05-.002 mm.	3.6	14.4
Total clay < .002 mm.	2.3	18.2
Water-dispersible clay < .002 mm	0.4	15.4
Moisture: 1/3 atmos.(%)	4.4	14.7
15 atmos.(%)	2.7	8.2
Organic carbon(%).	1.08	0.28
Exchangeable cations (me/100g soil):		
Ca	0.14	0.36
Mg	0.07	0.30
K	0.04	0.10
Na	0.05	0.06
Al	0.50	0.69
Cation-exch. capacity (me/100g).	2.36	3.43
Base saturation (%).	12.7	23.9
pH H_2O.	4.5	5.0
pH KCl.	3.9	4.0
Soil tests:		
K (lbs/A).	4	19
P_1 (lbs/A)	4	62
P_2 (lbs/A)	4	76
Total P (ppm).	140	...
Total CaO(%).	0.103	0.139
Total Fe_2O_3(%).	0.10	0.70
Total K_2O(%).	0.708	1.370

Profile 145042, Kparva sandy clay loam
Description after Sivarajasingham *(64)*

Location	After the second swamp from Tundula, on the right-hand side of the new road from Tundula to Segbwema via Baoma, 30 feet (9 m) from the edge of the swamp.
Physiography	Undulating upland.
Relief	Lower part of a long gentle slope of 3 percent.
Vegetation	A 7-year old, high, slightly impenetrable bush with many short trees.
Drainage	Poorly drained.
Parent material	A thick layer of gravel-free, locally transported material.
A_1 0-9 inches 0-23 cm Lab. No. S28568	Very dark gray (10YR 3/1) to very dark grayish brown (10YR 3/2); sandy clay loam; strong medium and fine subangular blocky and fine angular; friable, nonsticky, nonplastic; many fine and medium roots, which in the top 2 inches form a dense mat of horizontal spreading roots; clear, smooth boundary to horizon below.
B_{2t} 9-39 inches 23-99 cm Lab. No. S28567	Brownish yellow (10YR 6/8) with common, coarse, faint yellowish-brown (10YR 5/4) to light yellowish-brown (2.5Y 6/4) mottles, with darker fillings of brown to dark brown (10YR 4/3) material in old burrow channels; sandy clay; strong medium and fine subangular blocky, except that the darker material is strong fine granular; porous; friable, slightly sticky, slightly plastic; common fine and medium roots; gradual, smooth boundary to horizon below.
B_{3t} 39-66 inches 99-168 cm Lab. No. S28566	White (2.5Y 8/2) with common, medium, prominent strong brown (7.5YR 5/6) and few, coarse, distinct brownish-yellow (10YR 6/8) mottles; sandy clay; moderate fine subangular blocky; porous; friable, slightly sticky, slightly plastic; the strong brown mottles are firm to hard and may be regarded as plinthite glaebules; few fine roots; abrupt, smooth boundary to horizon below.
IIC_1 66-68 inches 168-173 cm	Stone line; yellow (10YR 7/8) with common, coarse, distinct white (2.5Y 8/2) mottles; gravelly clay loam; 40% quartz pebbles and 10% porous, medium, hardened plinthite glaebules.
$IIIC_2$ 68-80 inches 173-203 cm Lab. No. S28565	White (2.5Y 8/2) with common, coarse, distinct brownish-yellow (10YR 6/6) and yellow (10YR 7/6) mottles; sandy clay loam; moderate medium subangular blocky; firm to friable, sticky, slightly plastic; no roots.
Remarks	Water trickled through the stone line when all of the water in the pit was baled out. Depth of water table on April 20, 1966, was 56 inches (142 cm).
Diagnostic horizons	Ochric epipedon, 0-9 inches (0-23 cm). Argillic horizon, 9-66 inches (23-168 cm) probable, but not fully documented.

Profile 145042, Kparva sandy clay loam

Classification: Aquic Paleudult (or Aquic Tropeptic Haplorthox)

Illinois Lab. No.	S28568	S28567	S28566	S28565
Depth of horizon (inches)	0-9	9-39	39-66	68-80
Horizon	A_1	B_{2t}	B_{3t}	$IIIC_2$
Percent of entire sample > 2.0 mm.	4.7	5.0	12.1	12.7
Particle-size distribution of < 2 mm (%):				
Very coarse sand 2.0-1.0 mm	4.5	6.4	9.6	7.5
Coarse sand 1.0-.5 mm.	24.0	15.2	16.7	9.9
Medium sand .5-.25 mm	15.9	10.8	8.5	7.8
Fine sand .25-.1 mm.	15.7	10.4	8.2	15.1
Very fine sand .1-.05 mm	6.6	5.6	5.1	10.7
Total sand 2.0-.05 mm	66.2	48.3	47.7	50.2
Total silt .05-.002 mm.	12.4	13.1	14.6	24.3
Total clay < .002 mm.	21.4	38.6	37.7	25.5
Water-dispersible clay < .002 mm	4.8	22.1	0.6	4.4
Bulk density	1.1	1.2	1.2	...
Moisture: 1/3 atmos. (%).	15.2	19.8	22.0	38.0
15 atmos. (%).	11.0	14.3	16.0	14.0
Avail. moist.-hold. capacity[a].	0.05	0.07	0.06	...
Organic carbon (%)	2.64	0.46	0.29	0.32
Exchangeable cations (me/100g soil):				
Ca	0.26	0.06	0.06	0
Mg	0.23	0.06	0.18	0.18
K.	0.15	0.04	0.06	0.08
Na	0.05	0.04	0.05	0.08
Al	2.28	2.39	1.11	0.96
Cation-exch. capacity (me/100g).	10.43	5.07	5.29	11.07
Base saturation (%).	6.6	3.9	6.6	3.1
pH H_2O.	4.4	4.6	5.2	5.0
pH KCl.	3.7	3.8	4.0	4.2
Soil tests:				
K (lbs/A)	22	3	7	8
P_1 (lbs/A)	7	3	2	150
P_2 (lbs/A)	9	1	3	325
Total P (ppm).	370	...	...	...
Total CaO (%).	0.098	0.079	0.085	0.158
Total Fe_2O_3 (%).	1.82	2.89	4.08	7.30
Total K_2O (%).	0.436	0.488	0.593	1.480

[a]Inches of available moisture-holding capacity per inch of soil, adjusted for the amount of > 2.0 mm material.

Profile P71, Mabassia sandy clay loam, shallow phase
Described by R. Miedema on May 15, 1968

Location	Topographic map of Sierra Leone, scale 1:50,000, sheet 43, coordinates $HE26_1-85_5$; along the Makeni to Mankane path.
Physiography	Little depression in the flat summit of a low hill.
Relief	Slope, 0 to 3 percent.
Vegetation	Secondary bush, 3 to 7 years old.
Drainage	Well drained.
Parent material	Gravel-free colluvium, over gravelly colluvium, over weathering products of Precambrian granite and acid gneiss.
A_{11} 0-7 inches 0-17 cm Lab. No. S29832	Very dark (grayish) brown (10YR 2.5/2); sandy clay loam; weak fine and medium angular to subangular blocky; friable, slightly sticky, and slightly plastic; many macro- and mesopores; common distinct medium charcoal particles; common coarse and fine, many medium roots; very few fine and medium hardened plinthite glaebules; much ant and termite activity; clear, smooth boundary to horizon below.
A_{12} 7-25 inches 17-63 cm Lab. No. S29833	Dark brown (10YR 3/3); sandy clay loam; fine and medium subangular blocky; firm, slightly sticky, and slightly plastic; many macro- and mesopores; common distinct medium charcoal particles; few coarse, many medium, and common fine roots; few fine and medium hardened plinthite glaebules; much ant and termite activity; clear, smooth boundary to horizon below.
IIB_1 25-39 inches 63-99 cm Lab. No. S29834	Yellowish brown to light olive brown (10YR 5/4-2.5Y 5/4); gravelly sandy clay loam; weak fine and medium angular blocky; firm, slightly sticky, and slightly plastic; common macro- and many mesopores; common medium and fine roots; 20% uncoated, fine and medium, rounded and nodular, dense, red, hardened plinthite glaebules; common ant and termite activity; clear, smooth boundary to horizon below.
IIB_2 39-65 inches 99-165 cm Lab. No. S29835	Yellow (10YR 7/8); sandy clay loam; very weak fine and medium angular blocky; friable, slightly sticky, and slightly plastic; many macro- and mesopores; common distinct medium and fine reddish-yellow (7.5YR 7/8), strong brown (7.5YR 5/8), and red (10R 4/8) mottles; few medium and fine roots; 10% uncoated, fine and medium, rounded and nodular, dense, red, hardened plinthite glaebules; common ant and termite activity.
Diagnostic horizons	Umbric epipedon, 0-25 inches (0-63 cm). Cambic horizon, 25-65 inches (63-165 cm).

Profile P71, Mabassia sandy clay loam, shallow phase

Classification: "Plinthic" Udoxic Dystropept

Illinois Lab. No.	S29832	S29833	S29834	S29835
Depth of horizon (inches)	0-7	7-25	25-39	39-65
Horizon	A_{11}	A_{12}	IIB_1	IIB_2
Percent of entire sample > 2.0 mm.	0	0	20.1	9.3
Particle-size distribution of < 2mm (%):				
Very coarse sand 2.0-1.0 mm	8.8	5.6	15.0	11.8
Coarse sand 1.0-.5 mm.	13.5	10.0	14.5	16.8
Medium sand .5-.25 mm	23.2	23.7	23.5	23.4
Fine sand .25-.1 mm.	17.6	18.4	15.0	14.6
Very fine sand .1-.05 mm	4.4	4.2	3.4	3.4
Total sand 2.0-.05 mm	67.5	61.9	71.4	70.0
Total silt .05-.002 mm.	9.6	7.0	5.7	5.8
Total clay < .002 mm.	22.9	31.1	22.9	24.2
Water-dispersible clay < .002 mm.	4.9	7.7	10.4	2.5
Moisture: 1/3 atmos. (%)	17.7	15.7	12.9	13.7
15 atmos. (%)	11.7	12.6	9.3	9.8
Organic carbon (%)	3.55	1.64	0.82	0.55
Exchangeable cations (me/100g soil):				
Ca	2.26	0.26	0.21	0.11
Mg	0.73	0.27	0.11	0.10
K.	0.27	0.03	0.03	0.07
Na[a].	0.27	0.05	0.05	0.10
Al	0.44	1.04	0.72	0.40
Cation-exch. capacity (me/100g).	12.27	7.99	4.57	2.14
Base saturation (%).	28.8	7.6	8.8	17.8
pH H_2O.	5.1	4.8	4.8	4.7
pH KCl.	4.3	4.2	4.2	4.2
Soil tests:				
K (lbs/A)	260	74	52	94
P_1 (lbs/A)	24	5	6	5
Total CaO (%)	0.325	0.100	0.083	0.081
Total Fe_2O_3 (%)	5.69	6.50	5.57	4.91
Total K_2O (%)	0.525	0.467	0.421	0.502

[a]Estimated values.

Profile P108, Mabassia coarse sandy loam, deep phase
Described by J.M. Cawray and R. Miedema on June 20, 1968

Location	Topographic map of Sierra Leone, scale 1:50,000, sheet 43, coordinates HE19$_7$-87$_6$; along the Makeni to Pundung path.
Physiography	Summit of a low hill, gently sloping.
Relief	Slope 3 percent to northwest.
Vegetation	Medium bush with many wild oil palms.
Drainage	Well drained.
Parent material	Gravel-free colluvium.
A_{11} 0-6 inches 0-14 cm Lab. No. S29836	Very dark gray (10YR 3/1); coarse sandy loam; weak fine subangular blocky; slightly sticky, slightly plastic; friable; many macro- and mesopores; few medium distinct charcoal particles; many fine, medium, and coarse roots; much termite, worm, and ant activity; clear, smooth boundary to horizon below.
A_{12} 6-13 inches 14-33 cm Lab. No. S29837	Very dark grayish brown (10YR 3/2); sandy clay loam; weak fine subangular blocky; friable, slightly sticky, slightly plastic; many macro- and mesopores; few medium distinct charcoal particles; many fine, medium, and coarse roots; much termite, worm, and ant activity; gradual, smooth boundary to horizon below.
B_1 13-26 inches 33-65 cm Lab. No. S29838	Dark yellowish brown (10YR 4/4); sandy clay; weak fine and medium subangular blocky; friable, slightly sticky, slightly plastic; many macro- and mesopores; many fine, medium, and coarse roots; much termite, worm, and ant activity; clear, smooth boundary to horizon below.
B_{21t} 26-35 inches 65-90 cm Lab. No. S29839	Strong brown (7.5YR 5/6); sandy clay; weak fine and medium subangular blocky; friable, slightly sticky, slightly plastic; many macro- and mesopores; many fine, common medium, and few coarse roots; common termite, worm, and ant activity; gradual, smooth boundary to horizon below.
B_{22t} 35-59 inches 90-150 cm Lab. No. S29840	Reddish yellow (7.5YR 6/8); sandy clay; weak fine and medium subangular blocky; friable, slightly sticky, slightly plastic; many macro- and mesopores; many fine, common medium, and few coarse roots; common termite, worm, and ant activity.
Diagnostic horizons	Umbric epipedon, 0-13 inches (0-33 cm). Argillic horizon, 26-59 inches (65-150 cm).

Profile P108, Mabassia coarse sandy loam, deep phase

Classification: Orthoxic Palehumult

Illinois Lab. No.	S29836	S29837	S29838	S29839	S29840
Depth of horizon (inches)	0-6	6-13	13-26	26-35	35-59
Horizon	A_{11}	A_{12}	B_1	B_{21t}	B_{22t}
Percent of entire sample > 2.0 mm.	0	0	0	0	0
Particle-size distribution of < 2mm (%):					
Very coarse sand 2.0-1.0 mm	10.9	8.3	7.6	9.0	12.4
Coarse sand 1.0-.5 mm.	19.7	16.4	15.7	13.7	14.0
Medium sand .5-.25 mm	20.1	16.2	16.0	12.6	11.2
Fine sand .25-.1 mm.	15.7	13.4	12.8	11.2	10.1
Very fine sand .1-.05 mm	4.4	4.3	3.8	4.5	4.0
Total sand 2.0-.05 mm	70.8	58.6	55.9	51.0	51.7
Total silt .05-.002 mm.	9.3	9.5	8.8	10.0	10.0
Total clay < .002 mm.	19.9	31.9	35.3	39.0	38.3
Water-dispersible clay < .002 mm	5.0	17.0	11.5	0.9	0.3
Bulk density	1.1	1.2	1.2	1.3	1.4
Moisture: 1/3 atmos. (%)	14.2	16.9	17.8	18.4	19.6
15 atmos. (%)	9.0	12.1	13.3	13.8	14.0
Avail. moist.-hold. capacity[a].	0.06	0.06	0.05	0.06	0.08
Organic carbon (%)	2.14	1.71	1.25	0.90	0.51
Exchangeable cations (me/100g soil):					
Ca	1.37	0.53	0.38	0.16	0.32
Mg	0.47	0.21	0	0.10	0.31
K.	0.34	0.06	0.02	0.02	0.03
Na[b].	0.34	0.10	0.04	0.04	0.05
Al	0.49	0.98	1.04	0.70	0.21
Cation-exch. capacity (me/100g).	7.71	7.92	7.85	5.71	4.07
Base saturation (%).	32.7	11.4	5.6	5.6	17.4
pH H_2O.	5.0	4.7	4.7	4.8	5.2
pH KCl.	4.2	4.2	4.1	4.1	4.6
Soil tests:					
K (lbs/A)	377	86	43	30	39
P_1 (lbs/A)	16	7	7	6	4
Total CaO (%)	0.187	0.116	0.098	0.087	0.092
Total Fe_2O_3 (%)	6.64	10.12	11.47	12.00	11.56
Total K_2O (%)	0.564	0.528	0.480	0.516	0.528

[a]Inches of available moisture-holding capacity per inch of soil.
[b]Estimated values.

Profile P2, Makeni very gravelly sandy clay loam
Described by W. van Vuure and R. Miedema on March 8, 1968

Location	Topographic map of Sierra Leone, scale 1:50,000, sheet 43, coordinates HE 27_4-86_5; on traverse A, near augerhole 4.
Physiography	Dissected erosion surface, sloping.
Relief	Slopes 14 percent to SSW and 10 percent to SE.
Vegetation	Secondary bush, 4 to 10 years old.
Drainage	Well drained.
Parent material	Gravelly to very gravelly weathering products of Pre-cambrian granite and acid gneiss.
A_1 0-10 inches 0-25 cm Lab. No. S29804	Dark brown (10YR 3/3); very gravelly sandy clay loam; structure and consistence not observable because of gravel content; common macro- and many mesopores; few fine distinct charcoal mottles; common coarse, many medium and fine roots; common ant and termite activity; 74% uncoated, fine and medium, rounded, dense, red and yellow, hardened plinthite glaebules; clear, smooth boundary to horizon below.
B_{21t} 10-20 inches 25-50 cm Lab. No. S29805	Yellowish red (5YR 4/8); very gravelly clay; very weak, very fine angular blocky; consistence is not observable because of high gravel content; common macro- and mesopores; common coarse, many medium and fine roots; low biological activity; 77% uncoated, fine and medium, rounded and nodular, dense, red and yellow, hardened plinthite glaebules; gradual, smooth boundary to horizon below.
B_{22t} 20-67 inches 50-170 cm Lab. No. S29806	Yellowish red (5YR 5/8); very gravelly clay; very weak, very fine angular blocky; firm, slightly sticky and plastic; common macro- and mesopores; few medium, common fine roots; 80% yellow-coated, medium and coarse, nodular and angular, dense, red, hardened plinthite glaebules, and a few very fine quartz gravels.
Diagnostic horizons	Umbric epipedon, 0-10 inches (0-25 cm). Argillic horizon, 10-67 inches (25-170 cm).

Profile P2, Makeni very gravelly sandy clay loam

Classification: Typic Paleudult

Illinois Lab. No.	S29804	S29805	S29806
Depth of horizon (inches)	0-10	10-20	20-67
Horizon	A_1	B_{21t}	B_{22t}
Percent of entire sample > 2.0 mm	74.1	76.7	81.1
Particle-size distribution of < 2 mm (%):			
Very coarse sand 2.0-1.0 mm.	6.8	7.8	4.7
Coarse sand 1.0-.5 mm	5.7	3.2	3.1
Medium sand .5-.25 mm.	12.1	5.1	4.5
Fine sand .25-.1 mm	20.7	9.3	7.3
Very fine sand .1-.05 mm.	7.4	5.2	4.9
Total sand 2.0-.05 mm.	52.7	30.6	24.5
Total silt .05-.002 mm	14.2	13.2	23.7
Total clay < .002 mm	33.1	56.2	51.8
Water-dispersible clay < .002 mm.	6.9	18.6	1.7
Bulk density.	1.3	1.4	1.5
Moisture: 1/3 atmos. (%)	27.5	28.4	30.4
15 atmos. (%)	15.9	21.7	23.7
Avail. moist.-hold. capacity[a]	0.04	0.02	0.02
Organic carbon (%).	4.19	1.87	1.13
Exchangeable cations (me/100g soil):			
Ca.	2.63	0.21	0.68
Mg.	2.10	0.84	0.79
K	0.25	0.04	0.03
Na.	0.10	0.09	0.06
Al.	0.27	1.05	0.16
Cation-exch. capacity (me/100g)	14.14	8.14	5.28
Base saturation (%)	35.9	14.5	29.5
pH H_2O.	5.2	4.7	5.2
pH KCl.	4.4	4.2	4.6
Soil tests:			
K (lbs/A)	194	65	30
P_1 (lbs/A).	14	3	1
Total CaO(%)	0.397	0.087	0.105
Total Fe_2O_3(%)	9.97	15.57	16.60
Total K_2O(%)	0.375	0.282	0.268

[a]Inches of available moisture-holding capacity per inch of soil, adjusted for the amount of > 2.0 mm material.

Profile P104, Makundu clay

Described by J. M. Cawray and R. Miedema on June 18, 1968

Location	Topographic map of Sierra Leone, scale 1:50,000, sheet 43, coordinates $HE12_4-91_2$; 300 feet (91 m) from Mabole River, on the road from Makundu to the river.
Physiography	Nearly level river terrace.
Relief	Concave, very gentle 1-percent slope to the south.
Vegetation	Dense secondary bush, with many wild oil palms.
Drainage	Moderately well to well drained.
Parent material	Alluvium from the Mabole River.
A_{11} 0-8 inches 0-20 cm Lab. No. S29841	Very dark gray (10YR 3/1); clay; weak fine angular and subangular blocky; friable, slightly sticky, and slightly plastic; many macro- and mesopores; few medium distinct charcoal mottles; many coarse, medium, and fine roots; much ant, termite, and worm activity; clear, smooth boundary to horizon below.
A_{12} 8-16 inches 20-41 cm Lab. No. S29842	Very dark grayish brown to dark brown (10YR 3/2.5); clay; weak fine angular and subangular blocky; friable, slightly sticky, and slightly plastic; many macro- and mesopores; few medium distinct charcoal mottles; many coarse, medium, and fine roots; much ant, termite, and worm activity; clear, smooth boundary to horizon below.
AB 16-21 inches 41-53 cm Lab. No. S29843	Dark yellowish brown (10YR 4/4); silty clay; weak fine angular and subangular blocky; friable, sticky, and plastic; many macro- and mesopores; few medium distinct charcoal mottles; many coarse, medium, and fine roots; much ant, termite, and worm activity; clear, smooth boundary to horizon below.
B_1 21-28 inches 53-71 cm Lab. No. S29844	Yellowish brown (10YR 5/6); clay; moderate fine and medium angular and subangular blocky; firm, sticky, and plastic; many macro- and mesopores; few medium distinct charcoal mottles; few fine faint yellowish-red (5YR 4/6) mottles; common coarse, many medium and fine roots; much ant, termite, and worm activity; gradual, smooth boundary to horizon below.
B_{21} 28-43 inches 71-108 cm Lab. No. S29845	Brownish yellow (10YR 6/6); clay; moderate fine and medium angular and subangular blocky; firm, sticky, and plastic; common macro- and mesopores; common medium distinct yellowish-red (5YR 4/8) mottles; few medium, common fine roots; much ant, termite, and worm activity; gradual, wavy boundary to horizon below.
B_{22} 43-74 inches 108-188 cm Lab. No. S29846	Brownish yellow (10YR 6/6); clay; moderate angular and subangular blocky; firm, sticky, and plastic; common macro- and mesopores; many medium prominent yellowish-red (5YR 5/6) mottles; common fine roots; common ant, termite, and worm activity.
Diagnostic horizons	Umbric epipedon, 0-16 inches (0-41 cm). Oxic horizon, 21-74 inches (53-188 cm).

Profile P104, Makundu clay

Classification: Plinthic "Tropeptic" Umbriorthox

Illinois Lab. No.	S29841	S29842	S29843	S29844	S29845	S29846
Depth of horizon (inches)	0-8	8-16	16-21	21-28	28-43	43-74
Horizon	A_{11}	A_{12}	AB	B_1	B_{21}	B_{22}
Percent of entire sample > 2.0 mm. . .	0	0	0	0	0	0
Particle-size distribution of < 2 mm (%):						
Very coarse sand 2.0-1.0 mm. . . .	0.8	0.4				
Coarse sand 1.0-.5 mm	1.7	1.0				
Medium sand .5-.25 mm. . . .	2.2	1.7				
Fine sand .25-.1 mm	5.4	6.6				
Very fine sand .1-.05 mm. . . .	5.9	7.9				
Total sand 2.0-.05 mm. . . .	16.0	17.6	8.1	5.4	4.7	4.3
Total silt .05-.002 mm . . .	37.1	35.6	42.1	34.8	34.0	35.3
Total clay < .002 mm . . .	46.9	46.8	49.8	59.8	61.3	60.4
Water-dispersible clay < .002 mm . .	12.7	9.0	27.9	1.3	0.5	1.0
Bulk density	0.8	0.9	1.0	1.1	1.2	1.3
Moisture: 1/3 atmos. (%).	43.0	39.7	36.4	32.4	32.5	33.3
15 atmos. (%)	29.1	28.9	27.1	25.8	25.8	25.2
Avail. moist.-hold. capacity[a]	0.11	0.10	0.09	0.07	0.08	0.11
Organic carbon (%)	5.06	3.62	2.57	1.40	0.78	0.40
Exch. cations (me/100g soil):						
Ca	3.20	0.42	0.21	0.21	0.21	0.21
Mg	1.16	0.42	0.21	0.11	0.26	0.11
K	0.53	0.19	0.08	0.05	0.05	0.07
Na[b]	0.53	0.20	0.11	0.08	0.08	0.10
Al	0.41	1.35	1.94	1.69	0.81	1.04
Cation-exch. capacity (me/100g). . .	23.62	19.69	15.77	9.70	8.85	3.79
Base saturation(%)	22.9	6.2	3.9	4.6	6.8	12.9
pH H_2O	5.3	5.0	4.7	4.9	5.2	5.4
pH KCl	4.5	4.3	4.2	4.1	4.2	4.2
Soil tests:						
K (lbs/A).	369	166	86	56	56	65
P_1 (lbs/A).	18	12	5	3	3	8
Total CaO(%)	0.290	0.130	0.110	0.097	0.087	0.082
Total Fe_2O_3(%)	10.39	10.94	11.10	11.46	11.79	10.84
Total K_2O(%)	1.324	1.288	1.435	1.382	1.172	1.192

[a]Inches of available moisture-holding capacity per inch of soil.
[b]Estimated values.

Profile P8, Mankane sandy loam

Described by W. van Vuure and J. M. Cawray on March 20, 1968

Location	Topographic map of Sierra Leone, scale 1:50,000, sheet 43, coordinates $HE27_8$-87_4; on traverse E, approximately 16 feet (5 m) from Mayankan stream bed.
Physiography	Valley bottom swamp.
Relief	Concave, very gentle 1-percent slope to southeast.
Vegetation	Grasses, rice, few raphia palms, and few wild oil palms.
Drainage	Very poorly drained.
Parent material	Gravel-free alluvium over kaolinitic residuum from quartz-rich granitic bedrock (Precambrian).
A_1 0-6 inches 0-15 cm Lab. No. S29807	Dark gray (10YR 4/1); sandy loam; weak fine and medium subangular blocky; slightly sticky and plastic; many macro- and mesopores; many fine distinct root-rust mottles; many fine and few medium roots; clear, smooth boundary to horizon below.
B_g 6-21 inches 15-54 cm Lab. No. S29808	Gray to light gray (10YR 6/1); sandy loam; weak fine and medium angular blocky; slightly sticky and plastic; many macro- and mesopores; many prominent fine and medium yellowish-red (5YR 5/8) plinthite mottles; few fine, common medium roots; gradual, smooth boundary to horizon below.
C_g 21-25 inches 54-64 cm Lab. No. S29809	Light brownish gray (10YR 6/2); loamy coarse sand; very weak fine and medium angular blocky; nonsticky, slightly plastic; many macro- and mesopores; many prominent fine and medium yellowish-red (5YR 5/8), and yellowish-red to red (2.5YR 5/8-5YR 5/8) plinthite mottles; very few fine roots.
Diagnostic horizons	Ochric epipedon, 0-6 inches (0-15 cm). Cambic horizon, 6-21 inches (15-54 cm).

Profile P8, Mankane sandy loam

Classification: Plinthic Tropaquept

Illinois Lab. No.	S29807	S29808	S29809
Depth of horizon (inches)	0-6	6-21	21-25
Horizon	A_1	B_g	C_g
Percent of entire sample > 2.0 mm.	1.0	1.5	0.8
Particle-size distribution of < 2 mm (%):			
Very coarse sand 2.0-1.0 mm	2.1	4.1	4.9
Coarse sand 1.0-.5 mm.	8.9	13.0	16.5
Medium sand .5-.25 mm	20.4	23.5	27.5
Fine sand .25-.1 mm.	28.8	24.7	24.9
Very fine sand .1-.05 mm	11.0	8.3	6.7
Total sand 2.0-.05 mm	71.2	73.6	80.5
Total silt .05-.002 mm.	16.1	13.4	9.1
Total clay < .002 mm.	12.7	13.0	10.4
Water-dispersible clay < .002 mm	4.3	12.3	10.4
Bulk density	1.0	1.3	1.4
Moisture: 1/3 atmos.(%)	16.5	12.2	9.3
15 atmos.(%)	7.2	6.2	4.7
Avail. moist.-hold. capacity[a]	0.09	0.08	0.06
Organic carbon(%)	1.79	0.55	0.43
Exchangeable cations (me/100g soil):			
Ca	0.21	0.16	0.16
Mg	0.42	0.26	0.21
K	0.03	0.02	0.01
Na	0.10	0.08	0.07
Al	0.77	0.40	0.33
Cation-exch. capacity (me/100g)	4.21	2.43	1.79
Base saturation (%)	18.1	21.4	25.1
pH H_2O	4.6	4.9	4.9
pH KCl	4.2	4.1	4.1
Soil tests:			
K (lbs/A)	65	48	43
P_1 (lbs/A)	9	3	10
Total CaO(%)	0.108	0.094	0.088
Total Fe_2O_3(%)	2.24	2.12	0.54
Total K_2O (%)	2.023	2.080	1.402

[a]Inches of available moisture-holding capacity per inch of soil.

Profile Kpuabu 1, Manowa sandy clay loam
Description after Sivarajasingham *(64)*

Location	Kpuabu Cocoa Experiment Station; about 450 feet (137 m) from the Kenema-Joru road on the road to the Station Office, and about 150 feet (46 m) on the right-hand side from the Station Office road.
Physiography	Accordant, flat-topped hill of the dissected lateritic upland.
Relief	Upper, convex 5-percent slope.
Vegetation	Cocoa plantation under many tall trees of original secondary vegetation; good grass cover.
Drainage	Moderately well drained.
Parent material	A thin layer of gravel-free material over a thick, very gravelly layer of locally transported material.
A_1 0-10 inches 0-25 cm Lab. No. S28558	Very dark grayish brown (10YR 3/2); sandy clay loam; moderate medium and fine subangular blocky; porous; friable, slightly sticky, slightly plastic; common fine, few medium, and very few coarse roots; clear, smooth boundary to horizon below.
A_3 10-21 inches 25-53 cm Lab. No. S28557	Dark brown (10YR 3/3); very gravelly sandy clay; 70% yellow-coated, nodular, coarse and medium, dense, red and yellow, hardened plinthite glaebules; weak fine subangular blocky aggregates with no strong interface; friable, sticky, slightly plastic; few fine and very few medium roots; gradual, smooth boundary to horizon below.
B_{21} 21-35 inches 53-89 cm	Dark yellowish brown to yellowish brown (10YR 4/4-5/6); very gravelly sandy clay; 60% yellow-coated and uncoated, round, fine, dense, red and black, hardened plinthite glaebules; weak fine subangular blocky aggregates with no strong interface; friable, sticky, slightly plastic; very few fine and medium roots; gradual, smooth boundary to horizon below.
B_{22t} 35-70 inches 89-178 cm Lab. No. S28556	Strong brown (7.5YR 5/8); very gravelly clay; 75% yellow-coated, nodular, coarse, dense, red and yellow, hardened plinthite glaebules; weak fine subangular blocky aggregates with no strong interface; porous; friable, sticky, slightly plastic; very few fine and medium roots.
Remarks	This soil is very gravelly and droughty and would be expected to be unsuitable for cocoa. The cocoa planted in 1959 appears as stunted trees of very poor health, with many vacant patches because of low survival rate of the planted seedlings. Management is very good, but shade appears to be excessive.
Diagnostic horizons	Umbric epipedon, 0-21 inches (0-53 cm). Argillic horizon, 21-70 inches (53-178 cm) probable, but not fully documented.

Profile Kpuabu 1, Manowa sandy clay loam

Classification: Orthoxic Palehumult (or Typic Umbriorthox)

Illinois Lab. No.	S28558	S28557	S28556
Depth of horizon (inches)	0-10	10-21	35-70
Horizon	A_1	A_3	B_{22t}
Percent of entire sample > 2.0 mm[a]	0	70	75
Particle-size distribution of < 2 mm (%):			
Very coarse sand 2.0-1.0 mm	3.3	3.4	3.3
Coarse sand 1.0-.5 mm.	9.0	7.1	9.2
Medium sand .5-.25 mm	12.1	9.8	7.7
Fine sand .25-.1 mm.	22.8	19.6	11.5
Very fine sand .1-.05 mm	10.2	9.5	7.7
Total sand 2.0-.05 mm	57.4	49.2	38.9
Total silt .05-.002 mm.	11.8	12.4	13.3
Total clay < .002 mm.	30.8	38.4	47.8
Water-dispersible clay < .002 mm.	2.9	3.9	0.6
Bulk density.	...	1.4	1.5
Moisture: 1/3 atmos. (%)	18.8	17.1	22.0
15 atmos. (%)	12.6	13.3	17.6
Avail. moist.-hold. capacity[b]	...	0.02	0.02
Organic carbon (%).	2.69	1.90	0.71
Exchangeable cations (me/100g soil):			
Ca.	0.01	0.07	0
Mg.	0.10	0.08	0.08
K	0.10	0.07	0.06
Na.	0.04	0.05	0.04
Al.	3.06	2.50	0.67
Cation-exch. capacity (me/100g)	11.79	9.29	6.00
Base saturation (%)	2.1	2.9	3.0
pH H_2O.	4.3	4.5	4.8
pH KCl.	3.8	3.9	4.2
Soil tests:			
K (lbs/A)	9	3	1
P_1(lbs/A)	5	2	0
P_2(lbs/A)	8	4	2
Total P (ppm)	390	370	...
Total CaO(%).	0.076	0.074	0.069
Total Fe_2O_3(%).	8.10	8.99	11.19
Total K_2O(%).	0.169	0.180	0.215

[a]Volume percent of total sample estimated in the field.

[b]Inches of available moisture-holding capacity per inch of soil, adjusted for the amount of > 2.0 mm material.

Profile P49, Masheka sandy loam

Described by J. M. Cawray, A. A. Thomas, and R. Miedema on April 9, 1968

Location	Topographic map of Sierra Leone, scale 1:50,000, sheet 43, coordinates $HE25_8-86_9$.
Physiography	Gently sloping, old tributary terrace.
Relief	Slope 4 percent east toward swamp.
Vegetation	Upland farm of pigeon peas, with nearby vegetation of tall elephant grass and many wild oil palms.
Drainage	Well drained.
Parent material	Gravel-free colluvium or alluvium or a mixture of both, over weathering products of Precambrian granite and acid gneiss.
A_{11} 0-16 inches 0-40 cm Lab. No. S29823	Very dark brown (10YR 2/2); sandy loam; weak fine and medium subangular blocky; slightly hard, friable, slightly sticky, and slightly plastic; few fine distinct charcoal particles; many fine, medium, and coarse roots; much termite and ant activity, few worm holes; gradual, smooth boundary to horizon below.
A_{12} 16-26 inches 40-65 cm Lab. No. S29824	Very dark grayish brown (10YR 3/2); sandy clay loam; weak medium subangular blocky; slightly hard, friable, slightly sticky, slightly plastic; many macro- and mesopores; many fine, common medium and coarse roots; much termite and ant activity, common worm holes; clear, smooth boundary to horizon below.
B_{21} 26-38 inches 65-96 cm Lab. No. S29825	Brown to dark brown (10YR 4/3); sandy clay loam; weak medium and coarse angular blocky; slightly hard, friable, slightly sticky, and slightly plastic; many macro- and mesopores; few medium prominent charcoal particles; many fine, common medium and coarse roots; much termite and ant activity, and common worm activity; gradual, smooth boundary to horizon below.
B_{22} 38-54 inches 96-137 cm	Yellowish brown (10YR 5/6); sandy clay loam; weak medium and coarse angular blocky; slightly hard, friable, slightly sticky, and plastic; common macro- and mesopores; few fine faint yellowish-red (5YR 4/8) mottles; common fine and medium, few coarse roots; common termite, ant, and worm activity; clear, smooth boundary to horizon below.
IIB_{23} 54-68 inches 137-173 cm Lab. No. S29826	Yellow (2.5Y 7/6); gravelly sandy clay loam; weak medium and coarse angular blocky; friable, slightly sticky, and plastic; common macro- and mesopores; many medium prominent yellowish-red (5YR 4/6) mottles; common fine, few medium roots; common termite, ant, and worm activity; 39% fine, uncoated, red, hardened plinthite glaebules, and a few quartz gravels.
Diagnostic horizons	Umbric epipedon, 0-26 inches (0-65 cm). Argillic horizon, 54-68 inches (137-173 cm) probable, but not fully documented.

Profile P49, Masheka sandy loam

Classification: Orthoxic Palehumult (or Udoxic Dystropept)

Illinois Lab. No.	S29823	S29824	S29825	S29826
Depth of horizon (inches)	0-16	16-26	26-38	54-68
Horizon	A_{11}	A_{12}	B_{21}	IIB_{23}
Percent of entire sample > 2.0 mm.	0	0	0	39.0
Particle-size distribution of < 2 mm (%):				
Very coarse sand 2.0-1.0 mm	5.8	4.7	7.1	9.4
Coarse sand 1.0-.5 mm.	15.8	11.9	15.4	13.4
Medium sand .5-.25 mm	29.7	25.3	23.5	19.4
Fine sand .25-.1 mm.	18.3	18.8	15.4	12.9
Very fine sand .1-.05 mm	4.3	5.3	4.6	4.3
Total sand 2.0-.05 mm	73.9	66.0	66.0	59.4
Total silt .05-.002 mm.	9.7	9.0	9.6	12.2
Total clay < .002 mm.	16.4	25.0	24.4	28.4
Water-dispersible clay < .002 mm	3.7	7.4	13.4	1.6
Bulk density	1.1	1.2	1.3	...
Moisture: 1/3 atmos. (%)	14.5	12.2	12.0	13.4
15 atmos. (%)	9.0	9.2	10.0	10.8
Avail. moist.-hold. capacity[a].	0.06	0.04	0.03	...
Organic carbon (%)	2.96	1.17	0.70	0.47
Exchangeable cations (me/100g soil):				
Ca	1.89	0.26	0.11	0.05
Mg	0.47	0.21	0.15	0.16
K	0.11	0.03	0.02	0.03
Na[b].	0.12	0.06	0.05	0.05
Al	0.33	1.28	1.04	0.75
Cation-exch. capacity (me/100g).	8.79	5.86	4.07	3.99
Base saturation (%).	29.5	9.6	8.1	7.3
pH H_2O	5.4	4.5	4.5	5.0
pH KCl	4.6	4.1	4.0	4.1
Soil tests:				
K (lbs/A).	125	56	48	52
P_1(lbs/A).	17	6	5	2
Total CaO(%)	0.305	0.095	0.094	0.078
Total Fe_2O_3(%)	3.23	3.98	3.55	4.64
Total K_2O(%)	1.092	1.076	1.041	1.157

[a]Inches of available moisture-holding capacity per inch of soil.
[b]Estimated values.

Profile P9, Masuba sandy clay loam
Described by R. Miedema and A. A. Thomas on March 20, 1968

Location	Topographic map of Sierra Leone, scale 1:50,000, sheet 43, coordinates HE27_8-87_2; on traverse E, 525 feet (160 m) from profile P8.
Physiography	Lower part of stream terrace near valley edge.
Relief	Slope 0 to 3 percent.
Vegetation	Farm with cassava, Kandi trees and weeds, and many wild oil palms.
Drainage	Moderately well drained.
Parent material	Gravel-free, transported alluvial/colluvial material.
A_p 0-7 inches 0-19 cm Lab. No. S29810	Very dark grayish brown (10YR 3/2); sandy clay loam; weak fine to medium angular blocky; very hard; common macro- and many mesopores; few distinct fine charcoal mottles; many coarse, medium, and fine roots; many large and medium ant holes; clear, smooth boundary to horizon below.
B_1 7-22 inches 19-57 cm Lab. No. S29811	Pale brown (10YR 6/3); sandy clay loam; weak fine to medium angular blocky; very hard; many macro- and mesopores; few distinct fine charcoal mottles; common fine distinct reddish-yellow to strong brown (7.5YR 5.5/8) to red (2.5YR 5/8) mottles; common coarse, many medium and fine roots; less than 10% uncoated, nodular, coarse, porous, red, hardened plinthite glaebules, with few quartz grains; many large and medium ant holes; gradual, smooth boundary to horizon below.
B_2 22-67 inches 57-170 cm Lab. No. S29812	Very pale brown (10YR 6.5/3); sandy clay loam; weak fine angular blocky; firm; many macro- and mesopores; many distinct fine and medium yellowish-red (5YR 5/8) and reddish-yellow (7.5YR 6/8) mottles; common distinct fine and medium charcoal mottles; few coarse, common medium, and many fine roots; less than 10% gravel, similar to B_1 horizon, and one quartz stone; common worm holes with dark coatings.
Diagnostic horizons	Ochric epipedon, 0-7 inches (0-19 cm). Cambic horizon, 7-67 inches (19-170 cm).

Profile P9, Masuba sandy clay loam

Classification: "Plinthic" Udoxic Dystropept

Illinois Lab. No.	S29810	S29811	S29812
Depth of horizon (inches)	0-7	7-22	22-67
Horizon	A_p	B_1	B_2
Percent of entire sample > 2.0 mm.	0.9	1.8	2.0
Particle-size distribution of < 2 mm (%): . . .			
Very coarse sand 2.0-1.0 mm	3.7	4.8	5.7
Coarse sand 1.0-.5 mm.	19.1	18.1	20.9
Medium sand .5-.25 mm	20.9	18.2	17.6
Fine sand .25-.1 mm.	14.1	12.5	10.9
Very fine sand .1-.05 mm	6.2	6.0	5.3
Total sand 2.0-.05 mm	64.0	59.6	60.4
Total silt .05-.002 mm	12.6	13.6	13.9
Total clay < .002 mm.	23.4	26.8	25.7
Water-dispersible clay < .002 mm	14.5	14.5	2.5
Bulk density	1.1	1.3	1.3
Moisture: 1/3 atmos.(%)	15.8	15.1	15.7
15 atmos.(%)	10.1	10.1	10.3
Avail. moist.-hold. capacity[a].	0.06	0.06	0.07
Organic carbon (%)	1.25	0.62	0.51
Exchangeable cations (me/100g soil):			
Ca	0.47	0.16	0.21
Mg	0.37	0.16	0.16
K	0.03	0.02	0.01
Na	0.08	0.08	0.08
Al	0.99	1.09	1.05
Cation-exch. capacity (me/100g).	5.71	3.79	3.14
Base saturation (%).	16.6	11.1	14.6
pH H_2O.	4.7	4.6	4.8
pH KCl.	4.1	4.0	4.0
Soil tests:			
K (lbs/A).	60	65	43
P_1 (lbs/A)	8	3	3
Total CaO(%).	0.133	0.078	0.078
Total Fe_2O_3(%).	2.67	3.13	3.18
Total K_2O(%).	1.361	1.277	1.200

[a]Inches of available moisture-holding capacity per inch of soil.

Profile Kpuabu 3, Moa clay
Description after Sivarajasingham (*64*)

Location	Kpuabu Cocoa Experiment Station; near the path from the nursery buildings to the wooden bridge over the stream.
Physiography	Bottomland (river terrace).
Relief	Middle of a narrow, level terrace adjoining a stream whose bed has incised about 10 feet (3 m) below the terrace surface.
Vegetation	A thick stand of cocoa planted in 1960, with dense foliage forming a close canopy under adequate shade of many tall trees of the original secondary forest.
Drainage	Moderately good. The land may be flooded two or three times a year for durations of one or two weeks. Flood water drains rapidly from the surface layers, but even during the height of the dry season the water table is encountered within 6 or 7 feet (2 m) below the surface.
Parent material	A thick layer of clayey river alluvium.
A_1 0-6 inches 0-15 cm Lab. No. S28555	Very dark grayish brown (10YR 3/2); clay; strong fine subangular blocky and fine granular; porous; friable, slightly sticky, slightly plastic; termites and earthworms present; many fine and medium roots; clear, smooth boundary to horizon below.
B_{21} 6-21 inches 15-53 cm Lab. No. S28554	Strong brown to dark brown and brown (7.5YR 5/6-4/4); clay; strong fine subangular blocky; porous; friable, sticky, slightly plastic; common fine and medium roots; gradual, smooth boundary to horizon below.
B_{22} 21-31 inches 53-79 cm	Strong brown (7.5YR 5/6-5/8) with few, fine, distinct yellowish-red (5YR 4/8) to red (2.5YR 4/8) mottles; clay; strong medium and fine subangular blocky; porous; friable, sticky, slightly plastic; common fine and medium roots; gradual, smooth boundary to horizon below.
B_3 31-59 inches 79-150 cm Lab. No. S28553	Brownish yellow (10YR 6/8) with few, medium distinct strong brown (7.5YR 5/8) and red (2.5YR 4/8) mottles; yellow (2.5Y 7/6) mottles are more numerous with increasing depth; clay; strong medium subangular blocky; porous; friable, sticky, slightly plastic; few fine and medium roots; gradual, smooth boundary to horizon below.
C_{1g} 59-71 inches 150-180 cm	Mottled white (N 8/), yellow (2.5Y 7/6), yellowish brown (10YR 5/8), and strong brown (7.5YR 5/6) in a variegated pattern; sandy clay; wet; massive clods; the strong brown mottles are firm to hard and may be considered as incipient plinthite glaebules.
Diagnostic horizons	Ochric epipedon, 0-6 inches (0-15 cm). Oxic horizon, 21-59 inches (53-150 cm) probable, but not fully documented.

Profile Kpuabu 3, Moa clay

Classification: Tropeptic Haplorthox (or Fluventic Udoxic Dystropept)

Illinois Lab. No.	S28555	S28554	S28553
Depth of horizon (inches)	0-6	6-21	31-59
Horizon	A_1	B_{21}	B_3
Percent of entire sample > 2.0 mm.	0	2.3	5.3
Particle-size distribution of < 2 mm (%):			
Very coarse sand 2.0-1.0 mm	2.3	1.7	2.6
Coarse sand 1.0-.5 mm.	5.1	5.0	5.3
Medium sand .5-.25 mm	7.0	5.1	5.3
Fine sand .25-.1 mm.	14.8	11.7	11.4
Very fine sand .1-.05 mm	7.9	7.7	6.8
Total sand 2.0-.05 mm	37.2	31.1	31.3
Total silt .05-.002 mm	22.2	20.7	19.8
Total clay < .002 mm.	40.6	48.2	48.9
Water-dispersible clay < .002 mm	14.4	9.4	0.3
Bulk density	0.7	0.8	1.3
Moisture: 1/3 atmos.(%)	27.8	26.6	27.6
15 atmos.(%)	18.4	19.3	20.4
Avail. moist.-hold. capacity[a].	0.07	0.06	0.09
Organic carbon (%)	2.98	0.91	0.41
Exchangeable cations (me/100g soil):			
Ca	0.61	0.06	0.06
Mg	0.23	0.08	0.21
K	0.14	0.09	0.07
Na	0.05	0.08	0.05
Al	2.78	1.78	1.17
Cation-exch. capacity (me/100g).	13.79	7.94	6.50
Base saturation (%).	7.5	3.9	6.0
pH H_2O.	4.5	4.6	5.1
pH KCl.	3.8	3.8	4.0
Soil tests:			
K (lbs/A).	39	8	10
P_1 (lbs/A)	5	1	1
P_2 (lbs/A)	7	2	7
Total P (ppm).	440	320	...
Total CaO(%).	0.146	0.097	0.078
Total Fe_2O_3(%).	7.38	8.35	8.98
Total K_2O(%).	0.570	0.557	0.519

[a]Inches of available moisture-holding capacity per inch of soil.

Profile N14, Mokoli silty clay
Described by J. C. Dijkerman on April 1, 1966

Location	On the proposed new experimental farm northwest of the Njala University College Campus, pit N14 is located 422 feet (129 m) east of the Taia River and 53 feet (16 m) south of the path from Nyawama to Rover. On aerial photograph 39-SL25-083, pit N14 is 12.4 cm west and 7.4 cm south of northeast corner mark.
Physiography	Drainageway in lower terrace of Taia River.
Relief	Very gentle concave, in middle of drainageway.
Vegetation	Water-loving bushes and low grasses.
Drainage	Poorly drained; waterlogged for three months.
Parent material	Clayey alluvium.
A_1 0-6 inches 0-15 cm Lab. No. S29123	Very dark grayish brown (10YR 3/2); silty clay; moderate fine and medium subangular blocky, breaking into moderate medium granular; friable; common fine and medium pores; common fine and medium roots; clear, smooth boundary to horizon below.
A_3 6-15 inches 15-38 cm Lab. No. S29124	Yellowish brown to dark brown (10YR 5/4-4/3) with common fine faint soft reddish-brown (5YR 4/4) mottles; clay; strong medium to very fine subangular blocky; friable; common fine and medium pores; common fine and medium roots; gradual, smooth boundary to horizon below.
B_{21} 15-27 inches 38-68 cm Lab. No. S29125	Yellowish brown (10YR 5/4) with common medium distinct yellowish-red (5YR 5/6) mottles; clay, with much mica; strong medium to fine blocky; friable; common fine and medium pores; few fine and medium roots; diffuse, smooth boundary to horizon below.
B_{22} 27-60 inches 68-153 cm Lab. No. S29126	Light yellowish brown (10YR 6/4) with many medium distinct yellowish-red and reddish-brown (5YR 5/6 and 2.5YR 4/4) mottles; clay, with much mica; strong medium to fine blocky; friable; common fine and medium pores; few fine and medium roots.
Diagnostic horizons	Ochric epipedon, 0-15 inches (0-38 cm). Cambic horizon, 15-60 inches (38-153 cm).

Profile N14, Mokoli silty clay

Classification: Fluventic Udoxic Dystropept

Illinois Lab. No.	S29123	S29124	S29125	S29126
Depth of horizon (inches)	0-6	6-15	15-27	27-60
Horizon	A_1	A_3	B_{21}	B_{22}
Percent of entire sample > 2.0 mm.	0	0	0	0
Particle-size distribution of < 2 mm (%):				
Total sand 2.0-.05 mm.	2.8	1.7	1.9	5.3
Coarse silt .05-.02 mm.	2.4	5.6	4.0	8.0
Fine silt .02-.002 mm	37.6	26.1	31.4	30.3
Total silt .05-.002 mm	40.0	31.7	35.4	38.3
Total clay < .002 mm	57.2	66.6	62.7	56.4
Water-dispersible clay < .002 mm	32.2	50.4	2.2	1.0
Bulk density	1.3	1.3	1.3	1.4
Moisture: 1/3 atmos.(%)	44.4	34.5	35.2	34.7
15 atmos.(%)	28.2	27.2	27.6	25.9
Avail. moist.-hold. capacity[a]	0.21	0.09	0.10	0.12
Organic carbon (%)	5.54	1.50	0.65	0.55
Exchangeable cations (me/100g soil):				
Ca	0.31	0.10	0.08	0.13
Mg	0.33	0.08	0.25	0.46
K	0.12	0.01	0.01	0.02
Na	0.10	0.04	0.04	0.05
Al	2.89	2.61	2.05	1.61
Cation-exch. capacity (me/100g)	22.58	11.57	9.07	8.43
Base saturation (%)	3.8	2.0	4.2	7.8
pH H_2O	4.5	4.6	4.8	5.0
pH KCl	3.7	3.6	3.7	3.7
Soil tests:				
K (lbs/A)	116	48	35	56
P_1 (lbs/A)	35	5	8	9
P_2 (lbs/A)	45	7	15	17
Total P (ppm)	820	...	...	...
Total CaO(%)	0.152	0.117	0.113	0.141
Total Fe_2O_3(%)	4.57	5.98	7.52	7.73
Total K_2O(%)	1.14	1.13	1.18	1.23

[a]Inches of available moisture-holding capacity per inch of soil.

Profile N42, Mokonde fine sandy loam

Described by J. C. Dijkerman on March 23, 1966

Location	On proposed new experimental farm northwest of Njala University College Campus; a few feet east of path from Bonjema to Belebu, 2,550 feet (777 m) north of junction of this path with path toward Gbesebu.
Physiography	Colluvial footslope or upper river terrace.
Relief	Upper part of a straight 2- to 3-percent slope.
Vegetation	Secondary farm bush.
Drainage	Moderately well drained.
Parent material	Gravel-free colluvium, over gravelly colluvium, over residual material.
A_1 0-5 inches 0-13 cm Lab. No. S28648	Very dark gray (10YR 3/1); fine sandy loam; weak fine and medium subangular blocky, breaking to weak medium to fine granular; friable; common medium and fine, and few coarse roots; many pores of all sizes; gradual, smooth boundary to horizon below.
A_3 5-15 inches 13-38 cm Lab. No. S29732	Dark grayish brown (10YR 4/2) to dark brown (10YR 4/3); fine sandy loam with a few clean quartz grains; weak fine and medium subangular blocky, breaking to weak fine and medium granular; friable; common fine and medium, and few coarse roots; common fine and medium pores; clear, smooth boundary to horizon below.
IIB_{21} 15-30 inches 38-76 cm Lab. No. S28649	Yellowish brown (10YR 5/4); very gravelly (60% by volume) sandy clay loam; gravels are mainly irregular to round, 1/4" to 1/2" in diameter, dense, reddish-black to dusky red (10R 2/1-3/2) hardened plinthite glaebules; common quartz pebbles; massive to fine and very fine weak granular; firm in place but friable to crush; common medium and fine roots; common medium and fine pores; clear, smooth boundary to horizon below.
$IIIB_{22}$ 30-39 inches 76-99 cm Lab. No. S29734	Yellowish brown (10YR 5/4-5/6) with many prominent medium and coarse red (10R 4/4-2.5YR 4/6) and yellowish-red (5YR 4/6) mottles, most of which are hard to crush (gravel); gravelly (40%) sandy clay loam; gravels are irregular, 1/4" to 3/4" in diameter, nondense, hardened plinthite glaebules with colors described under mottles; massive to very weak medium and fine angular blocky; firm and hard in place; friable to crush except for hardened mottles; common medium and fine roots; common pores of all sizes; gradual, smooth boundary to horizon below.
$IIIB_{23}$ 39-60 inches 99-153 cm Lab. No. S28650	Light yellowish brown (2.5Y 6/4) to brownish yellow (10YR 6/6) with many prominent medium and coarse red (10R 4/4-2.5YR 4/6) and yellowish-red (5YR 4/6) mottles, most of which are hard to crush (gravel); gravelly (40%) sandy clay loam; gravels as in $IIIB_{22}$ horizon; massive; very firm and very hard; common medium and fine roots; common pores of all sizes; gradual, smooth boundary to horizon below.
$IIIB_{24}$ 60-67 inches 153-170 cm Lab. No. S29736	Light brownish gray (2.5Y 6/2-6/3) with many prominent medium and coarse red (10R 4/4-2.5YR 4/6) and yellowish-red (5YR 4/6) mottles, most of which are hard to crush (gravel); gravelly (30%) clay loam; gravels as in $IIIB_{22}$ horizon; massive to weak medium and fine angular blocky; firm and hard; few medium and fine roots; common pores of all sizes.
Diagnostic horizons	Ochric epipedon, 0-15 inches (0-38 cm). Argillic horizon, 15-67 inches (38-170 cm) probable, but not fully documented.

Profile N42, Mokonde fine sandy loam

Classification: Plinthic Paleudult (or "Plinthic" Udoxic Dystropept)

Illinois Lab. No.	S28648	S29732	S28649	S29734	S28650	S29736
Depth of horizon (inches)	0-5	5-15	15-30	30-39	39-60	60-67
Horizon	A_1	A_3	IIB_{21}	$IIIB_{22}$	$IIIB_{23}$	$IIIB_{24}$
Percent of entire sample > 2.0 mm. . . .	1	5	55	55	53	40
Particle-size distribution of < 2 mm (%):						
Very coarse sand 2.0-1.0 mm.	5.4	1.0	15.7	1.6	19.7	1.3
Coarse sand 1.0-.5 mm	8.6	10.6	9.1	13.7	8.1	13.9
Medium sand .5-.25 mm.	10.5	10.8	7.0	8.5	4.7	7.9
Fine sand .25-.1 mm	25.0	21.7	15.4	13.0	8.3	10.7
Very fine sand .1-.05 mm.	15.9	14.8	11.2	10.1	7.1	8.8
Total sand 2.0-.05 mm	65.4	58.9	58.4	46.9	47.9	42.6
Total silt .05-.002 mm	22.7	21.9	17.8	18.9	19.8	22.3
Total clay < .002 mm	11.9	19.2	23.8	34.2	32.3	35.1
Water-dispersible clay < .002 mm	9.2	12.5	23.6	27.8	10.1	1.7
Bulk density	1.4	1.4	1.5	1.7	1.8	1.8
Moisture: 1/3 atmos. (%).	15.4	15.3	14.8	21.3	17.0	22.5
15 atmos. (%).	7.1	7.5	10.0	13.2	12.4	14.5
Avail. moist.-hold. capacity[a]	0.12	0.10	0.03	0.06	0.04	0.08
Organic carbon (%)	1.70	0.83	0.49	0.48	0.28	0.21
Exchangeable cations (me/100g soil):						
Ca	0.46	0.08	0.03	0.20	0.04	0.13
Mg	0.27	0.10	0.07	0.03	0.13	0.13
K.	0.10	0.04	0.06	0.05	0.06	0.04
Na	0.04	0.06	0.03	0.08	0.03	0.04
Al	2.00	0.95	1.89	1.77	2.50	4.22
Cation-exch. capacity (me/100g).	7.29	4.79	4.36	6.57	6.14	10.07
Base saturation (%).	11.9	5.8	4.4	5.5	4.2	3.4
pH H_2O	4.5	4.4	4.7	4.6	4.9	4.9
pH KCl	3.6	3.7	3.7	3.6	3.5	3.4
Soil tests:						
K (lbs/A).	102	65	65	65	69	55
P_1 (lbs/A).	12	6	3	1	1	1
P_2 (lbs/A).	12	6	3	1	1	1
Total P (ppm).	144	78	100	148	142	182
Total CaO(%)	0.109	...	0.069	...	0.067	...
Total Fe_2O_3(%)	1.60	...	3.81	...	7.13	...
Total K_2O(%)	0.375	...	0.662	...	0.933	...

[a]Inches of available moisture-holding capacity per inch of soil, adjusted for the amount of > 2.0 mm material.

Profile N123, Momenga gravelly clay
Described by H. Breteler on January 18, 1967

Location	Extreme southwestern corner of the Oil Palm Station of Njala University College. From the junction of the Kania boundary road and the path along the river near surveyor stone No. PB-B 829, 111 feet (34 m) down the steep slope towards the Taia River. Pit N123 is on the lower part of the steep slope.
Physiography	Escarpment of higher erosion surface towards the river.
Relief	Lower part of very steep (54-percent) slope.
Vegetation	Old secondary bush.
Drainage	Well drained.
Parent material	Colluvial material high in hardened plinthite glaebules, over residual material from weathering siltstone.
A_1 0-3 inches 0-8 cm Lab. No. S29058	Dark yellowish brown (10YR 4/4); gravelly (50% by volume) clay; gravels are mainly round, 1/4" to 1/2" in diameter, hardened plinthite glaebules with outside colors of dark brown (7.5YR 2/3) and inside colors of dark red to red (10R 3/6-4/8); very weak fine and medium angular to subangular blocky, breaking to weak very fine granular; friable; many fine, medium, and coarse roots; gradual, smooth boundary to horizon below.
A_3 3-9 inches 8-23 cm Lab. No. S29060	Strong brown (7.5YR 5/6); gravelly (50%) clay; gravels are mainly round and nodular hardened plinthite glaebules similar to those in the A_1 horizon; weak very fine and fine angular to subangular blocky, breaking into weak to moderate very fine and fine granular; friable; common fine, medium, and coarse roots; many fine, medium, and coarse pores; gradual, smooth boundary to horizon below.
B_2 9-33 inches 23-84 cm Lab. No. S29062	Yellowish red (5YR 5/6) with common fine, medium, and coarse, slightly hard, distinct dark red to red (10R 3/6-4/8) mottles, and few fine, medium, and coarse, distinct white (N 8/) rock mottles (saprolite); gravelly (25%) clay; gravels are mainly angular, round and nodular, hardened plinthite glaebules, 1/3" to 3" in diameter, with outside colors of dark red to black and inside colors of dark red to red (10R 3/6-4/8); some quartz gravels; weak to moderate fine, medium, and coarse angular to subangular blocky, breaking into weak to moderate very fine and fine granular; friable; common fine, medium, and coarse roots; many fine, medium, and coarse pores; gradual, smooth boundary to horizon below.
IIB_3 33-40 inches 84-102 cm Lab. No. S29064	Reddish yellow (7.5YR 6/7) with many fine, medium, and coarse, slightly hard and soft, distinct dark red (10R 3/6) mottles, and common fine, medium, and coarse, distinct white (N 8/) rock mottles (saprolite); gravelly clay with a few hardened plinthite glaebules similar to those in the B_2 horizon; weak to moderate fine and medium angular blocky, breaking into weak to moderate very fine and fine granular; friable; common fine, medium, and coarse pores; few fine and medium roots; gradual, smooth boundary to horizon below.
IIC 40-62 inches 102-157 cm Lab. No. S29065	White (N 8/) with few fine, medium, and coarse, distinct dark red to red (10R 3/6-4/8) mottles, and many fine, medium, and coarse yellow (10YR 8/6-7/6) mottles; silty clay; very weak fine angular blocky, breaking into weak to moderate very fine and fine granular; firm; common fine and medium pores; few fine roots. This horizon is a transition zone to the unweathered bedrock (soft siltstone); more than 50% of this horizon consists of soft white (N 8/) weathering bedrock (saprolite).
Diagnostic horizons	Ochric epipedon, 0-9 inches (0-23 cm). Cambic horizon, 9-40 inches (23-102 cm).

Profile N123, Momenga gravelly clay

Classification: "Plinthic" Dystropept

Illinois Lab. No.	S29058	S29060	S29062	S29064	S29065
Depth of horizon (inches)	0-3	3-9	9-33	33-40	40-62
Horizon	A_1	A_3	B_2	IIB_3	IIC
Percent of entire sample > 2.0 mm. . . .	34.6	37.2	30.8	34.6	0
Particle-size distribution of < 2 mm (%):					
Very coarse sand 2.0-1.0 mm	5.9	4.5	4.3	2.5	0.1
Coarse sand 1.0-.5 mm.	4.4	3.2	3.1	2.0	0.1
Medium sand .5-.25 mm	4.2	3.0	2.6	1.7	0.2
Fine sand .25-.1 mm.	6.9	5.2	4.2	2.5	0.3
Very fine sand .1-.05 mm	4.8	4.7	4.2	3.0	1.6
Total sand 2.0-.05 mm	26.2	20.6	18.4	11.7	2.3
Coarse silt .05-.02 mm	3.4	3.6	3.0	2.6	3.8
Fine silt .02-.002 mm.	25.8	22.0	24.2	33.5	52.6
Total silt .05-.002 mm.	29.2	25.6	27.2	36.1	56.4
Total clay < .002 mm.	44.6	53.8	54.4	52.2	40.6
Water-dispersible clay < .002 mm. . . .	25.6	38.6	38.0	39.5	28.6
Bulk density	1.4	1.6	1.5	1.5	1.5
Moisture: 1/3 atmos. (%).	33.5	29.8	30.2	33.6	37.7
15 atmos. (%).	21.2	21.0	21.1	20.5	10.5
Avail. moist.-hold. capacity[a].	0.11	0.09	0.10	0.13	0.41
Organic carbon (%)	3.94	1.32	0.54	0.31	0.06
Exchangeable cations (me/100g soil):					
Ca	0.84	0.20	0.10	0.05	0.05
Mg	0.77	0.47	0.16	...	0.80
K.	0.24	0.07	0.06	0.05	0.04
Na	0.08	0.06	0.04	0.04	0.04
Al	6.11	6.44	8.44	12.78	9.11
Cation-exch. capacity (me/100g).	21.08	15.29	15.65	20.36	13.00
Base saturation (%).	9.2	5.2	2.3	...	7.2
pH H_2O	4.1	4.2	4.4	4.6	4.2
pH KCl	3.2	3.4	3.3	3.1	3.0
Soil tests:					
K (lbs/A)	182	110	65	48	35
P_1 (lbs/A)	29	6	2	3	2
P_2 (lbs/A)	32	7	2	3	2
Total P (ppm).	440	...	...	...	...
Total CaO(%)	0.168	0.077	0.070	0.067	0.062
Total Fe_2O_3(%)	5.26	5.43	5.46	5.02	2.47
Total K_2O(%)	1.76	1.82	2.10	2.56	3.32

[a]Inches of available moisture-holding capacity per inch of soil, adjusted for the amount of > 2.0 mm material.

Profile N86, Momenga gravelly sandy clay loam
Described by D.H. Westerveld on January 23, 1967

Location	On proposed new experimental farm northwest of Njala University College Campus. Pit N86 is along the north boundary traverse of the farm, about 1,000 feet (305 m) east of the Taia River.
Physiography	On escarpment from second terrace toward upland.
Relief	Straight, steep 15-percent slope.
Vegetation	Secondary bush.
Drainage	Well drained.
Parent material	Colluvium high in hardened plinthite glaebules and quartz gravel, over residuum weathered from bedrock.
A_1 0-6 inches 0-15 cm Lab. No. S29135	Very dark grayish brown (10YR 3/2); gravelly sandy clay loam; one-third of the gravel is rounded quartz, and two-thirds is round and nodular, 1/4" to 3" in diameter, hardened plinthite glaebules, reddish black (10R 2/1) outside and dusky red (10R 3/2-3/4) inside; moderate to weak fine, medium, and coarse granular; friable; many fine, medium, and coarse pores; many fine, medium, and coarse roots; gradual, smooth boundary to horizon below.
A_3 6-16 inches 15-41 cm Lab. No. S29137	Yellowish brown to strong brown (10YR-7.5YR 5/6); gravelly sandy clay loam; gravel is similar to that in the A_1 horizon except that half is hardened plinthite glaebules and half is rounded quartz; weak fine, medium, and coarse granular; friable; many fine, medium, and coarse pores; many fine, medium, and coarse roots; gradual, smooth boundary to horizon below.
B_1 16-24 inches 41-61 cm Lab. No. S29139	Strong brown (7.5YR 5/8); gravelly clay, with gravel similar to that in the A_3 horizon; weak fine, medium, and coarse granular; friable; many fine, medium, and coarse pores; common fine and medium roots; clear, wavy boundary to horizon below.
IIB_{21} 24-38 inches 61-96 cm Lab. No. S29141	Reddish yellow (7.5YR 6/8) with few fine and medium brownish-yellow (10YR 6/8) and red (2.5YR 4/8) mottles; gravelly clay; half of the gravel is angular quartz (part of a residual vein), and half is round and nodular, 1/4" to 1" in diameter, hardened plinthite glaebules, red (10R 4/6-4/8) outside and inside; weak to moderate fine and medium angular to subangular blocky, breaking into weak to moderate fine, medium, and coarse granular; friable; many fine, medium, and coarse pores; few fine roots; gradual, smooth boundary to horizon below.
IIB_{22} 38-50 inches 96-127 cm Lab. No. S29143	Reddish yellow (7.5YR 6/8) with many fine and medium distinct red (2.5YR 4/8) mottles, and few fine and medium faint yellow (10YR 7/6) mottles; gravelly clay, with gravel similar to that in the IIB_{21} horizon; weak to moderate fine and medium angular to subangular blocky, breaking into weak to moderate fine, medium, and coarse granular; friable; many fine, medium, and coarse pores; few fine roots; gradual, smooth boundary to horizon below.
IIB_3 50-63 inches 127-160 cm Lab. No. S29145	Yellow (10YR 7/6) with many fine and medium distinct red (2.5YR 4/8) and common fine and medium faint dark yellowish-brown (10YR 4/8) mottles, and few fine and medium faint saprolitic white (N 8/) mottles; gravelly clay, with gravel similar to that in the IIB_{21} horizon; weak fine and medium angular to subangular blocky, breaking into weak fine, medium, and coarse granular; friable; many fine, medium, and coarse pores; few fine roots.
Diagnostic horizons	Ochric epipedon, 0-16 inches (0-41 cm). Cambic horizon, 16-63 inches (41-160 cm).

Profile N86, Momenga gravelly sandy clay loam

Classification: "Plinthic" Dystropept

Illinois Lab. No.		S29135	S29137	S29139	S29141	S29143	S29145
Depth of horizon (inches)		0-6	6-16	16-24	24-38	38-50	50-63
Horizon		A_1	A_3	B_1	IIB_{21}	IIB_{22}	IIB_3
Percent of entire sample > 2.0 mm. . . .		42.0	37.1	42.9	30.5	34.9	37.9
Particle-size distribution of < 2 mm (%):							
Very coarse sand	2.0-1.0 mm	18.1	26.7	14.5	9.3	7.6	5.1
Coarse sand	1.0-.5 mm.	6.6	9.1	7.9	5.9	5.1	4.2
Medium sand	.5-.25 mm	4.3	3.7	4.1	3.6	3.1	2.8
Fine sand	.25-.1 mm.	10.6	6.8	6.4	5.7	4.9	4.6
Very fine sand	.1-.05 mm	7.5	5.0	4.9	4.8	5.0	4.8
Total sand	2.0-.05 mm	47.1	51.3	37.8	29.3	25.7	21.5
Total silt	.05-.002 mm.	27.7	18.3	21.1	25.3	27.7	30.7
Total clay	< .002 mm.	25.2	30.4	41.1	45.4	46.6	47.8
Water-dispersible clay < .002 mm		18.9	26.3	31.3	15.8	19.8	21.2
Moisture: 1/3 atmos. (%).		22.1	19.2	23.9	27.8	30.8	33.7
15 atmos. (%).		12.9	12.4	16.5	18.3	19.7	20.8
Organic carbon (%)		2.26	1.04	0.60	0.36	0.34	0.25
Exchangeable cations (me/100g soil):							
Ca		1.08	0.23	0.28	0.18	0.13	0.18
Mg		0.48	0.21	0.23	0.23	0.33	0.26
K		0.11	0.04	0.04	0.04	0.04	0.04
Na		0.05	0.04	0.04	0.04	0.05	0.04
Al		3.00	3.67	4.22	6.67	8.67	11.10
Cation-exch. capacity (me/100g).		12.15	8.72	10.15	12.50	15.22	17.08
Base saturation (%).		14.2	6.0	5.8	3.9	3.6	3.0
pH H_2O.		4.3	4.3	4.4	4.5	4.6	4.7
pH KCl.		3.4	3.3	3.3	3.3	3.3	3.2
Soil tests:							
K (lbs/A).		174	99	102	74	74	78
P_1 (lbs/A)		8	3	2	1	1	1
P_2 (lbs/A)		8	4	3	1	1	1
Total P (ppm).		180	...	...	...	...	...
Total CaO(%).		0.152	0.078	0.080	0.071	0.067	0.068
Total Fe_2O_3(%).		3.80	4.42	5.82	6.18	6.96	6.68
Total K_2O(%).		1.48	1.56	1.93	2.15	2.26	2.49

Profile N44, Momenga gravelly fine sandy loam
Described by J. C. Dijkerman on March 23, 1966

Location	On proposed new experimental farm northwest of Njala University College Campus. Pit N44 is a few feet west of path from Bonjema to Belebu, about 3,700 feet (1,128 m) north of junction of this path with the path toward Gbesebu.
Physiography	Dissected upland erosion surface.
Relief	Convex 5-percent slope, near the crest of a distinct ridge.
Vegetation	Secondary farm bush.
Drainage	Well drained.
Parent material	Colluvial material high in hardened plinthite glaebules, over residual material weathered from bedrock.
A_1 0-7 inches 0-18 cm Lab. No. S28645	Very dark grayish brown (10YR 3/2); gravelly fine sandy loam; gravel is mainly irregular to round, 1/4" to 1/2" in diameter, dense, reddish-black to dusky red (10R 2/1-3/2) hardened plinthite glaebules, plus some quartz gravel; weak fine and very fine granular; friable; common medium and fine roots; common pores of all sizes; gradual, smooth boundary to horizon below.
A_3 7-15 inches 18-38 cm Lab. No. S29728	Dark yellowish brown (10YR 4/4); very gravelly clay loam, with gravel similar to that in the A_1 horizon; weak fine and very fine granular; friable; common medium and fine roots; common pores of all sizes; clear, irregular lower boundary with tongues, 1 to 2 inches wide, going down to the middle of the horizon below.
B_{21} 15-33 inches 38-84 cm Lab. No. S28646	Yellowish red (5YR 5/6-4/6); very gravelly clay; gravel is mainly round to irregular, 1/4" to 3/4" in diameter, nondense, red (10R 4/4-4/6) hardened plinthite glaebules, plus some quartz gravel; weak medium to very fine subangular blocky; firm in place but friable to crush; common medium and fine roots; common pores of all sizes; clear, smooth boundary to horizon below.
IIB_{22} 33-42 inches 84-107 cm Lab. No. S29729	Yellowish red (5YR 4/6-5/6) with common, medium and coarse, slightly hard to hard, distinct red (10R-2.5YR 4/6) mottles, and few medium and fine, soft, distinct brownish-yellow (10YR 6/6) mottles; gravelly clay, with gravel that is nondense, irregular, hardened plinthite mottles; moderate fine and very fine angular blocky; firm in place but friable to crush; common medium and fine roots; common pores of all sizes; gradual, smooth boundary to horizon below.
IIB_{23} 42-57 inches 107-145 cm Lab. No. S28647	Mixed yellowish red (5YR 5/6) and reddish yellow (7.5YR 6/6) with many, medium and coarse, distinct red (2.5YR 4/6) mostly hard mottles, and common, medium and fine, distinct brownish-yellow (10YR 6/6) soft mottles; gravelly clay, with gravel similar to that in the IIB_{22} horizon; moderate medium to very fine angular blocky; slightly firm in place, friable to crush; common medium and fine roots; common pores of all sizes; gradual, smooth boundary to horizon below.
IIB_{24} 57-69 inches 145-175 cm Lab. No. S29730	Reddish yellow (7.5YR 7/6) to yellow (10YR 7/6), with many coarse prominent red (2.5YR 4/6) mostly hard mottles, and common, medium and fine, pale yellow (2.5Y 8/4) soft mottles; clay, with gravel similar to that in the IIB_{22} horizon; strong medium to very fine angular blocky; slightly firm in place, friable to crush; few fine roots; common pores of all sizes. Augering to a depth of 120 inches (305 cm) revealed a gradual decrease in the matrix chroma to light gray (10YR 7/1) with small pieces of weathered siltstone (the local bedrock) below 100 inches (254 cm).
Diagnostic horizons	Ochric epipedon, 0-15 inches (0-38 cm). Cambic horizon, 15-69 inches (38-175 cm).

Profile N44, Momenga gravelly fine sandy loam

Classification: "Plinthic" Dystropept

Illinois Lab. No.	S28645	S29728	S28646	S29729	S28647	S29730
Depth of horizon (inches)	0-7	7-15	15-33	33-42	42-57	57-69
Horizon	A_1	A_3	B_{21}	IIB_{22}	IIB_{23}	IIB_{24}
Percent of entire sample > 2.0 mm . .	51	75	63	40	35	16
Particle-size distribution of < 2 mm (%):						
Very coarse sand 2.0-1.0 mm. . . .	8.1	1.0	13.4	0.5	6.3	0.6
Coarse sand 1.0-.5 mm	6.9	7.8	4.1	7.0	3.1	7.2
Medium sand .5-.25 mm. . . .	7.5	5.2	2.2	4.3	1.8	4.7
Fine sand .25-.1 mm	21.4	15.1	4.0	6.2	3.7	6.3
Very fine sand .1-.05 mm. . . .	15.6	14.3	4.4	6.5	4.9	7.2
Total sand 2.0-.05 mm. . . .	59.5	43.4	28.1	24.5	19.8	26.0
Total silt .05-.002 mm . . .	21.3	22.9	20.1	21.9	27.1	27.7
Total clay < .002 mm . . .	19.2	33.7	51.8	53.6	53.1	46.6
Water-dispersible clay < .002 mm . .	3.1	13.9	38.8	25.2	8.6	3.0
Moisture: 1/3 atmos. (%)	...	...	...	32.2	31.2	33.3
15 atmos. (%)	...	...	...	24.0	23.0	21.2
Organic carbon (%).	3.35	1.45	0.68	0.52	0.35	0.23
Exchangeable cations (me/100g soil):						
Ca.	3.77	0.36	0.03	0.15	0.06	0.18
Mg.	1.15	0.29	0.31	0.13	0.22	0.10
K	0.18	0.09	0.11	0.08	0.11	0.10
Na.	0.07	0.09	0.03	0.08	0.03	0.14
Al.	0.77	3.89	8.44	7.78	12.78	12.67
Cation-exch. capacity (me/100g) . . .	13.50	9.30	12.50	17.30	17.58	...
Base saturation (%)	38.3	8.9	3.8	2.5	2.4	...
pH H_2O.	5.0	4.7	4.7	5.0	4.9	5.2
pH KCl.	4.0	...	3.3	3.4	3.3	3.4
Soil tests:						
K (lbs/A).	174	126	106	106	102	86
P_1 (lbs/A).	15	4	0	1	0	1
P_2 (lbs/A).	16	6	2	1	1	1
Total P (ppm)	202	138	138	135	127	127
Total CaO(%)	0.327	...	0.067	...	0.064	...
Total Fe_2O_3(%)	4.09	...	8.73	...	11.00	...
Total K_2O(%)	0.773	...	1.860	...	2.160	...

Profile N109, Njala gravelly clay loam
Described by H. Breteler on December 29, 1966

Location	Southwestern corner of the Oil Palm Station of Njala University College. From the junction of the Kania boundary road and the village path to Pujehun, 84 feet (26 m) along the boundary line uphill towards the Taia River. Pit N109 is located between palms 1155 and 993.
Physiography	Dissected erosion surface; on the slope between the highest erosion surface and the upper river terrace.
Relief	Lower part of convex 8-percent slope, on mapping unit 3, Njala, sloping.
Vegetation	Oil palm plantation.
Drainage	Well drained.
Parent material	Colluvial material high in hardened plinthite glaebules.
A_1 0-14 inches 0-35 cm Lab. No. S29072	Dark brown (10YR 3/3); very gravelly (70% by volume) clay loam; gravels are mainly round and nodular, 1/4" to 1/2" in diameter, hardened plinthite glaebules with outside colors of yellowish red (5YR 4/6) and inside colors of yellowish red and very dusky red (5YR 4/6, 4/8, 5/8, and 10R 2/2); weak to moderate very fine and fine subangular blocky, breaking into very weak, very fine granular; very friable; many fine, medium, and coarse pores; many fine, medium, and coarse roots; gradual, smooth boundary to horizon below. This A_1 horizon is thick enough and just dark enough to qualify as an umbric epipedon (see Section 4). Most profiles of Njala soils have thinner or lighter colored A_1 horizons, which are ochric rather than umbric.
A_3 14-21 inches 35-53 cm Lab. No. S29074	Dark yellowish brown (10YR 4/4); very gravelly (80%) clay; gravels are mainly round and nodular, 1/4" to 3" in diameter, hardened plinthite glaebules with outside colors of yellowish red and very dusky red (5YR 5/8 and 10R 2/2) and inside colors of dark red, red, and reddish yellow (10R 3/6, 4/8, and 7.5YR 6/8); weak very fine, fine, and medium subangular blocky, breaking into weak to moderate very fine, fine, and medium granular; very friable; many fine, medium, and coarse pores; many fine, medium, and coarse roots; gradual, smooth boundary to horizon below.
B_{21t} 21-49 inches 53-125 cm Lab. No. S29076	Strong brown (7.5YR 5/8); very gravelly (70%) clay; gravels are mainly round and nodular, 1/4" to 3" in diameter, hardened plinthite glaebules with outside colors of red (2.5YR 4/8-5/8) and inside colors of red and very dusky red (10R 4/6 and 2/2); very weak fine, medium, and coarse angular to subangular blocky, breaking into weak to moderate very fine and fine granular; friable; many fine, medium, and coarse pores; common fine, medium, and coarse roots; gradual, smooth boundary to horizon below.
B_{22t} 49-62 inches 125-157 cm Lab. No. S29078	Yellowish red (5YR 5/8); gravelly (50%) clay; gravels are mainly round and nodular, 1/4" to 1" in diameter, hardened plinthite glaebules with outside colors of yellowish red (5YR 5/8) and inside colors of red and very dusky red (10R 4/6 and 2/2); very weak fine, medium, and coarse angular to subangular blocky, breaking into weak to moderate very fine and fine granular; friable; common fine, medium, and coarse pores; common fine, medium, and coarse roots.
Diagnostic horizons	Umbric epipedon, 0-14 inches (0-35 cm). Argillic horizon, 21-62 inches (53-157 cm).

Profile N109, Njala gravelly clay loam

Classification: Orthoxic Palehumult

Illinois Lab. No.	S29072	S29074	S29076	S29078
Depth of horizon (inches)	0-14	14-21	21-49	49-62
Horizon	A_1	A_3	B_{21t}	B_{22t}
Percent of entire sample > 2.0 mm.	47.2	45.2	40.4	35.6
Particle-size distribution of < 2 mm (%):				
Very coarse sand 2.0-1.0 mm	5.4	7.4	7.2	7.0
Coarse sand 1.0-.5 mm.	4.6	3.6	3.6	3.0
Medium sand .5-.25 mm	7.1	3.1	2.4	2.0
Fine sand .25-.1 mm.	16.4	9.0	5.2	4.2
Very fine sand .1-.05 mm	9.1	9.0	5.8	5.5
Total sand 2.0-.05 mm	42.6	32.1	24.2	21.7
Coarse silt .05-.02 mm	5.3	4.1	3.7	4.1
Fine silt .02-.002 mm.	16.4	13.2	11.6	15.5
Total silt .05-.002 mm.	21.7	17.3	15.3	19.6
Total clay < .002 mm.	35.7	50.6	60.5	58.7
Water-dispersible clay < .002 mm	15.7	41.4	27.5	1.5
Bulk density	...	...	1.5	1.6
Moisture: 1/3 atmos. (%).	...	23.3	25.4	26.3
15 atmos. (%).	...	19.9	21.4	22.0
Avail. moist.-hold. capacity[a].	...	...	0.04	0.05
Organic carbon (%)	2.78	1.31	0.68	0.46
Exchangeable cations (me/100g soil):				
Ca	0.36	0.15	0.28	0.28
Mg	0.28	0.16	0.23	0.21
K.	0.06	0.02	0.04	0.03
Na	0.06	0.05	0.04	0.03
Al	3.00	2.94	1.72	1.83
Cation-exch. capacity (me/100g).	13.22	9.65	7.72	7.43
Base saturation (%).	5.7	3.9	7.6	7.4
pH H_2O	4.5	4.6	4.8	4.8
pH KCl	3.8	3.8	3.7	3.6
Soil tests:				
K (lbs/A).	98	78	65	43
P_1(lbs/A).	10	4	3	3
P_2(lbs/A).	12	4	3	3
Total P (ppm).	274	226	229	181
Total CaO(%)	0.113	0.081	0.083	0.077
Total Fe_2O_3(%)	5.09	5.86	6.80	6.90
Total K_2O(%)	0.74	0.84	...	1.15

[a]Inches of available moisture-holding capacity per inch of soil, adjusted for the amount of > 2.0 mm material.

Profile N108, Njala gravelly fine sandy loam
Described by D.H. Westerveld on December 12, 1966

Location
Oil Palm Station of Njala University College, adjacent to the south boundar road and 1,874 feet (571 m) northwest of Kania.

Physiography
Upper (third) river terrace, near the upland.

Relief
Very gentle, slightly concave slope.

Vegetation
Secondary bush.

Drainage
Moderately well drained.

Parent material
Colluvial material, high in hardened plinthite glaebules and quartz, over residual material weathered from bedrock.

A_1
0-4 inches
0-10 cm
Lab. No. S29080

Very dark grayish brown (10YR 3/2); gravelly fine sandy loam; weak fine an medium angular to subangular blocky, breaking into weak to moderate fine a medium granular; friable; many fine, medium, and coarse pores; many fine, medium, and coarse roots; clear, smooth boundary to horizon below.

IIA_3
4-14 inches
10-35 cm
Lab. No. S29082

Dark yellowish brown (10YR 4/4); gravelly sandy clay loam; most of the gra el is round and angular, 1/4" to 1" in diameter, hardened plinthite glaebules, dark reddish brown (5YR 2/2) outside and weak red (2.5YR 4/2) insid and the rest is rounded quartz gravel; very weak fine and medium angular t subangular blocky, breaking to weak to moderate fine, medium, and coarse granular; friable; many fine, medium, and coarse pores; many fine, medium, and coarse roots; clear, wavy boundary to horizon below.

IIB_{1t}
14-24 inches
35-61 cm
Lab. No. S29084

Yellowish brown (10YR 5/6) to reddish yellow (7.5YR 6/8) and strong brown (7.5YR 5/8) with few fine distinct light red to red (2.5YR 6/8-5/8) mottle gravelly sandy clay loam, with gravel similar to that in the IIA_3 horizon except that two-thirds is hardened plinthite glaebules and one-third is rounded quartz gravel; very weak fine, medium, and coarse angular to subang ular blocky, breaking into weak to moderate fine, medium, and coarse granular; friable; many fine, medium, and coarse pores; common fine, medium, an coarse roots; gradual, wavy boundary to horizon below.

IIB_{21t}
24-35 inches
61-89 cm
Lab. No. S29086

Yellowish brown (10YR 5/8) with common medium distinct red (2.5YR 4/8) mottles and few fine faint brownish-yellow (10YR 6/8) and dark brown (10YR 3/ mottles; gravelly clay loam; half of the gravel is rounded quartz, and hal is nodular and angular, 1/4" to 1" in diameter, hardened plinthite glaebules, strong brown (7.5YR 5/6) outside and red (2.5YR 4/8) inside; weak fine, medium, and coarse angular to subangular blocky, breaking into weak moderate fine, medium, and coarse granular; friable; many fine, medium, an coarse pores; few fine and medium roots; gradual, wavy boundary to horizon below.

$IIIB_{22}$
35-57 inches
89-145 cm
Lab. No. S29088

Brownish yellow (10YR 6/6) with many medium and coarse prominent red (2.5Y 4/8) mottles and few medium faint brownish-yellow (10YR 6/8) and yellowish-brown (10YR 5/4) mottles; gravelly clay loam, with gravel similar to that the IIB_{21t} horizon but mostly red (2.5YR 4/8) hardened plinthite glaebules with only a few rounded quartz gravels; very weak fine and medium angular subangular blocky, breaking into weak to moderate fine, medium, and coarse granular; friable; many fine, medium, and coarse pores; few fine and mediu roots.

Diagnostic horizons
Ochric epipedon, 0-14 inches (0-35 cm).
Argillic horizon, 14-57 inches (35-145 cm).

Profile N108, Njala gravelly fine sandy loam

Classification: Plinthic Paleudult

Illinois Lab. No.	S29080	S29082	S29084	S29086	S29088
Depth of horizon (inches)	0-4	4-14	14-24	24-35	35-57
Horizon	A_1	IIA_3	IIB_{1t}	IIB_{21t}	$IIIB_{22}$
Percent of entire sample > 2.0 mm. . . .	38.6	38.7	36.8	36.8	43.1
Particle-size distribution of < 2 mm (%):					
Very coarse sand 2.0-1.0 mm	4.3	12.4	8.9	8.1	9.6
Coarse sand 1.0-.5 mm.	6.0	5.2	8.2	7.4	6.9
Medium sand .5-.25 mm	12.4	6.7	6.5	5.3	4.6
Fine sand .25-.1 mm.	24.6	17.8	13.8	9.9	8.8
Very fine sand .1-.05 mm	9.6	12.0	11.0	9.6	9.7
Total sand 2.0-.05 mm	56.9	54.1	48.4	40.3	39.6
Total silt .05-.002 mm.	23.9	21.4	21.8	21.1	23.4
Total clay < .002 mm.	19.2	24.5	29.8	38.6	37.0
Water-dispersible clay < .002 mm	3.7	8.7	...	25.2	2.5
Moisture: 1/3 atmos. (%).	20.2	17.9	...	20.3	21.5
15 atmos. (%).	8.6	8.9	...	13.5	14.9
Organic carbon (%)	3.05	1.22	0.71	0.54	0.33
Exchangeable cations (me/100g soil):					
Ca	0.33	0.10	0.10	0.07	0.07
Mg	0.13	0.13	0.08	0.06	0.13
K	0.05	0.02	0.05	0.07	0.02
Na	0.06	0.04	0.04	0.03	0.03
Al	2.72	1.94	1.61	1.44	1.33
Cation-exch. capacity (me/100g).	10.65	6.50	5.14	6.00	6.72
Base saturation (%).	5.4	4.5	5.3	3.8	3.7
pH H_2O.	4.0	4.4	4.6	4.4	4.5
pH KCl.	3.5	3.8	...	3.6	3.6
Soil tests:					
K (lbs/A).	126	86	90	98	60
P_1 (lbs/A)	16	6	5	4	2
P_2 (lbs/A)	16	6	5	4	2
Total P (ppm).	149	110	...	129	...
Total CaO(%).	0.090	0.081	0.074	0.070	0.068
Total Fe_2O_3(%).	1.89	2.47	2.97	5.56	7.98
Total K_2O(%).	0.53	0.63	0.76	0.94	1.08

Profile N100, Nyawama sandy clay loam
Described by H. Breteler on December 2, 1966

Location	Near the office of the Oil Palm Station at Njala University College. After crossing the Taia River, the main road (planted with coconut palms) goes northwest until it turns toward the office; pit N100 is located 470 feet (143 m) southwest from this turn in the road, and 32 feet (10 m) northwest from the middle of the road between palms 70, 71, and 117. On aerial photograph 39-SL25-083, pit N100 is 8.2 cm west and 7.8 cm south of northeast corner mark.
Physiography	Second terrace of Taia River.
Relief	Very gentle, convex slope.
Vegetation	Oil palm plantation.
Drainage	Moderately well drained.
Parent material	Gravel-free alluvium.
A_1 0-21 inches 0-53 cm Lab. No. S29102	Very dark grayish brown (10YR 3/2); sandy clay loam; weak fine, medium, and coarse subangular blocky, breaking into weak very fine, fine, and medium granular; firm; many fine, medium, and coarse pores; many fine, medium, and coarse roots; gradual, smooth boundary to horizon below.
A_3 21-31 inches 53-79 cm Lab. No. S29103	Dark brown (10YR 3/3); sandy clay loam; weak fine, medium, and coarse angular to subangular blocky, breaking into very weak fine and medium granular; friable; many fine, medium, and coarse pores; common fine, medium, and coarse roots; gradual, smooth boundary to horizon below.
B_{21} 31-42 inches 79-107 cm Lab. No. S29104	Yellowish brown (10YR 5/4) with common fine distinct yellowish-red (5YR 5/8) mottles; sandy clay loam; very weak fine, medium, and coarse angular to subangular blocky, breaking into very weak fine and medium granular; firm; many fine, medium, and coarse pores; common fine, medium, and coarse roots; gradual, smooth boundary to horizon below.
B_{22t} 42-60 inches 107-153 cm Lab. No. S29105	Yellowish brown (10YR 5/4) with many fine and medium distinct yellowish-red (5YR 5/8) mottles; sandy clay loam; very weak fine, medium, and coarse angular to subangular blocky, breaking into weak fine, medium, and coarse granular; firm; common fine, medium, and coarse pores; common fine, medium, and coarse roots.
Diagnostic horizons	Umbric epipedon, 0-31 inches (0-79 cm). Argillic horizon, 42-60 inches (107-153 cm) probable, but not fully documented.

Profile N100, Nyawama sandy clay loam

Classification: "Plinthic" Orthoxic Palehumult (or Plinthic Umbriorthox)

Illinois Lab. No.	S29102	S29103	S29104	S29105
Depth of horizon (inches)	0-21	21-31	31-42	42-60
Horizon	A_1	A_3	B_{21}	B_{22t}
Percent of entire sample > 2.0 mm.	0	0	0	0
Particle-size distribution of < 2 mm (%):				
Very coarse sand 2.0-1.0 mm	0.2	0.3	0.3	0.3
Coarse sand 1.0-.5 mm.	0.8	0.9	1.1	1.0
Medium sand .5-.25 mm	5.7	4.9	5.5	4.6
Fine sand .25-.1 mm.	37.2	33.9	31.3	30.2
Very fine sand .1-.05 mm	18.4	18.2	17.2	15.2
Total sand 2.0-.05 mm	62.3	58.2	55.4	51.3
Coarse silt .05-.02 mm	5.0	5.0	5.4	4.9
Fine silt .02-.002 mm.	9.6	9.3	8.6	9.0
Total silt .05-.002 mm.	14.6	14.3	14.0	13.9
Total clay < .002 mm.	23.1	27.5	30.6	34.8
Water-dispersible clay < .002 mm	4.2	10.8	14.2	12.0
Bulk density	1.4	1.5	1.5	1.6
Moisture: 1/3 atmos. (%)	16.1	16.6	17.6	20.1
15 atmos. (%)	9.1	10.5	11.2	12.3
Avail. moist.-hold. capacity[a]	0.10	0.09	0.10	0.12
Organic carbon (%)	1.26	0.60	0.41	0.28
Exchangeable cations (me/100g soil):				
Ca	0.08	0.08	0.08	0.13
Mg	0.10	0.10	0.05	0.10
K	0.02	0.01	0.02	0.02
Na	0.05	0.05	0.04	0.04
Al	2.00	1.83	1.50	1.33
Cation-exch. capacity (me/100g)	6.72	4.93	4.64	4.64
Base saturation (%)	3.7	4.9	4.1	6.2
pH H_2O	4.3	4.3	4.3	4.3
pH KCl	3.7	3.7	3.7	3.5
Soil tests:				
K (lbs/A)	69	56	52	56
P_1 (lbs/A)	11	5	3	3
P_2 (lbs/A)	12	5	4	4
Total P (ppm)	200	...	...	...
Total CaO(%)	0.076	0.070	0.069	0.074
Total Fe_2O_3(%)	1.45	1.73	1.89	2.02
Total K_2O(%)	0.33	0.35	0.41	0.45

[a]Inches of available moisture-holding capacity per inch of soil.

Profile N71, Nyawama clay loam
Described by D. H. Westerveld on January 6, 1967

Location	On proposed new experimental farm northwest of Njala University College Campus. Pit N71 is on traverse 1, about 800 feet (244 m) west of the junction of this traverse with the east boundary creek. On aerial photograph 39-SL25-083, pit N71 is 9.6 cm west and 4.7 cm south of northeast corner mark.
Physiography	Middle terrace of Taia River.
Relief	Nearly level.
Vegetation	Secondary bush.
Drainage	Moderately well drained.
Parent material	Gravel-free alluvium.
A_1 0-11 inches 0-28 cm Lab. No. S29119	Dark brown (10YR 3/3); clay loam; weak fine and medium subangular blocky, breaking into weak to moderate fine, medium, and coarse granular; friable; many fine, medium, and coarse pores; many fine, medium, and coarse roots; gradual, smooth boundary to horizon below.
B_1 11-17 inches 28-43 cm Lab. No. S29120	Dark yellowish brown (10YR 4/4); clay; weak fine and medium angular to subangular blocky, breaking into weak to moderate fine, medium, and coarse granular; friable; many fine, medium, and coarse pores; many fine, medium, and coarse roots; gradual, smooth boundary to horizon below.
B_{21t} 17-26 inches 43-66 cm Lab. No. S29121	Yellowish brown (10YR 5/8) with few fine and medium distinct red (2.5YR 4/8) mottles; clay; weak fine, medium, and coarse angular to subangular blocky, breaking into weak to moderate fine, medium, and coarse granular; friable; many fine, medium, and coarse pores; common fine, medium, and coarse roots; gradual, smooth boundary to horizon below.
B_{22t} 26-50 inches 66-127 cm Lab. No. S29122	Brownish yellow (10YR 6/8) with few fine faint reddish-yellow (7.5YR 6/8) and many fine, medium, and coarse distinct red (2.5YR 4/8) slightly hard mottles; clay; weak fine, medium, and coarse angular to subangular blocky, breaking into weak to moderate fine, medium, and coarse granular; friable; many fine, medium, and coarse pores; few fine, medium, and coarse roots.
Diagnostic horizons	Umbric epipedon, 0-11 inches (0-28 cm). Argillic horizon, 17-50 inches (43-127 cm) probable, but not fully documented.

Profile N71, Nyawama clay loam

Classification: "Plinthic" Orthoxic Palehumult (or Plinthic Umbriorthox)

Illinois Lab. No.	S29119	S29120	S29121	S29122
Depth of horizon (inches)	0-11	11-17	17-26	26-50
Horizon	A_1	B_1	B_{21t}	B_{22t}
Percent of entire sample > 2.0 mm.	0	0	0	0
Particle-size distribution of < 2 mm (%):				
Very coarse sand 2.0-1.0 mm	0.2	0.1	0.1	0.2
Coarse sand 1.0-.5 mm.	1.1	0.8	0.8	0.8
Medium sand .5-.25 mm	2.5	1.9	1.5	1.4
Fine sand .25-.1 mm.	20.6	18.0	14.2	11.8
Very fine sand .1-.05 mm	15.5	15.6	14.2	12.4
Total sand 2.0-.05 mm	39.9	36.4	30.8	26.6
Total silt .05-.002 mm.	23.0	22.9	21.9	22.5
Total clay < .002 mm.	37.1	40.7	47.3	50.9
Water-dispersible clay < .002 mm	8.7	20.2	13.3	0.8
Moisture: 1/3 atmos. (%).	22.6	20.6	21.7	24.4
15 atmos. (%)	16.0	15.3	17.0	19.1
Organic carbon (%)	2.55	1.23	0.78	0.34
Exchangeable cations (me/100g soil):				
Ca	0.15	0.10	0.08	0.15
Mg	0.08	0.10	0.05	0.03
K.	0.06	0.06	0.06	0.06
Na	0.03	0.07	0.05	0.05
Al	2.05	1.67	1.39	1.11
Cation-exch. capacity (me/100g).	10.22	6.29	5.64	5.72
Base saturation (%).	3.1	5.2	4.3	5.1
pH H_2O	4.7	4.7	4.8	5.1
pH KCl	4.0	3.9	3.8	3.9
Soil tests:				
K (lbs/A).	98	74	82	78
P_1(lbs/A).	8	3	2	3
P_2(lbs/A).	9	3	3	3
Total P (ppm).	220	...	...	...
Total CaO(%)	0.091	0.081	0.075	0.076
Total Fe_2O_3(%)	2.46	2.87	3.34	4.24
Total K_2O(%)	0.81	0.84	0.83	0.82

Profile N15, Nyawama sandy clay loam
Described by H. Breteler on January 5, 1967

Location	On proposed new experimental farm northwest of Njala University College Campus. Pit N15 is 528 feet (161 m) east of Taia River and 37 feet (11 m) south of the path from Nyawama to the river. On aerial photograph 39-SL25-083, pit N15 is 12.3 cm west and 7.3 cm south of northeast corner mark.
Physiography	Middle terrace of Taia River, close to the escarpment down to the lowest terrace.
Relief	Nearly level.
Vegetation	Bamboo and ferns.
Drainage	Moderately well drained.
Parent material	Gravel-free alluvium.
A_1 0-5 inches 0-13 cm Lab. No. S29130	Dark brown (10YR 3/3); sandy clay loam; weak fine and medium angular to subangular blocky, breaking into very weak very fine granular; friable; many fine, medium, and coarse pores; many fine, medium, and coarse roots; clear, smooth boundary to horizon below.
A_3 5-14 inches 13-35 cm Lab. No. S29131	Yellowish brown (10YR 5/5) with few fine faint dark brown (10YR 3/3) mottles; sandy clay loam; weak to moderate very fine, fine, and medium angular to subangular blocky, breaking into weak to moderate very fine granular; friable; many fine, medium, and coarse pores; many fine, medium, and coarse roots; gradual, smooth boundary to horizon below.
B_{21t} 14-33 inches 35-84 cm Lab. No. S29132	Yellowish brown (10YR 5/8) with few fine faint red (2.5YR 5/8) mottles; clay; weak very fine, fine, and medium angular to subangular blocky, breaking into weak very fine and fine granular; friable; many fine, medium, and coarse pores; many fine, medium, and coarse roots; gradual, smooth boundary to horizon below.
B_{22t} 33-50 inches 84-127 cm Lab. No. S29133	Yellowish brown (10YR 5/8) with many fine, medium, and coarse distinct red (2.5YR 5/8) mottles; clay; weak to moderate very fine, fine, and medium angular blocky, breaking into weak very fine and fine granular; friable; common fine, medium, and coarse pores; common fine, medium, and coarse roots.
Diagnostic horizons	Ochric epipedon, 0-14 inches (0-35 cm). Argillic horizon, 14-50 inches (35-127 cm) probable, but not fully documented.

Profile N15, Nyawama sandy clay loam

Classification: Plinthic "Orthoxic" Paleudult (or Plinthic Haplorthox)

Illinois Lab. No.	S29130	S29131	S29132	S29133
Depth of horizon (inches)	0-5	5-14	14-33	33-50
Horizon	A_1	A_3	B_{21t}	B_{22t}
Percent of entire sample > 2.0 mm.	0	0	0	0
Particle-size distribution of < 2 mm (%):				
Very coarse sand 2.0-1.0 mm	0.5	0.2	0.1	0.1
Coarse sand 1.0-.5 mm.	0.5	0.2	0.2	0.4
Medium sand .5-.25 mm	1.5	0.9	0.6	0.9
Fine sand .25-.1 mm.	29.2	24.5	19.3	15.1
Very fine sand .1-.05 mm	21.6	22.6	21.3	18.3
Total sand 2.0-.05 mm	53.3	48.4	41.5	34.8
Total silt .05-.002 mm.	23.1	19.2	17.7	19.4
Total clay < .002 mm.	23.6	32.4	40.8	45.8
Water-dispersible clay < .002 mm	7.6	16.8	16.8	0.4
Moisture: 1/3 atmos. (%).	18.0	17.0	19.3	22.4
15 atmos. (%).	12.0	12.4	14.4	17.4
Organic carbon (%)	3.34	1.01	0.78	0.52
Exchangeable cations (me/100g soil):				
Ca	2.33	0.43	0.28	0.15
Mg	1.12	0.34	0.26	0.21
K	0.11	0.03	0.06	0.03
Na	0.05	0.06	0.06	0.04
Al	0.49	1.17	1.28	1.22
Cation-exch. capacity (me/100g).	10.29	5.50	5.14	5.64
Base saturation (%).	35.1	15.6	12.8	7.6
pH H_2O.	5.0	4.8	4.3	4.8
pH KCl.	4.0	3.9	3.8	3.8
Soil tests:				
K (lbs/A).	114	78	106	56
P_1 (lbs/A)	18	8	3	4
P_2 (lbs/A)	20	9	4	5
Total P (ppm).	180	...	...	...
Total CaO(%).	0.301	0.131	0.117	0.089
Total Fe_2O_3(%).	2.14	2.66	3.22	5.14
Total K_2O(%).	1.40	1.40	1.33	1.19

Profile P1, Panlap sandy loam

Described by W. van Vuure and R. Miedema on March 8, 1968

Location	Topographic map of Sierra Leone, scale 1:50,000, sheet 43, coordinates $HE27_6$-86_4; on traverse A, near old rail line.
Physiography	Valley bottom, at the edge of a swamp.
Relief	Concave, gentle slope of 3 percent to SSW.
Vegetation	Abandoned rice farm with grasses and raphia palm.
Drainage	Poorly drained.
Parent material	Gravel-free alluvium or colluvium or a mixture of both from adjacent hills.
A_{11} 0-11 inches 0-28 cm Lab. No. S29800	Black (10YR 2/1); sandy loam; very weak, very fine subangular blocky; very friable, slightly sticky, and plastic; common macro-and mesopores; few faint root-rust mottles and few medium distinct charcoal mottles; common coarse, many medium and fine roots; common ant and termite activity, and a few worm holes; clear, smooth boundary to horizon below.
A_{12} 11-23 inches 28-58 cm Lab. No. S29801	Very dark grayish brown to dark grayish brown (10YR 3.5/2); loamy sand; weak fine subangular blocky; friable, slightly sticky, and nonplastic; few macro- and many mesopores; common coarse, many medium, and common fine roots; very few fine quartz gravels, and very few very fine, red, hardened plinthite glaebules; common ant, termite, and worm activity; clear, smooth boundary to horizon below.
AC 23-37 inches 58-93 cm Lab. No. S29802	Brown (10YR 5/3); loamy sand; weak fine subangular blocky; friable, slightly sticky, and nonplastic; few macro- and many mesopores; many coarse prominent yellowish-red (5YR 5/8) plinthite mottles, vertically elongated along root channels; few coarse, common medium and fine roots; few fine quartz gravels, and very few very fine, red, hardened plinthite glaebules; few ants and termites, and common worm activity; clear, smooth boundary to horizon below.
C_g 37-60 inches 93-153 cm Lab. No. S29803	Light brownish gray (10YR 6/2); coarse sandy loam; very weak fine subangular blocky; friable, slightly sticky, and nonplastic to slightly plastic; many mesopores; many coarse prominent strong brown (7.5YR 5/8), reddish-yellow (7.5YR 6/8), yellowish-red (10YR 6/7), and red (2.5YR 5/8) plinthite mottles; few faint white kaolinite mottles; common fine quartz gravel; common worm activity.
Diagnostic horizon	Umbric epipedon, 0-11 inches (0-28 cm).

Profile P1, Panlap sandy loam

Classification: Aeric Plinthic Tropaquept

Illinois Lab. No. Depth of horizon (inches) Horizon	S29800 0-11 A_{11}	S29801 11-23 A_{12}	S29802 23-37 AC	S29803 37-60 C_g
Percent of entire sample > 2.0 mm.	1.5	2.6	9.2	6.0
Particle-size distribution of < 2 mm (%):				
Very coarse sand 2.0-1.0 mm	2.4	4.8	6.4	9.8
Coarse sand 1.0-.5 mm.	12.9	15.0	17.1	19.5
Medium sand .5-.25 mm	39.1	30.7	31.9	28.8
Fine sand .25-.1 mm.	19.0	24.0	20.2	16.1
Very fine sand .1-.05 mm	4.6	6.7	5.3	3.8
Total sand 2.0-.05 mm	78.0	81.2	80.9	78.0
Total silt .05-.002 mm.	11.0	8.1	7.3	9.5
Total clay < .002 mm.	11.0	10.7	11.8	12.5
Water-dispersible clay < .002 mm	2.3	5.7	9.4	11.8
Bulk density	1.1	1.3	1.4	1.5
Moisture: 1/3 atmos. (%).	12.4	8.8	9.3	13.4
15 atmos. (%).	6.2	5.5	5.9	6.4
Avail. moist.-hold. capacity[a].	0.07	0.04	0.05	0.09
Organic carbon (%)	1.60	0.67	0.35	0.27
Exchangeable cations (me/100g soil):				
Ca	0.58	0.58	0.47	0.38
Mg	0.47	0.47	0.48	0.44
K	0.02	0.02	0.02	0.03
Na	0.07	0.07	0.06	0.09
Al	0.85	0.65	0.37	0.31
Cation-exch. capacity (me/100g).	3.64	3.00	1.79	1.71
Base saturation (%).	31.3	38.0	57.5	55.0
pH H_2O.	4.9	4.9	5.0	4.7
pH KCl.	...	4.2	4.2	4.0
Soil tests:				
K (lbs/A).	56	43	43	43
P_1 (lbs/A)	16	9	7	4
Total CaO(%).	0.099	0.082	0.080	0.099
Total Fe_2O_3(%).	1.12	1.17	3.08	1.59
Total K_2O(%).	0.999	0.884	0.841	...

[a]Inches of available moisture-holding capacity per inch of soil, adjusted for the amount of > 2.0 mm material.

Profile N47, Pelewahun loam

Described by J.C. Dijkerman on March 28, 1966

Location	On proposed new experimental farm northwest of Njala University College Campus. From junction of path from Bonjema to Belebu with path to Gbesebu, 132 feet (40 m) along path towards Belebu, thence 253 feet (76 m) east along small farm path; pit N47 is 74 feet (22 m) southeast of this point.
Physiography	Lower portions of colluvial footslopes or in drainageways and swamps.
Relief	In the bottom of a small drainageway, on a 2-percent concave slope.
Vegetation	Sedges and water-loving shrubs.
Drainage	Poorly drained.
Parent material	Gravel-free colluvium, over gravelly colluvium, over residual material.
A_1 0-11 inches 0-28 cm Lab. No. S28655	Very dark gray to dark gray (10YR 4/1-3/1) with common fine, and few medium and coarse, distinct yellowish-red (5YR 4/8) mottles, mainly along root channels; loam; weak coarse to fine subangular blocky, breaking to moderate coarse to fine granular; friable; many medium and fine roots; many pores of all sizes; clear, smooth boundary to horizon below.
B_1 11-17 inches 28-43 cm Lab. No. S29737	Gray (10YR 5/1) with common fine distinct strong brown (7.5YR 5/8) mottles; sandy clay loam; weak to moderate medium and fine angular blocky; friable; common medium and fine roots; many pores of all sizes; clear, smooth boundary to horizon below.
B_{21t} 17-25 inches 43-63 cm Lab. No. S28656	Light brownish gray (10YR-2.5Y 6/2) with many, medium and fine, soft, distinct, strong brown (7.5YR 5/8) mottles and many coarse prominent red (10R 4/6) mottles, most of which are slightly hard to crush; clay loam; moderate coarse and medium angular blocky, with thin distinct light gray (10YR 6/1) clay coatings on some horizontal and vertical ped surfaces; slightly firm in place but friable to crush; common medium and fine roots; common pores of all sizes; abrupt, smooth boundary to horizon below.
IIB_{22t} 25-41 inches 63-104 cm Lab. No. S28657, matrix	Sixty percent coarse hard prominent red (10R 4/6) mottles, 30% coarse, slightly hard, prominent yellowish-red (5YR 5/8) mottles, and 10% coarse, soft, prominent light gray (10YR 7/1) mottles in the form of clayey vertical channels about 1 cm wide; very gravelly clay loam; the gravels form a stone line and consist of equal proportions of quartz pebbles and irregular, nondense, red (10R 4/6) hardened plinthite glaebules 1/4" to 3/4" in diameter; massive; very firm; no roots; few medium pores; clear, wavy boundary to horizon below.
Lab. No. S29738, channel	A few gray (10YR 6/1) gravelly clay, vertical channels, 2 to 3 inches wide, break through this massive horizon and connect B_{21t} with $IIIB_{23t}$. The channels were sampled separately under Lab. No. S29738.
$IIIB_{23t}$ 41-72 inches 104-183 cm Lab. No. S28658	White (10YR 8/1) with many soft fine, medium, and coarse, distinct red (10R 4/6) and strong brown (7.5YR 5/8) mottles; clay, with common fragments of weathered bedrock (siltstone); strong medium to fine angular blocky, with distinct thick light gray (10YR 7/1-6/1) clay coatings on most horizontal and vertical ped surfaces; firm; no roots; few medium pores.
Diagnostic horizons	Umbric epipedon, 0-11 inches (0-28 cm). Argillic horizon, 17-72 inches (43-183 cm).

Profile N47, Pelewahun loam

Classification: Typic Plinthaquult

Illinois Lab. No.	S28655	S29737	S28656	S29738	S28657	S28658
Depth of horizon (inches)	0-11	11-17	17-25	25-41	25-41	41-72
Horizon	A_1	B_1	B_{21t}	IIB_{22t} channel	IIB_{22t} matrix	$IIIB_{23t}$
Percent of entire sample > 2.0 mm. .	<1	1	5	20	54	10
Particle-size distribution of <2 mm (%):						
Very coarse sand 2.0-1.0 mm . . .	1.4	0.7	4.6	0.7	11.3	1.6
Coarse sand 1.0-.5 mm. . . .	3.4	11.4	10.8	8.3	13.6	2.0
Medium sand .5-.25 mm . . .	6.5	14.1	10.2	4.3	8.1	1.5
Fine sand .25-.1 mm. . . .	16.2	17.6	11.8	4.9	4.7	2.0
Very fine sand .1-.05 mm . . .	11.4	9.2	6.3	2.8	3.5	2.2
Total sand 2.0-.05 mm . . .	38.9	53.0	43.7	21.0	41.2	9.3
Total silt .05-.002 mm. . .	38.1	22.4	23.8	28.9	19.2	37.3
Total clay < .002 mm. . .	23.0	24.6	32.5	50.1	39.6	53.4
Water-dispersible clay < .002 mm . .	11.5	23.6	30.6	46.6	7.4	35.0
Bulk density	1.5	1.7	1.8	...	1.9	1.9
Moisture: 1/3 atmos. (%).	26.0	16.9	19.2	30.6	22.6	36.0
15 atmos. (%).	9.7	8.8	11.4	19.6	14.2	20.4
Avail. moist.-hold. capacity[a]. . . .	0.24	0.14	0.13	...	0.07	0.27
Organic carbon (%)	2.39	0.32	0.19	0.53	0.21	0.19
Exchangeable cations (me/100g soil):						
Ca	0.17	0.20	0.05	0.28	0.05	0.26
Mg	0.16	0.08	0.26	0.44	0.46	0.49
K.	0.15	0.02	0.05	0.05	0.06	0.08
Na	0.03	0.05	0.03	0.09	0.04	0.04
Al	2.89	3.50	5.44	5.22	5.89	8.44
Cation-exch. capacity (me/100g). . .	10.21	7.22	8.29	13.29	9.58	12.65
Base saturation (%).	5.0	4.8	4.7	6.5	6.4	6.9
pH H_2O	4.3	4.4	4.4	4.3	4.8	4.8
pH KCl	3.5	3.2	3.2	3.2	3.3	3.2
Soil tests:						
K (lbs/A)	158	48	56	86	78	86
P_1 (lbs/A)	23	6	3	8	1	1
P_2 (lbs/A)	24	6	4	8	2	1
Total P (ppm).	195	75	98	132	175	178
Total CaO (%).	0.085	...	0.070	...	0.072	0.077
Total Fe_2O_3 (%).	1.53	...	3.09	...	9.00	7.88
Total K_2O (%).	0.684	...	1.170	...	1.840	2.940

[a]Inches of available moisture-holding capacity per inch of soil, adjusted for the amount of > 2 mm material.

Profile N106, Pelewahun fine sandy loam
Described by D.H. Westerveld on December 28, 1966

Location	Oil Palm Station of Njala University College, on the south boundary road, 655 feet (200 m) northwest of Kania. On aerial photograph 39-SL25-083, pit N106 is 10 cm west and 9.5 cm south of northeast corner mark.
Physiography	Drainageway in the third river terrace.
Relief	Very gentle concave, low area.
Vegetation	Secondary bush.
Drainage	Poorly drained.
Parent material	Deep gravel-free colluvial material, over colluvial material high in plinthite glaebules and quartz.
A_1 0-15 inches 0-38 cm Lab. No. S29089	Dark grayish brown to very dark grayish brown (10YR 4/2-3/2); fine sandy loam; weak fine and medium angular to subangular blocky, breaking into weak to moderate fine and medium granular; friable; many fine, medium, and coarse pores; many fine, medium, and coarse roots; clear, wavy boundary to horizon below. This horizon is darker and thicker than in typical Pelewahun.
B_{1gt} 15-26 inches 38-66 cm Lab. No. S29090	Gray (10YR 5/1-6/1); clay loam; weak fine and medium angular to subangular blocky, breaking into weak to moderate fine and medium granular; friable; many fine, medium, and coarse pores; common fine and medium roots; gradual, wavy boundary to horizon below.
B_{21gt} 26-41 inches 66-104 cm Lab. No. S29091	Gray (10YR 5/1-6/1) with common fine and medium distinct yellowish-red (5YR 5/8) and red (2.5YR 4/8) mottles; clay loam; weak fine and medium angular to subangular blocky, breaking into weak to moderate fine and medium granular; firm; many fine, medium, and coarse pores; common fine and medium roots; clear, wavy boundary to horizon below.
IIB_{22g} 41-58 inches 104-147 cm Lab. No. S29093	Gray (10YR 6/1) with many fine and medium prominent red (2.5YR 4/8) mottles, and common fine and medium distinct yellow (10YR 7/8) mottles; gravelly (50% by volume) clay loam, with half of the gravels rounded quartz gravels, and half nodular, very hard laterite glaebules, 1/4" to 3" in diameter, with outside and inside colors of red (2.5YR 4/8); very weak fine and medium angular to subangular blocky, breaking into fine and medium granular; firm; common fine, medium, and coarse pores; few fine roots
Diagnostic horizons	Umbric epipedon, 0-15 inches (0-38 cm). Argillic horizon, 15-41 inches (38-104 cm).

Profile N106, Pelewahun fine sandy loam

Classification: Plinthic Paleaquult

Illinois Lab. No. Depth of horizon (inches) Horizon	S29089 0-15 A_1	S29090 15-26 B_{1gt}	S29091 26-41 B_{21gt}	S29093 41-58 IIB_{22g}
Percent of entire sample > 2.0 mm.	0	0	0	33.1
Particle-size distribution of < 2 mm (%):				
Very coarse sand 2.0-1.0 mm	1.0	1.6	1.8	6.4
Coarse sand 1.0-.5 mm.	2.8	4.1	3.7	5.7
Medium sand .5-.25 mm	7.3	5.2	4.4	5.3
Fine sand .25-.1 mm.	26.8	19.3	13.6	13.0
Very fine sand .1-.05 mm	14.8	11.0	11.3	10.2
Total sand 2.0-.05 mm	52.7	41.2	34.8	40.6
Coarse silt .05-.02 mm	8.6	7.4	6.3	7.1
Fine silt .02-.002 mm.	23.3	23.9	23.0	25.0
Total silt .05-.002 mm.	31.9	31.3	29.3	32.1
Total clay < .002 mm.	15.4	27.5	35.9	27.3
Water-dispersible clay < .002 mm	10.2	25.1	22.0	13.6
Moisture: 1/3 atmos. (%).	11.3	13.9	16.4	15.8
15 atmos. (%).	6.2	9.9	12.3	11.5
Organic carbon (%)	1.12	0.41	0.32	0.22
Exchangeable cations (me/100g soil):				
Ca	0.10	0.13	0.03	0.10
Mg	0.08	0.03	0.07	0.10
K	0.02	0.02	0.03	0.01
Na	0.03	0.04	0.05	0.05
Al	1.72	2.00	2.66	3.17
Cation-exch. capacity (me/100g).	5.86	5.64	6.72	7.79
Base saturation (%).	3.9	3.9	2.7	3.3
pH H_2O	4.4	4.4	4.4	4.7
pH KCl	3.6	3.5	3.3	3.4
Soil tests:				
K (lbs/A).	52	39	39	43
P_1 (lbs/A)	12	29	5	4
P_2 (lbs/A)	15	31	5	4
Total P (ppm).	135	68	100	105
Total CaO(%).	0.077	0.072	0.069	0.067
Total Fe_2O_3(%).	0.60	0.92	1.62	3.82
Total K_2O(%).	0.24	0.44	0.62	0.71

Profile Kpuabu 2, Pendembu fine sandy loam

Description after Sivarajasingham (*64*)

Location	Kpuabu Cocoa Experiment Station, about halfway between the nursery buildings and the stream.
Physiography	Accordant, flat-topped hill of the dissected lateritic upland.
Relief	Long, gentle, concave slope of about 2 percent.
Vegetation	Cocoa plantation under adequate shade of many tall trees of original secondary forest. Although the soil is deep and gravel-free and would have been expected to be suitable, the cocoa planted in 1959 shows many large, vacant patches.
Drainage	Imperfectly drained.
Parent material	A thick layer of gravel-free, locally transported, leached parent material.
A_1 0-7 inches 0-18 cm Lab. No. S28552	Very dark gray (10YR 3/1); fine sandy loam; weak, medium, and fine, subangular blocky; friable, slightly sticky, nonplastic; very few fine pores; common fine and medium roots; clear, smooth boundary to horizon below.
A_3 7-18 inches 18-46 cm Lab. No. S28551	Dark grayish brown (2.5Y 4/2-10YR 4/2); sandy clay loam; dense clods breaking to weak fine subangular blocky aggregates with no characteristic interface; friable, slightly sticky, slightly plastic; very few pores and few large burrow holes; common fine and medium and few coarse roots in the first 5 inches, then decreasing gradually with depth; clear, smooth boundary to horizon below.
B_{1t} 18-37 inches 46-94 cm	Yellowish brown (10YR 5/4) to light olive brown (2.5Y 5/4); sandy clay loam; dense clods as in A_3 horizon; friable to firm, slightly sticky, slightly plastic; few pores with clay coatings along the pore walls; few fine and medium roots; gradual, smooth boundary to horizon below.
B_{2t} 37-54 inches 94-137 cm Lab. No. S28550	Yellow (2.5Y 7/6) to brownish yellow (10YR 6/6); sandy clay loam; massive clods breaking to weak very fine subangular blocky aggregates with no characteristic interface; friable to firm, slightly plastic, slightly sticky; few pores with clay coatings along the pore walls; very few fine and medium roots; gradual, smooth boundary to horizon below.
B_{3t} 54-72 inches 137-183 cm	Pale yellow to yellow (2.5Y 7/6) with common medium, faint yellowish-brown (10YR 5/6) and few medium, prominent red (2.5YR 4/8) mottles; sandy clay loam; massive clods as in B_{2t} horizon; firm, slightly sticky, slightly plastic; many fine pores with clay coatings; very few very fine roots; gradual, smooth boundary to horizon below.
C_{1g} 72-80 inches 183-203 cm	White (2.5Y 8/2) with common medium, prominent yellowish-brown (10YR 5/6) and strong brown (7.5YR 5/8) mottles; sandy clay; massive; wet; firm, sticky, slightly plastic; the strong brown mottles are firm to hard and may be considered as incipient plinthite glaebules; no roots.
Diagnostic horizons	Ochric epipedon, 0-18 inches (0-46 cm). Argillic horizon, 18-27 inches (46-183 cm).

Profile Kpuabu 2, Pendembu fine sandy loam

Classification: Typic Paleudult

Illinois Lab. No.	S28552	S28551	S28550
Depth of horizon (inches)	0-7	7-18	37-54
Horizon	A_1	A_3	B_{2t}
Percent of entire sample > 2.0 mm	15.5	3.1	2.4
Particle-size distribution of < 2mm (%):			
Very coarse sand 2.0-1.0 mm.	3.4	3.6	3.6
Coarse sand 1.0-.5 mm	11.9	10.1	10.3
Medium sand .5-.25 mm.	5.3	11.6	11.9
Fine sand .25-.1 mm	26.8	24.6	21.4
Very fine sand .1-.05 mm.	10.8	13.2	10.5
Total sand 2.0-.05 mm.	68.6	63.0	57.5
Total silt .05-.002 mm	11.7	13.2	12.2
Total clay < .002 mm	19.7	23.8	30.3
Water-dispersible clay < .002 mm.	2.7	6.8	0.3
Bulk density.	0.9	0.9	1.0
Moisture: 1/3 atmos. (%)	14.3	13.3	15.0
15 atmos. (%)	9.1	8.7	10.7
Avail. moist.-hold. capacity[a]	0.04	0.04	0.04
Organic carbon (%).	2.25	0.85	0.32
Exchangeable cations (me/100g soil):			
Ca.	0	0.06	0.06
Mg.	0.08	0.03	0.03
K	0.10	0.06	0.05
Na.	0.05	0.04	0.04
Al.	3.56	2.39	1.22
Cation-exch. capacity (me/100g)	9.44	4.79	3.50
Base saturation (%)	2.4	4.0	5.1
pH H_2O	4.1	4.4	4.7
pH KCl	3.6	3.8	3.9
Soil tests:			
K (lbs/A).	5	...	8
P_1 (lbs/A).	10	2	2
P_2 (lbs/A).	12	4	4
Total P (ppm)	240	180	...
Total CaO (%)	0.076	0.072	0.067
Total Fe_2O_3 (%)	2.52	3.00	3.10
Total K_2O (%)	0.194	0.219	0.249

[a]Inches of available moisture-holding capacity per inch of soil, adjusted for the amount of > 2.0 mm material.

Profile N80, Pujehun fine sandy clay loam
Described by J. C. Dijkerman on January 11, 1967

Location	On proposed new experimental farm northwest of Njala University College Campus. Along the surveyor path following the Taia River from Gbesebu to Nyawama, pit N80 is 591 feet (180 m) south of the Gbesebu path, at surveyor stone SLS 21/64 BP 138; it is 10.2 cm west and 3.7 cm south of northeast corner mark on aerial photograph 39-SL-24-083.
Physiography	Lower terrace of Taia River.
Relief	Very gentle convex slope, on natural levee along the Taia River.
Vegetation	Secondary bush.
Drainage	Well drained.
Parent material	Gravel-free alluvium.
A_1 0-4 inches 0-10 cm Lab. No. S29110	Very dark grayish brown to dark brown (10YR 3/2-3/3); fine sandy clay loam; very weak fine and very fine subangular blocky, breaking into weak fine and very fine granular; friable; many fine, medium, and coarse pores; many fine, medium, and coarse roots; clear, smooth boundary to horizon below.
A_3 4-12 inches 10-30 cm Lab. No. S29111	Dark yellowish brown (10YR 4/4); fine sandy clay loam with much mica; very weak fine and very fine subangular blocky, breaking into very weak fine and very fine granular; friable; many fine, medium, and coarse pores; many fine, medium, and coarse roots; gradual, smooth boundary to horizon below.
B_{21} 12-31 inches 30-79 cm Lab. No. S29112	Yellowish red (10YR 5/6); fine sandy loam with much mica; very weak fine and very fine subangular blocky, breaking into very weak fine and very fine granular; friable; many fine and medium pores; common fine and medium roots; gradual, smooth boundary to horizon below.
B_{22} 31-55 inches 79-140 cm Lab. No. S29113	Strong brown (7.5YR 5/6) with common fine and medium faint yellowish-red (5YR 4/6) mottles; clay loam containing much mica; weak to moderate fine and very fine angular blocky to subangular blocky, breaking into fine and very fine granular; friable; many fine and medium pores; common fine and medium roots.
Diagnostic horizons	Ochric epipedon, 0-12 inches (0-30 cm). Cambic horizon, 12-55 inches (30-140 cm).

Profile N80, Pujehun fine sandy clay loam

Classification: Fluventic Udoxic Dystropept

Illinois Lab. No.	S29110	S29111	S29112	S29113
Depth of horizon (inches)	0-4	4-12	12-31	31-55
Horizon	A_1	A_3	B_{21}	B_{22}
Percent of entire sample > 2.0 mm	0	0	0	0
Particle-size distribution of < 2 mm (%):				
Very coarse sand 2.0-1.0 mm.	0.4	0.1	0.1	0
Coarse sand 1.0-.5 mm	0.2	0.1	0.1	0.1
Medium sand .5-.25 mm.	1.6	1.5	1.1	0.7
Fine sand .25-.1 mm	39.6	40.3	46.1	23.8
Very fine sand .1-.05 mm.	20.8	21.2	24.3	20.4
Total sand 2.0-.05 mm.	62.6	63.2	71.7	45.0
Coarse silt .05-.02 mm.	3.8	3.4	2.6	5.3
Fine silt .02-.002 mm	13.2	10.8	9.0	15.0
Total silt .05-.002 mm	17.0	14.2	11.6	20.3
Total clay < .002 mm	20.4	22.6	16.7	34.7
Water-dispersible clay < .002 mm	3.6	10.4	10.7	0.7
Bulk density.	1.2	1.4	1.4	1.5
Moisture: 1/3 atmos. (%)	20.3	17.0	12.8	26.2
15 atmos. (%)	11.3	9.5	7.3	14.6
Avail.moist.-hold. capacity[a].	0.11	0.10	0.08	0.17
Organic carbon (%).	2.71	0.94	0.32	0.28
Exchangeable cations (me/100g soil):				
Ca.	0.10	0.10	0.10	0.08
Mg.	0.08	0.05	0.05	0.12
K	0.05	0.04	0.01	0.02
Na.	0.04	0.04	0.05	0.05
Al.	1.61	1.02	0.61	0.95
Cation-exch. capacity (me/100g)	8.86	4.86	2.79	4.43
Base saturation (%)	3.0	4.7	7.5	6.1
pH H_2O	4.4	4.5	4.5	4.8
pH KCl	3.9	4.0	3.9	3.9
Soil tests:				
K (lbs/A).	106	60	52	60
P_1 (lbs/A).	15	4	6	3
P_2 (lbs/A).	17	4	6	3
Total P (ppm)	300	...	...	...
Total CaO (%)	0.293	0.289	0.327	0.190
Total Fe_2O_3 (%)	2.89	3.02	2.56	4.36
Total K_2O (%)	2.10	2.18	2.68	1.96

[a]Inches of available moisture-holding capacity per inch of soil.

Profile R1, Rokupr clay, oxidized phase
Described by J. C. Dijkerman and D. H. Westerveld on May 5, 1967

Location	Rice Research Station, Rokupr; pit R1 is in plot 47 on side of ditch; 210 feet (64 m) east of Great Scarcies River. The area east of this ditch is empoldered (for a map of the Station see *1955 Annual Report of the West African Rice Research Station*, Rokupr, Sierra Leone).
Physiography	Tidal swamp.
Relief	Nearly level.
Vegetation	Land is plowed and ready for the next rice crop. The original vegetation was mangrove.
Drainage	Very poorly drained. The plot is empoldered and the surface has dried (oxidized) thoroughly during the dry season. When the soil description was written, brackish water was 20 inches below the surface during low tide.
Parent material	Alluvium.
A_1 0-5 inches 0-13 cm Lab. No. S29747	Very dark gray to very dark grayish brown (10YR 3/1-3/2) with common medium and coarse prominent yellowish-brown (10YR 5/6) and brown (7.5YR 5/6) mottles; clay; some pieces of undecomposed organic matter; ripe, cannot be molded through fingers (firm); many large crab holes (0.5 to 2 cm wide); sticky and plastic; clear, smooth boundary to horizon below.
B_{21g} 5-22 inches 13-56 cm Lab. No. S29748	Very dark gray (10YR 3/1-N 3/) with common medium and coarse prominent yellowish-brown (10YR 5/6), strong brown (7.5YR 5/6), and yellowish-red (5YR 5/8) mottles; when dry, these mottles are pale yellow (2.5Y 8/4); clay loam; some pieces of undecomposed organic matter; half ripe, can just be molded through fingers; many large crab holes (0.5 to 2 cm wide); sticky and plastic; gradual, smooth boundary to horizon below.
B_{22g} 22-57 inches 56-145 cm Lab. No. S29749	Very dark gray (N 3/); few, very fine, faint strong brown (7.5YR 5/6) mottles; silty clay; some pieces of undecomposed organic matter; half ripe, can just be molded through fingers; sticky and plastic.
Remarks	Very low pH and yellow mottles are typical cat clay characteristics, which develop upon oxidation.
Diagnostic horizons	Ochric epipedon, 0-5 inches (0-13 cm). Sulfuric horizon, 5-22 inches (13-56 cm).

Profile R1, Rokupr clay, oxidized phase

Classification: Typic Sulfaquept

Illinois Lab. No.	S29747	S29748	S29749
Depth of horizon (inches)	0-5	5-22	22-57
Horizon	A_1	B_{21g}	B_{22g}
Percent of entire sample > 2.0 mm.	0	0	0
Particle-size distribution of < 2 mm (%):			
Total sand 2.0-.05 mm.	14.9	22.4	15.2
Coarse silt .05-.02 mm.	8.0	9.8	9.2
Fine silt .02-.002 mm	24.5	30.1	31.4
Total silt .05-.002 mm	32.5	39.9	40.6
Total clay < .002 mm	52.6	37.7	44.2
Water-dispersible clay < .002 mm	14.8	10.5	4.8
Organic carbon (%)*	6.05	...	...
Exchangeable cations (me/100g soil)[a]:			
Ca	3.50	3.80	4.40
Mg	2.67	0.42	1.97
Al	1.44	4.33	4.77
Cation-exch. capacity (me/100g)	25.90	20.30	23.30
Water:ethanol extract (ppm):			
Ca	400	92	185
Mg	135	540	1,150
Mn	12	120	120
Fe	45	9,000	1,950
Al	16	2,450	460
pH H_2O	2.9	3.0	4.5
Soil test:			
Total P (ppm)	265	160	205
Total S(%)[b]	1.15	11.54	9.06

[a] 1.0N KCl extract instead of conventional NH_4OAc method.
[b] Analyses from C. Chavengsaksongkram *(15)*.
*Analyses by D.S. Amara.

Profile R2, Rokupr silty clay, reduced phase
Described by J. C. Dijkerman and D. H. Westerveld on May 5, 1967

Location	Rice Research Station, Rokupr. Pit R2 is in the middle of plot 54, 75 feet (23 m) east of Great Scarcies River. This area is not empoldered and does not become dry during the dry season.
Physiography	Tidal swamp.
Relief	Nearly level.
Vegetation	The land is plowed and ready for the next rice crop. The original vegetation was mangrove.
Drainage	Very poorly drained. Flooded daily at high tide. Brackish water was 5 inches below the surface during low tide when this soil description was written.
Parent material	Alluvium.
A_1 0-3 inches 0-8 cm Lab. No. S29750	Very dark grayish brown (10YR 3/2) with common medium and coarse, distinct, strong brown (7.5YR 5/6) mottles; silty clay; some undecomposed organic matter that is mainly roots; half ripe, can be molded through fingers; sticky and plastic; boundary to horizon below is clear and irregular because of plowing.
B_{2g} 3-26 inches 8-66 cm Lab. No. S29751	Very dark gray (N 3/); clay; some large remnants of mangrove vegetation; half ripe, can be molded through fingers; sticky and plastic. The color of the subsoil changes from very dark grayish brown (10YR 3/2) to very dark gray (N 3/) by exposing water-saturated subsoil clods to the air. This change is completed in about half a minute.
Diagnostic horizon	Ochric epipedon, 0-3 inches (0-8 cm).

Profile R2, Rokupr silty clay, reduced phase

Classification: Typic Sulfaquent

Illinois Lab. No.	S29750	S29751
Depth of horizon (inches)	0-3	3-26
Horizon	A_1	B_{2g}
Percent of entire sample > 2.0 mm	0	0
Particle-size distribution of < 2 mm (%):		
Total sand 2.0-.05 mm.	11.5	4.0
Coarse silt .05-.02 mm.	14.7	9.8
Fine silt .02-.002 mm	30.0	26.2
Total silt .05-.002 mm	44.7	36.0
Total clay < .002 mm	43.8	60.0
Water-dispersible clay < .002 mm	2.4	3.0
Organic carbon (%)*	6.13	...
Exchangeable cations (me/100g soil):[a]		
Ca.	3.00	4.90
Mg.	3.25	3.75
Al.	2.13	4.00
Cation-exch. capacity (me/100g)	20.00	24.60
Water:ethanol extract (ppm):		
Ca.	90	580
Mg.	420	800
Mn.	22	55
Fe.	135	420
Al.	24	125
pH H_2O.	4.3	2.1
Soil test:		
Total P (ppm)	500	235
Total S (%)[b]	1.87	5.18

[a]1.ON KCl extract instead of conventional NH_4OAc method.
[b]Analyses from C. Chavengsaksongkram (*15*).
*Analyses by D.S. Amara.

Profile T149, Sahama sand
Described by J. C. Dijkerman

Location	Torma Bum soil survey area; just before entering the village of Sahama, about 1 mile north of Gbamani. On aerial photograph 61-SL3-023, pit T149 is 8.8 cm west and 16.0 cm south of northeast corner mark.
Physiography	Beach ridge, about 8 miles from the coast and parallel to it.
Relief	The slope is very gentle, convex on a ridge about 1/8-mile wide.
Vegetation	Secondary bush with many oil palms.
Drainage	Well drained.
Parent material	Beach sand of Bullom deposits.
A_{11} 0-6 inches 0-15 cm Lab. No. S29722	Very dark grayish brown (10YR 3/2); sand; single grain to very weak medium and fine granular; very friable; many coarse, medium, and fine roots; many coarse, medium, and fine pores; gradual, smooth boundary to horizon below.
A_{12} 6-11 inches 15-28 cm Lab. No. S29723	Very dark grayish brown to dark brown (10YR 3/2-3/3); sand; single grain to very weak medium and fine granular and subangular blocky; very friable; many coarse, medium, and fine roots; many coarse, medium, and fine pores; gradual, smooth boundary to horizon below.
A_3 11-20 inches 28-51 cm Lab. No. S29724	Dark brown (10YR 3/3); sand; single grain to very weak medium and fine granular and subangular blocky; very friable; common medium and fine roots; many medium and fine pores; gradual, smooth boundary to horizon below.
B_1 20-31 inches 51-79 cm Lab. No. S29725	Dark yellowish brown (10YR 4/4); sand; single grain to very weak medium and fine granular and subangular blocky; friable; common medium and fine roots; many medium and fine pores; gradual, smooth boundary to horizon below.
B_{21} 31-40 inches 79-102 cm Lab. No. S29726	Brown to dark brown (7.5YR 4/4); sand; single grain to very weak medium and fine granular and subangular blocky; friable; common medium and fine roots; many medium and fine pores; gradual, smooth boundary to horizon below.
B_{22} 40-55 inches 102-140 cm Lab. No. S29727	Strong brown (7.5YR 5/6); loamy sand; single grain to very weak medium and fine granular and subangular blocky; friable; few medium and fine roots; common medium and fine pores.
Diagnostic horizons	Borderline umbric-ochric epipedon; umbric colors 0-20 inches (0-51 cm), but organic carbon content of the A_{12} horizon is below 0.6%.

Profile T149, Sahama sand

Classification: Typic Quartzipsamment

Illinois Lab. No.	S29722	S29723	S29724	S29725	S29726	S29727
Depth of horizon (inches)	0-6	6-11	11-20	20-31	31-40	40-55
Horizon	A_{11}	A_{12}	A_3	B_1	B_{21}	B_{22}
Percent of entire sample > 2.0 mm.	1	< 1	< 1	< 1	< 1	< 1
Particle-size distribution of < 2 mm (%):						
Very coarse sand 2.0-1.0 mm	1.4	1.1	0.8	1.6	2.6	0.9
Coarse sand 1.0-.5 mm.	27.8	28.3	27.3	36.6	41.5	28.1
Medium sand .5-.25 mm	28.0	25.9	26.5	27.3	26.0	29.0
Fine sand .25-.1 mm.	28.2	27.5	28.5	22.0	20.6	26.4
Very fine sand .1-.05 mm	7.2	7.4	7.8	4.6	4.2	5.5
Total sand 2.0-.05 mm	92.6	90.2	90.9	92.1	94.9	89.9
Total silt .05-.002 mm.	1.2	1.2	1.8	0.7	0.2	0.9
Total clay < .002 mm.	6.2	8.6	7.3	7.2	4.9	9.2
Water-dispersible clay < .002 mm.	2.9	5.2	3.6	4.7	1.4	5.4
Bulk density	1.4	1.6	1.7	1.7	1.8	1.9
Moisture: 1/3 atmos. (%).	4.1	4.4	5.2	5.1	5.1	5.0
15 atmos. (%).	2.8	3.1	3.4	3.2	3.8	3.6
Avail. moist.-hold. capacity[a].	0.02	0.02	0.03	0.03	0.02	0.03
Organic carbon (%)	0.90	0.52	0.78	0.55	1.66	0.29
Exchangeable cations (me/100g soil):						
Ca	0.10	0.15	0.13	0.10	0.41	0.10
Mg	0.10	...	0.02	0.03	0.31	0.05
K.	0.07	0.02	0.06	0.03	0.09	0.04
Na	0.08	0.06	0.03	0.06	0.10	0.06
Al	0.68	0.69	0.83	0.74	0.70	0.50
Cation-exch. capacity (me/100g).	3.29	2.07	3.22	2.36	5.22	2.64
Base saturation (%).	10.6	...	7.5	9.3	17.4	9.5
pH H_2O	4.9	4.8	4.6	4.7	4.3	5.1
pH KCl	4.0	4.2	4.0	4.2	3.7	4.4
Soil tests:						
K (lbs/A)	106	90	98	86	166	86
P_1 (lbs/A)	18	22	11	15	41	23
P_2 (lbs/A)	18	22	11	15	41	27

[a]Inches of available moisture-holding capacity per inch of soil.

Profile 145005, Segbwema gravelly sandy clay loam

Description after Sivarajasingham (*64*)

Location	On a very high hill on the right-hand side of the road from Mano Junction to Segbwema Junction. The path leading to the pit starts from the village of Niahun and goes southwards.
Physiography	Very high hills.
Relief	The pit is on the middle part of a very steep (42-percent), straight slope of a very high hill.
Vegetation	The land was in upland rice during 1965; in 1966 it was under a low succulent to woody herbaceous vegetation with many wild oil palms.
Drainage	Well drained.
Parent material	Residual, presumably from rock of granodioritic composition.
A_1 0-13 inches 0-33 cm Lab. No. S28564	Strong brown (7.5YR 5/6); gravelly sandy clay loam; strong fine subangular blocky and granular; medium density and porosity; friable, slightly sticky, slightly plastic; common fine and medium roots; clear, smooth boundary to horizon below.
B_{21} 13-28 inches 33-71 cm	Red to weak red (10R 4/6-4/4); heavy sandy clay loam, slightly gritty; strong medium subangular blocky; porous; friable, slightly sticky, slightly plastic; few fine roots; gradual, smooth boundary to horizon below.
B_{22} 28-60 inches 71-153 cm Lab. No. S28563	Red (2.5YR 4/6) with few coarse red (10R-7.5R 4/6) mottles; clay loam with fine white specks of decomposing feldspar indicating its saprolitic nature; strong medium subangular blocky; porous; friable, slightly sticky, slightly plastic; few fine roots; diffuse, smooth boundary to horizon below.
C_1 60-94 inches 153-239 cm Lab. No. S28562	Red (2.5YR 4/8 and 10R 4/8) in equal amounts present as coarse faint mottles; also contains white decomposing feldspar and black decomposing hornblende; sandy clay loam; weak fine subangular blocky; porous; nonsticky, slightly plastic; few fine roots.
Diagnostic horizons	Ochric epipedon, 0-13 inches (0-33 cm). Oxic horizon, 13-60 inches (33-153 cm) probable, but not fully documented.

Profile 145005, Segbwema gravelly sandy clay loam

Classification: Tropeptic Haplorthox (or Udoxic Dystropept)

Illinois Lab. No.		S28564	S28563	S28562
Depth of horizon (inches)		0-13	28-60	60-94
Horizon		A_1	B_{22}	C_1
Percent of entire sample > 2.0 mm.		22.8	11.4	8.5
Particle-size distribution of < 2 mm (%):				
Very coarse sand	2.0-1.0 mm	13.9	10.1	16.2
Coarse sand	1.0-.5 mm.	14.5	8.6	12.6
Medium sand	.5-.25 mm	9.4	5.6	5.8
Fine sand	.25-.1 mm.	11.5	8.8	8.5
Very fine sand	.1-.05 mm	7.0	8.4	8.6
Total sand	2.0-.05 mm	55.9	41.1	51.1
Total silt	.05-.002 mm.	17.3	25.1	25.5
Total clay	< .002 mm.	26.8	34.0	23.7
Water-dispersible clay	< .002 mm.	11.4	0.2	0.2
Bulk density		1.1	1.2	1.4
Moisture: 1/3 atmos. (%)		20.0	28.0	23.0
15 atmos. (%)		13.8	16.6	14.3
Avail. moist.-hold. capacity[a]		0.05	0.12	0.11
Organic carbon (%)		2.01	0.24	0.10
Exchangeable cations (me/100g soil):				
Ca		0.96	0.05	0.05
Mg		0.44	0.13	0.10
K		0.35	0.03	0.08
Na		0.06	0.04	0.07
Al		0.93	1.28	1.11
Cation-exch. capacity (me/100g)		10.65	6.86	6.00
Base saturation (%)		17.0	3.6	5.0
pH H_2O		4.7	5.2	5.5
pH KCl		3.8	4.0	4.0
Soil tests:				
K (lbs/A)		62	10	14
P_1 (lbs/A)		4	0	0
P_2 (lbs/A)		8	0	0
Total P (ppm)		240	...	...
Total CaO(%)		0.205	0.066	0.067
Total Fe_2O_3(%)		5.50	7.78	4.85
Total K_2O(%)		1.270	0.501	1.890

[a]Inches of available moisture-holding capacity per inch of soil, adjusted for the amount of > 2.0 mm material.

Profile N101, Taiama clay loam
Described by T.N. Lamboi on December 21, 1966

Location	At Njala University College, near the office of the Oil Palm Station, pit N101 is 227 feet (69 m) southwest and 26 feet (8 m) northwest of junction of road 6 and road 1. On aerial photograph 39-SL25-083, pit N101 is 8.3 cm west and 8.1 cm south of northeast corner mark.
Physiography	Drainageway on middle terrace of Taia River.
Relief	Gentle concave slope; bottom of drainageway.
Vegetation	Oil palm plantation.
Drainage	Poorly drained.
Parent material	Gravel-free alluvium.
A_1 0-13 inches 0-33 cm Lab. No. S29106	Very dark grayish brown (10YR 3/2); clay loam; very weak to weak fine, medium, and coarse angular to subangular blocky, breaking into weak to moderate fine, medium, and coarse granular; friable; many fine, medium, and coarse pores; many fine, medium, and coarse roots; gradual, smooth boundary to horizon below.
A_{3g} 13-31 inches 33-79 cm Lab. No. S29107	Dark gray (10YR 4/1) with a few fine, faint light gray (N 7/) mottles; sandy clay loam; very weak fine, medium, and coarse angular to subangular blocky, breaking into weak to moderate fine, medium, and coarse granular; friable; many fine, medium, and coarse pores; many fine and medium roots and common coarse roots; abrupt, smooth boundary to horizon below.
B_{21gt} 31-42 inches 79-107 cm Lab. No. S29108	Gray to light gray (10YR 6/1-7/1) with many medium and coarse distinct red (2.5YR 4/8) mottles, common medium and coarse distinct yellowish-brown (10YR 5/6-5/8) mottles, and few fine and medium distinct dark gray (10YR 4/1) mottles; sandy clay loam; very weak fine, medium, and coarse angular to subangular blocky, breaking into weak fine, medium, and coarse granular; friable; many fine, medium, and coarse pores; common fine and medium roots and few coarse roots; diffuse, irregular boundary to horizon below.
B_{22gt} 42-63 inches 107-160 cm Lab. No. S29109	Gray (10YR 6/1) with many fine, medium, and coarse prominent red (2.5YR 4/8) mottles, and common fine, medium, and coarse distinct yellowish-brown (10YR 5/8) mottles; sandy clay; very weak fine, medium, and coarse angular to subangular blocky, breaking into very weak fine, medium, and coarse granular; friable; many fine, medium, and coarse pores; few fine, medium, and coarse roots.
Diagnostic horizons	Umbric epipedon, 0-13 inches (0-33 cm). Argillic horizon, 31-63 inches (79-160 cm).

Profile N101, Taiama clay loam

Classification: Plinthic Umbric Paleaquult

Illinois Lab. No.	S29106	S29107	S29108	S29109
Depth of horizon (inches)	0-13	13-31	31-42	42-63
Horizon	A_1	A_{3g}	B_{21gt}	B_{22gt}
Percent of entire sample > 2.0 mm.	0	0	0	0
Particle-size distribution of < 2 mm (%):				
Very coarse sand 2.0-1.0 mm	0.3	0.6	0.7	0.6
Coarse sand 1.0-.5 mm.	0.6	1.5	2.0	1.8
Medium sand .5-.25 mm	2.5	6.3	6.4	6.6
Fine sand .25-.1 mm.	17.2	36.6	32.9	26.9
Very fine sand .1-.05 mm	10.7	17.2	14.2	13.1
Total sand 2.0-.05 mm	31.3	62.2	56.2	49.0
Coarse silt .05-.02 mm	6.5	5.3	4.3	4.0
Fine silt .02-.002 mm.	27.0	11.0	8.8	9.6
Total silt .05-.002 mm.	33.5	16.3	13.1	13.6
Total clay < .002 mm.	35.2	21.5	30.7	37.4
Water-dispersible clay < .002 mm	10.3	14.1	2.2	0.6
Bulk density	1.2	1.6	1.7	1.7
Moisture: 1/3 atmos. (%)	21.8	15.6	15.5	19.0
15 atmos. (%)	12.0	8.9	10.0	12.4
Avail. moist.-hold. capacity[a]	0.12	0.11	0.09	0.11
Organic carbon (%)	3.24	0.46	0.13	0.06
Exchangeable cations (me/100g soil):				
Ca	0.20	0.15	0.08	0.10
Mg	0.13	...	0.12	0.10
K	0.02	0.01	0.02	0.02
Na	0.06	0.03	0.03	0.03
Al	3.56	1.94	2.28	2.89
Cation-exch. capacity (me/100g)	14.15	5.14	5.00	6.36
Base saturation (%)	2.9	...	5.0	3.9
pH H_2O	4.4	4.2	4.4	4.7
pH KCl	3.6	3.4	3.2	3.3
Soil tests:				
K (lbs/A)	86	30	39	52
P_1 (lbs/A)	29	12	4	3
P_2 (lbs/A)	32	12	4	4
Total P (ppm)	300	...	...	...
Total CaO(%)	0.088	0.069	0.070	0.069
Total Fe_2O_3(%)	1.52	0.74	1.14	1.62
Total K_2O(%)	0.54	0.37	0.62	0.77

[a]Inches of available moisture-holding capacity per inch of soil.

Profile T183, Taso clay
Described by J. C. Dijkerman on March 4, 1966

Location	Torma Bum soil survey area, near the former sugar cane experimental plots; 528 feet (161 m) west of the former sugar cane office, and 898 feet (274 m) west of Sewa River. On aerial photograph 53-SL13-036, pit T183 is 12 cm west and 10 cm south of the northeast corner mark.
Physiography	Sewa River natural levee.
Relief	Convex 1-percent slope.
Vegetation	Predominantly tall elephant grass.
Drainage	Moderately well drained.
Parent material	Clayey alluvium.
A_1 0-6 inches 0-15 cm Lab. No. S28660	Black (10YR 2/1); clay; moderate very fine to coarse granular; friable; many fine and medium pores; many fine and medium roots; clear, smooth boundary to horizon below.
A_3 6-12 inches 15-30 cm Lab. No. S28661	Very dark grayish brown (10YR 3/2); clay; moderate coarse prismatic breaking into moderate medium to coarse angular blocks; firm; few medium and common fine pores; many fine and medium roots; clear, wavy boundary to horizon below.
B_{21} 12-22 inches 30-56 cm Lab. No. S28662	Yellowish brown (10YR 5/6) with common faint and distinct fine and medium strong brown (7.5YR 5/8) and yellowish-red (5YR 4/6) mottles; silty clay; moderate fine to very fine angular blocky; friable; many fine and medium pores; many fine and common medium roots; gradual, smooth boundary to horizon below.
B_{22} 22-35 inches 56-89 cm	Yellowish brown to light brown (10YR 6/4-2.5Y 6/4) with common to many distinct fine and medium strong brown (7.5YR 5/8) and yellowish-red (5YR 4/6) mottles; silty clay; moderate fine to very fine angular blocky; friable; many fine and medium pores; common fine and medium roots; gradual, smooth boundary to horizon below.
B_{23} 35-50 inches 89-127 cm Lab. No. S28663	Pale yellow (2.5Y 7/4) with many distinct fine and medium strong brown (7.5YR 5/8) and yellowish-red (5YR 4/6) mottles; silty clay; moderate very fine to fine angular blocky; friable; many fine and medium pores; few fine and medium roots.
Diagnostic horizons	Umbric epipedon, 0-12 inches (0-30 cm). Oxic horizon, 12-50 inches (30-127 cm).

Profile T183, Taso clay

Classification: Plinthic "Tropeptic" Umbriorthox

Illinois Lab. No.	S28660	S28661	S28662	S28663
Depth of horizon (inches)	0-6	6-12	12-22	35-50
Horizon	A_1	A_3	B_{21}	B_{23}
Percent of entire sample > 2.0 mm. . . .	<1	<1	0+	0+
Particle-size distribution of < 2 mm (%):				
Total sand 2.0-.05 mm	3.4	2.7	3.1	6.7
Total silt .05-.002 mm.	38.0	...	43.2	46.5
Total clay < .002 mm.	58.6	...	53.7	47.7
Water-dispersible clay < .002 mm	16.8	32.0	0.5	0.3
Bulk density	0.8	1.0	1.3	1.3
Moisture: 1/3 atmos. (%).	49.7	41.8	34.9	33.8
15 atmos. (%).	31.4	28.8	22.9	20.7
Avail. moist.-hold. capacity[a].	0.15	0.13	0.16	0.17
Organic carbon (%)	8.39	3.98	0.47	0.26
Exchangeable cations (me/100g soil):				
Ca	0.80	0.03	0.03	0.06
Mg	1.02	0.20	0.20	0.24
K.	0.44	0.15	0.06	0.09
Na	0.07	0.04	0.04	0.04
Al	4.39	3.89	1.56	1.61
Cation-exch. capacity (me/100g).	34.65	21.94	7.43	6.79
Base saturation (%).	6.7	1.9	4.4	6.3
pH H_2O	4.8	4.8	5.3	5.4
pH KCl	3.8	3.9	4.0	4.0
Soil tests:				
K (lbs/A).	280	146	86	82
P_1(lbs/A).	125+	10	3	7
P_2(lbs/A).	125+	13	6	14
Total P(ppm)	1,460	680	590	680
Total CaO(%)	0.196	0.132	0.114	0.143
Total Fe_2O_3(%)	6.85	7.50	5.70	7.10
Total K_2O(%)	1.550	1.520	1.740	2.200

[a]Inches of available moisture-holding capacity per inch of soil.

Profile P19, Timbo gravelly sandy clay loam

Described by J. M. Cawray, A. A. Thomas, and R. Miedema on March 27, 1968

Location	Topographic map of Sierra Leone, scale 1:50,000, sheet 43, coordinates $HE26_1-85_2$; near Timbo along the motor road from Makeni to Panlap.
Physiography	Dissected erosion surface.
Relief	Slope 6 percent to south.
Vegetation	Cassava and short weeds and grasses.
Drainage	Well drained.
Parent material	Gravelly weathering products of Precambrian granite and acid gneiss.
A_{11} 0-12 inches 0-30 cm Lab. No. S29818	Very dark grayish brown (10YR 3/2); gravelly sandy clay loam; weak fine subangular blocky; slightly hard, friable, slightly sticky, and slightly plastic; many macro- and mesopores; few fine distinct charcoal particles; common coarse and medium roots; 44% fine and medium, uncoated nodular, red, hardened plinthite glaebules, and a few decomposed rock fragments; clear, smooth boundary to horizon below.
A_{12} 12-19 inches 30-49 cm Lab. No. S29819	Dark brown (10YR 3/3); very gravelly sandy clay loam; weak fine subangular blocky; slightly hard, friable, slightly plastic; many macro- and mesopores; few fine distinct charcoal particles; common coarse, medium, and fine roots; 50% medium and fine, uncoated nodular, very hard, porous, yellow and red, decomposed rock fragments; clear, wavy boundary to horizon below.
AB 19-28 inches 49-70 cm Lab. No. S29820	Yellowish red (5YR 4/6); gravelly sandy clay loam; weak fine subangular blocky; friable, slightly sticky, and slightly plastic; many macro- and mesopores; few coarse, medium, and fine roots; 47% uncoated, very hard, porous, red and yellow, decomposed rock fragments; few feldspars and micas, especially in the decomposing rock pieces; gradual, wavy boundary to horizon below.
B_{21} 28-43 inches 70-110 cm Lab. No. S29821	Yellowish red (5YR 4/8); gravelly sandy clay loam; weak medium angular and subangular blocky; friable, slightly sticky, and slightly plastic; many macro- and mesopores; few coarse, medium, and fine roots; 44% coarse, medium, and fine, uncoated, soft to hard, porous, red and yellow, decomposed rock fragments; few micas and feldspars; diffuse, smooth boundary to horizon below.
B_{22} 43-70 inches 110-179 cm Lab. No. S29822	Yellowish red (5YR 5/8); gravelly sandy clay loam; weak medium angular blocky; sticky and plastic; common macro- and mesopores; few coarse, medium, and fine roots; 20% coarse and medium, uncoated, soft to hard, porous, red and yellow, decomposed rock fragments, with feldspars and micas.
Diagnostic horizons	Umbric epipedon, 0-19 inches (0-49 cm). Oxic horizon, 28-70 inches (70-179 cm) somewhat questionable because of the presence of primary minerals and evidence of rock structure. Cambic horizon, 19-70 inches (49-179 cm) if there is no oxic horizon between 28 and 70 inches.

Profile P19, Timbo gravelly sandy clay loam

Classification: Typic Umbriorthox (or Udoxic Dystropept)

Illinois Lab. No.	S29818	S29819	S29820	S29821	S29822
Depth of horizon (inches)	0-12	12-19	19-28	28-43	43-70
Horizon	A_{11}	A_{12}	AB	B_{21}	B_{22}
Percent of entire sample > 2.0 mm.	44.4	50.6	46.6	43.7	28.7
Particle-size distribution of < 2 mm (%):					
Very coarse sand 2.0-1.0 mm.	14.4	13.2	17.7	19.2	18.6
Coarse sand 1.0-.5 mm	8.3	8.9	10.1	8.3	7.2
Medium sand .5-.25 mm.	15.2	12.9	10.9	9.4	7.7
Fine sand .25-.1 mm	23.5	17.3	12.9	12.6	11.4
Very fine sand .1-.05 mm.	6.8	6.9	6.0	6.2	6.8
Total sand 2.0-.05 mm.	68.2	59.2	57.6	55.7	51.7
Total silt .05-.002 mm	11.7	12.6	11.7	13.6	14.6
Total clay < .002 mm	20.1	28.2	30.7	30.7	33.7
Water-dispersible clay < .002 mm	3.1	6.2	9.6	1.1	0.6
Bulk density	1.2	1.2	1.2	1.2	1.3
Moisture: 1/3 atmos. (%)	15.9	17.2	17.3	16.4	17.2
15 atmos. (%)	9.8	11.2	12.4	12.8	13.1
Avail. moist.-hold. capacity[a]	0.04	0.03	0.03	0.02	0.04
Organic carbon (%)	2.34	1.87	1.05	0.70	0.51
Exchangeable cations (me/100g soil):					
Ca	0.47	0.21	0.16	0.21	0.38
Mg	0.27	0.21	0.21	0.11	0.15
K	0.15	0.09	0.09	0.06	0.13
Na[b]	0.15	0.12	0.12	0.10	0.15
Al	0.82	1.09	0.43	0.31	0.24
Cation-exch. capacity (me/100g)	7.64	6.36	4.57	3.79	3.79
Base saturation (%)	13.6	9.9	12.7	12.7	21.4
pH H_2O	4.6	4.8	4.8	4.8	4.9
pH KCl	4.2	4.2	4.2	4.4	4.6
Soil tests:					
K (lbs/A)	166	125	106	102	118
P_1 (lbs/A)	28	8	4	3	2
Total CaO(%)	0.122	0.094	0.083	0.081	0.086
Total Fe_2O_3(%)	10.36	11.45	13.50	14.44	14.86
Total K_2O(%)	0.492	0.525	0.488	0.433	0.485

[a] Inches of available moisture-holding capacity per inch of soil, adjusted for the amount of > 2.0 mm material.

[b] Estimated values.

Profile P13, Tubum sandy loam

Described by J. M. Cawray, A. A. Thomas, and R. Miedema on March 23, 1968

Location	Topographic map of Sierra Leone, scale 1:50,000, sheet 43, coordinates $HE27_7-87_3$; on traverse E, 1,500 feet (457 m) from pit P7.
Physiography	Gently sloping terrace.
Relief	Slope 7 percent to NNW.
Vegetation	Tall elephant grass, medium trees, and many wild oil palms.
Drainage	Well drained.
Parent material	Alluvium or colluvium or a mixture of both, over weathering products of Precambrian granite and acid gneiss.
A_{11} 0-4 inches 0-11 cm Lab. No. S29813	Very dark brown (10YR 2/2); sandy loam; weak fine to medium subangular blocky; hard, friable, slightly sticky, and slightly plastic; many macro- and mesopores; few medium distinct charcoal particles; common coarse and medium, many fine roots; clear, smooth boundary to horizon below.
A_{12} 4-13 inches 11-34 cm Lab. No. S29814	Dark brown (10YR 3/3); sandy loam; weak coarse angular blocky; slightly hard, friable, slightly sticky, and slightly plastic; many macro- and mesopores; few medium distinct charcoal particles; few coarse, common medium, and many fine roots; clear, irregular boundary to horizon below.
B_1 13-25 inches 34-64 cm Lab. No. S29815	Dark yellowish brown (10YR 3/4); sandy clay loam; weak medium and coarse angular blocky; hard, firm, sticky, and plastic; many macro- and mesopores; few medium distinct charcoal particles; common coarse, medium, and fine roots; gradual, smooth boundary to horizon below.
B_{21} 25-33 inches 64-85 cm Lab. No. S29816	Dark yellowish brown (10YR 4/4); sandy clay loam; weak medium subangular blocky; hard, firm, sticky, and plastic; many macro- and mesopores; few medium distinct charcoal particles; common medium and many fine roots; abrupt, wavy boundary to horizon below.
IIB_{22} 33-54 inches 85-138 cm Lab. No. S29817	Yellowish brown (10YR 5/6); very gravelly sandy clay loam; weak fine subangular blocky; hard, firm, slightly sticky, and slightly plastic; many macro- and mesopores; few medium distinct charcoal particles; many fine roots; about 30 percent coarse quartz gravel and 40 percent medium black-coated and uncoated, nodular, dense, black to yellow, hardened plinthite glaebules.
Diagnostic horizons	Umbric epipedon, 0-13 inches (0-34 cm). Cambic horizon, 13-54 inches (34-138 cm).

Profile P13, Tubum sandy loam

Classification: Udoxic Dystropept

Illinois Lab. No.	S29813	S29814	S29815	S29816	S29817
Depth of horizon (inches)	0-4	4-13	13-25	25-33	33-54
Horizon	A_{11}	A_{12}	B_1	B_{21}	IIB_{22}
Percent of entire sample > 2.0 mm.	0.8	0.7	1.0	1.7	77.2
Particle-size distribution of < 2 mm (%):					
Very coarse sand 2.0-1.0 mm	2.5	3.0	3.2	4.1	8.7
Coarse sand 1.0-.5 mm.	14.5	16.2	15.4	14.4	18.5
Medium sand .5-.25 mm	27.6	26.4	22.5	21.1	19.7
Fine sand .25-.1 mm.	24.3	21.6	18.9	18.6	14.7
Very fine sand .1-.05 mm	9.0	8.1	7.8	8.3	6.8
Total sand 2.0-.05 mm	77.9	75.3	67.8	66.5	68.4
Total silt .05-.002 mm.	10.3	6.7	11.6	11.3	10.6
Total clay < .002 mm.	11.8	18.0	20.6	22.2	21.0
Water-dispersible clay < .002 mm	3.6	5.6	8.7	9.8	12.7
Bulk density	1.1	1.2	1.3	1.4	1.5
Moisture: 1/3 atmos. (%).	12.9	13.2	13.9	13.8	13.3
15 atmos. (%).	6.5	8.1	8.9	8.7	8.8
Avail. moist.-hold. capacity[a].	0.07	0.06	0.06	0.07	0.02
Organic carbon (%)	2.65	1.64	1.09	0.74	0.55
Exchangeable cations (me/100g soil):					
Ca	0.74	0.16	0.16	0.05	0.21
Mg	0.47	0.37	0.37	0.21	0.11
K	0.15	0.04	0.08	0.06	0.06
Na	0.14	0.09	0.12[b]	0.10[b]	0.10[b]
Al	0.67	1.12	1.30	1.29	0.98
Cation-exch. capacity (me/100g).	6.78	5.71	5.36	4.79	3.85
Base saturation (%).	22.1	11.6	13.6	8.8	12.5
pH H_2O.	4.9	4.7	4.7	4.6	4.7
pH KCl.	4.2	4.2	4.2	4.1	4.2
Soil tests:					
K (lbs/A).	190	86	65	52	65
P_1 (lbs/A)	21	8	5	4	4
Total CaO(%).	0.154	0.086	0.082	0.080	0.077
Total Fe_2O_3(%).	2.04	2.73	3.24	3.36	3.28
Total K_2O(%).	1.427	1.434	1.475	1.494	1.431

[a]Inches of available moisture-holding capacity per inch of soil, adjusted for the amount of > 2.0 mm material.

[b]Estimated value.

Profile 145010, Vaahun gravelly sandy clay loam
Description after Sivarajasingham (*64*)

Location	On a very high hill on the left side of the road from Mano Junction to Segbwema Junction after the village of Niahun. The foot path to the hill starts from the road at a point opposite the village school.
Physiography	Very high hills.
Relief	The pit is on the upper part of a very steep (38-percent) slope of a very high hill.
Vegetation	The area was in upland rice during 1965; in 1966 it was under low, succulent herbaceous bush.
Drainage	Moderately well drained.
Parent material	Residual from quartz-rich granite.
A_1 0-6 inches 0-15 cm Lab. No. S28561	Very dark gray (10YR 3/1); gravelly sandy clay loam, slightly gritty; few fine, very hard, fresh rock gravel and charcoal particles; strong fine granular and fine subangular blocky; friable, nonsticky, slightly plastic; common fine and medium roots; clear, smooth boundary to horizon below.
B_1 6-20 inches 15-51 cm Lab. No. S28560	Yellowish brown (10YR 5/6) with large fillings in old burrow holes of dark brown (10YR 3/3) material, presumably derived from A_1; gravelly clay; strong fine subangular blocky; friable, slightly sticky, slightly plastic; common fine and medium roots; gradual, smooth boundary to horizon below.
B_2 20-28 inches 51-71 cm Lab. No. S28559	Yellowish brown (10YR 5/6) with many medium, faint dark yellowish-brown (10YR 4/4) mottles; gravelly clay; strong fine subangular blocky; friable, slightly sticky, slightly plastic; few hard, decomposing and fresh rock gravel; soil material probably derived from rock weathered in place with a little local movement; common fine and medium roots; abrupt, irregular to wavy boundary to horizon below.
C_1 28-40 inches 71-102 cm	Soft, decomposing, coarse-grained, quartz-rich, gneissic granite containing feldspar, biotite, and coarse hornblende grains.
Diagnostic horizons	Ochric epipedon, 0-6 inches (0-15 cm). Cambic horizon, 6-28 inches (15-71 cm).

Profile 145010, Vaahun gravelly sandy clay loam

Classification: Typic Dystropept

Illinois Lab. No.		S28561	S28560	S28559
Depth of horizon (inches)		0-6	6-20	20-28
Horizon		A_1	B_1	B_2
Percent of entire sample > 2.0 mm		26.9	30.1	33.4
Particle-size distribution of < 2 mm (%):				
Very coarse sand	2.0-1.0 mm	20.5	11.5	8.2
Coarse sand	1.0-.5 mm	15.0	7.7	8.8
Medium sand	.5-.25 mm	7.0	4.1	4.4
Fine sand	.25-.1 mm	8.3	5.3	5.8
Very fine sand	.1-.05 mm	5.6	3.6	4.8
Total sand	2.0-.05 mm	56.4	32.1	31.7
Total silt	.05-.002 mm	14.5	11.1	13.2
Total clay	< .002 mm	29.1	56.8	55.1
Water-dispersible clay < .002 mm		6.5	24.0	15.3
Moisture: 1/3 atmos. (%)		19.4	26.1	28.1
15 atmos. (%)		14.7	20.5	21.1
Organic carbon (%)		3.80	1.10	0.90
Exchangeable cations (me/100g soil):				
Ca		5.18	1.17	1.05
Mg		1.51	0.60	0.52
K		0.55	0.06	0.07
Na		0.06	0.07	0.08
Al		0.31	2.33	1.83
Cation-exch. capacity (me/100g)		18.79	15.01	16.95
Base saturation (%)		38.9	12.7	10.1
pH H_2O		5.3	4.8	5.0
pH KCL		4.4	3.8	3.9
Soil tests:				
K (lbs/A)		...	9	1
P_1 (lbs/A)		4	1	1
P_2 (lbs/A)		9	3	2
Total P (ppm)		310	200	...
Total CaO(%)		1.190	0.566	0.743
Total Fe_2O_3(%)		5.80	7.05	7.50
Total K_2O(%)		0.716	0.510	0.250

APPENDIX C. AMOUNT AND CHARACTERIZATION OF THE CLAY FRACTION IN SELECTED SOILS IN SIERRA LEONE

Information given in the left-hand portion of Table I in Appendix C indicates the activity of the clay and the ease with which it disperses in water. This information is especially useful in classifying the soil series into higher categories according to *Soil Taxonomy* (*69*), as discussed in Section 4:12.

Estimates of amounts of different kinds of clay minerals were made primarily on X-ray diffractograms of glycolated, Mg-saturated, and K-saturated orientated clays on glass slides, using Cu Kα radiation at 35 kv and 15 ma (See also Table 3, pages 20 and 21). Other helpful analyses for estimating the kinds and amounts of clay minerals included the following:

— Cation-exchange capacity of the clay fraction by saturating the clay with 1N neutral ammonium acetate and removing excess salts on ceramic plates prior to distillation.

— Thermal gravimetric analyses (TGA) by weighing clay samples in an oven at hundred-degree intervals from 100° to 600° C.

— Differential thermal analyses (DTA) of a few key clay samples to check especially for kaolinite and gibbsite.

The composition of the clay fraction (< 0.002 mm) was determined primarily by measuring the areas under peaks of diffractograms of Mg-saturated samples (peak heights, in counts per second, were also compared). For illite, these were checked against total K_2O analyses of the clay fraction, where available. It is generally recognized (*47*) that kaolinite content tends to be overestimated from diffractograms because of the high intensity of their diffraction patterns. Therefore, the Mg-saturated area estimates for kaolinite content were reduced, usually 10 to 20 percent, on the basis of regressions between the content of kaolinite estimates from Mg-saturated area diffractograms versus weight loss from heat at 350° to 550° C. When the percent kaolinite estimates were reduced accordingly, estimates for the other clay materials were correspondingly increased to total 100 percent. In general, the reductions in kaolinite estimates for clay samples that contained interstratified materials were less than for samples that did not contain interstratified material.

The following clay minerals occurred in the soil samples studied: kaolinite, gibbsite, quartz, goethite, chlorite, illite, and an assemblage of interstratified minerals with 2d spacings of 10, 12, 14, and 24 Å (right-hand portion of Table I). According to Lucas (*47*), 10 Å illite interstratified with 14 Å chlorite gives a 24 Å mineral (10-14C) that is stable and unaffected by glycerol or heat treatment. We have found that potassium treatment likewise does not affect this mineral. Illite interstratified with 14 Å vermiculite gives a mineral (10-14V) that is unaffected by glycerol treatment but that decreases to 10 Å on heating to 550° C (*47*); we have further found that potassium treatment also collapses this mineral to 10 Å. Diffractograms show that the interaction of 10 Å illite with a 14 Å mineral — chlorite or vermiculite or both — is common in Sierra Leone soils and gives a sequence of 10, 12, 14, and 24 Å spacings. However, the proportion of 10 Å versus 14 Å material available influences the resultant assemblage of pure clays with these spacings and the interstratified combinations. For example, if all 10 Å material reacts with excess 14 Å material, no pure 10 Å material (illite) will remain, but 24 Å, 14 Å, and second-order 12 Å lines occur. Likewise, if all of the 14 Å material is interstratified, no pure chlorite (14 Å) will be evident. Vermiculite as a constituent of interstratification is common, but it is found only in trace amounts as an individual mineral.

Gibbsite is present in many of the soils; however, a limited number of DTA analyses showed lower amounts than the X-ray diffraction analyses. The problem of evaluating small percentages of gibbsite, primarily on the 4.8 Å diffraction line, is confounded by the 5.0 Å line of illite and a 4.7 Å line of chlorite. Therefore, when illite and chlorite are present in considerable amounts, the gibbsite values listed are probably maximum values.

Lucas (*47*) identified sepolite in Triassic clays, primarily on a sharp 12 Å line. It must be pointed out, however, that many of the soil clays, particularly in the Rokel River Series in Area G* in Sierra Leone, exhibit a 12 Å peak along with lines from kaolinite, illite, and chlorite that could mask the several diagnostic lines of sepolite. Therefore, sepolite could not definitely be ruled out as a constituent of these soils. Because interlayering is so pronounced, the 12 Å line seems to be more a second-order spacing of a 24 Å line rather than the mineral sepolite.

The amount of amorphous material in the clay fraction was not considered in this study. No alkali or reductant-base extractions or electron micrographs were made that would help evaluate the presence of amorphous minerals, which may occur in significant amounts.

The clay fraction (< 0.002 mm) of selected samples was analyzed for total potassium, iron, aluminum, and titanium by X-ray spectroscopy (Table II). The K_2O content (x 10) was especially helpful in estimating the amount of illite in the clay fraction. The clay was prepared by fusing 0.1 g of hydrogen-saturated clay with 0.1 g of La_2O_3 and 0.8 g $Li_2B_4O_7$ in graphite crucibles, followed by grinding and pressing.

Table I. Amount and characterization of the clay fraction (< 0.002 mm) in selected soils in Sierra Leone

Soil prov., Fig. 8	Soil series and profile no.	Depth, inches	Horizon	Clay (%)	Ratio I/E clay[a]	W.-d. clay (%)[b]	Ratio C/W clay[c]	2.5 x % 15 atm. H_2O	Me. extr. bases + Al x 100 / % clay[d]	Me. CEC x 100 / % clay[d]	Cation exch. cap., me/100g	Composition of the clay fraction: Quartz, %	Goethite, %	Gibbsite, %	Kaolinite, %	Illite, %	Chlorite, %	Interstratified 10-14C, 10-14V: Kind[e]	%
B*	*Sandy beach ridges*																		
	Sahama T149	0-6	A11	6.2		2.9	2.1	7.0	14.7	47.0	21.4	7	6	15	64		8		
		6-11	A12	8.6		5.2	1.7	7.8		24.1	22.9	8	7	16	60		9		
		11-20	A3	7.3		3.6	2.0	8.5	12.6	37.9	27.1	6	4	17	63	3	7		
		20-31	B1	7.2	1.0	4.7	1.5	8.0	12.0	29.5	22.3	5		12	72		11		
		31-40	B21	4.9	0.7	1.4	3.5	9.5	16.9	54.9	22.4	8		16	68		8		
		40-55	B22	9.2	1.3	5.4	1.7	9.0	8.2**	28.7	21.5	6	4	16	67		7		
	Gbamani T165	0-16	A21	1.3		0.6	2.2	2.0	167.0	64.5		46		9	39	6			
		16-41	A22	1.3		1.7	0.8	1.5	330.0	42.7	12.6	30		8	50	6	3	C	3
		41-48	B2h	5.6	4.3	2.3	2.4	10.8	13.8	83.4	33.3	13		5	67	6	5	C	4
		48-80	B21r	8.8	6.8	1.1	8.0	9.2	6.4**	31.8	4.9	16		19	65				
		80-120	C	11.1		0.6	18.5	10.0	6.8**	19.9	25.5	8		15	64	5	4	C	4
C*	*Tidal swamps*																		
	Rokupr, oxidized, R1	0-5	A1	52.6		14.8	3.6			49.2		6		4	75	3	6	C	6
		5-22	B21g	37.7	0.7	10.5	3.6			53.8		5		5	78	3	5	C	4
		22-57	B22g	44.2	0.8	4.8	9.2			52.7		6		4	78	3	6	C	3
	Rokupr, reduced, R2	0-3	A1	43.8		2.4	18.2			45.7		3	2	5	77	3	5	C	5
		3-26	B2g	60.0	1.4	3.0	20.0			41.0		5		6	75	3	6	C	5
D*	*Alluvial floodplain grasslands*																		
	Taso T183	0-6	A1	58.6		16.8	3.5	78.5	8.6	44.1	31.6	5	1	11	68	3	7	C	5
		6-12	A3			32.0		72.0	6.0**	30.5	20.7	5	2	13	60	4	9	C	7
		12-22	B21	53.7		0.5	107.4**	57.2	3.3**	13.0**	12.4	6	2	13	65	5	3	C	6
		35-50	B23	47.7		0.3	159.0**	51.8	3.9**	13.1**	14.0	6	3	13	67	5	2	C	4
	Gbehan T187	0-5	A1	54.5		15.9	3.4	92.8	6.1	50.0	18.1	3		8	69	4	14	C	2
		5-11	A3g	69.4		45.0	1.5	80.0	8.9**	38.2	22.7	4		12	64	3	14	C	3
		11-14	B1g	63.4	0.9	48.2	1.3	64.0	7.2**	17.6	13.8	5		17	63	4	6	C	5
		23-52	B22g	63.6	0.9	1.4	45.4**	67.0	10.1	14.3**	9.1	7		18	62	5	3	C	5
G*	*Rokel River Series, Njala area*																		
	Upland and colluvial footslopes																		
	Momenga N123	0-3	A1	44.6		25.6	1.7	53.0	15.2	39.8	26.0	12		5	57	14	3	V	9
		3-9	A3	53.8		38.6	1.4	52.5	13.5	28.4	27.6	11		5	51	11	4	V	18
		9-33	B2	54.4	1.0	38.0	1.4	52.8	16.2	28.8	28.9	7		7	63	5	3	V	15
		33-40	IIB3	52.2		39.5	1.3	51.2		39.0	22.3	6		4	60	11	5	V	14
		40-62	IIC	40.6		28.6	1.4	26.3	24.7	32.0	15.9				54	46			
	Momenga N86	0-6	A1	25.2		18.9	1.3	32.2	14.7	37.7	19.0	11	1	5	42	5	8	V	28
		6-16	A3	30.4		26.3	1.2	31.0	13.5	28.1	21.5	6	1	7	46	7	7	V,C	26
		16-24	B1	41.1	1.4	31.3	1.3	41.2	11.7	24.6	18.9	5	1	6	43	5	6	V,C	34
		24-38	IIB21	45.4		15.8	2.9	45.8	15.6	27.3	18.5	12	2	5	44	4	8	V	25
		38-50	IIB22	46.6		19.8	2.4	49.2	18.7	30.9	26.3	11	3	4	53	5	5	V	19
		50-63	IIB3	47.8		21.2	2.3	52.0	22.3	32.8	23.4	18	2	3	50	6	3	V	18
	Momenga N44	0-7	A1	19.2		3.1	6.2		30.9	70.3	25.1	9	2	5	50	10	6	V	18
		7-15	A3	33.7		13.9	2.4		14.0	27.6		7	3	10	43	4	9	C,V	24
		15-33	B21	51.8	1.5	38.8	1.3		17.2	24.1	19.8	12	2	9	45	5	5	V,C	22
		33-42	IIB22	53.6		25.2	2.1	60.0	13.7	28.8		6	2	6	51	5	7	C,V	23
		42-57	IIB23	53.1		8.6	6.2	57.5	23.0	30.6	23.6	12	3	7	47	5	5	V	21
		57-69	IIB24	46.6		3.0	15.5	53.0	24.9			7	3	5	51	4	5	V	25

(Footnotes given at end of table.)

	Njala N109	0-14	A1	35.7		15.7	2.3		10.5	37.0	26.0	2	1	6	65	1	11	C	14
		14-21	A3	50.6		41.4	1.2	49.8	6.6**	19.1	27.7			3	71	2	12	C	12
		21-49	B21t	60.5	1.2	27.5	2.2	53.5	3.8**	12.8**	18.4		3	7	68	1	9	C	12
		49-62	B22t	58.7	1.2	1.5	39.1**	55.0	4.1**	12.7**	15.5	3	2	5	70	3	7	C	10
	Njala N108	0-4	A1	19.2		3.7	5.2	21.5	15.3	49.5	28.2	3		4	61	4	13	V,C	15
		4-14	IIA3	24.5		8.7	2.8	22.2	9.1**	26.5	24.1	1	1	6	60	2	16	C	14
		14-24	IIB1t	29.8	1.2				6.3**	17.2	20.6	3	1	7	58	1	15	C	15
		24-35	IIB21t	38.6	1.6	25.2	1.5	33.8	4.3**	15.5**	22.4	3	2	6	60	2	11	C	16
		35-57	IIIB22	37.0		2.5	14.8	37.2	4.2**	18.1	18.7	5	2	8	68	1	7	C	9
	Mokonde N42	0-5	A1	11.9		9.2	1.3	17.8	16.1	41.0	25.6	3	2	8	49	4	14	C	20
		5-15	A3	19.2		12.5	1.5	18.8	6.4**	24.9		4	1	9	50	2	15	C	19
		15-30	IIB21	23.8		23.6	1.0	25.0	8.3**	17.4	21.4	3	2	10	49	3	12	C	21
		30-39	IIIB22	34.2		27.8	1.2	33.0	6.2**	19.2	22.1	3	1	9	58	2	8	C	19
		39-60	IIIB23	32.3		10.1	3.2	31.0	8.5**	19.0	20.1	3	2	9	51	5	10	C	20
		60-67	IIIB24	35.1		1.7	20.6**	36.2	12.6	27.8	21.7	2	1	8	56	4	9	V,C	20
	Bonjema N39	0-4	A1	13.0		5.4	2.4	16.5	14.9	51.1		7		13	40	6	13	C,V	21
		4-16	A3	16.4		11.0	1.5	16.2	8.5**	24.0		3		10	50	1	14	C,V	22
		16-25	81t	22.4	1.4	19.9	1.1	23.0	11.1	19.9		6	1	12	46	3	9	C,V	23
		25-33	IIB21	32.0		28.6	1.1	31.8	11.9	21.0		5	2	11	44	3	10	C,V	25
		33-57	IIIB22	39.4		13.9	2.8	39.0	12.3	25.0	24.0	3	1	8	51	3	7	V,C	27
		57-70	IIIB23	46.5		4.6	10.1	45.2	22.3	28.3	24.1	10	2	7	51	6	5	V	19
	Bonjema N105	0-20	A1	12.1		5.1	2.1	14.0	13.2	41.4	31.3	4		6	51	3	20	C,V	16
		20-32	Blt	21.0	1.7	16.6	1.3		8.6**	22.1	22.0			7	58	1	19	C	15
		32-40	IIB21	29.2		24.7	1.2	27.0	7.3**	19.1	21.4	3	1	6	62	1	15	C	12
		40-50	IIIB22	31.6		23.5	1.3	30.0	8.2**	19.4	21.3	3	2	6	59	2	17	C	11
		50-60	IIIB23	36.7		5.5	6.7	34.0	10.3	22.0	22.0	4	1	5	60	2	16	C,V	12
	Pelewahun N47	0-11	A1	23.0		11.5	2.0	24.2	14.0	42.2	27.4	6		14	38	2	20	C	20
		11-17	B1	24.6	1.1	23.6	1.0	22.0	15.7	29.3		5		9	46	1	16	C	23
		17-25	B21t	32.5	1.4	30.6	1.1	28.5	17.9	25.5	17.7	10		11	38	3	15	V,C	23
	channel	25-41	IIB22t	50.1		46.6	1.1	49.0	12.1	26.5		9		9	40	5	14	V,C	23
	matrix	25-41	IIB22t	39.6		7.4	5.4	35.5	16.4	24.2	17.6	11		6	46	11	10	C,V	16
		41-72	IIIB23t	53.4		35.0	1.5	51.0	17.4	23.7	15.9	15	1	6	46	10	8	V	14
	Pelewahun N106	0-15	A1	15.4		10.2	1.5	15.5	12.6	37.8	29.8	4		9	43		37	C	7
		15-26	B1gt	27.5	1.8	25.1	1.1	24.8	8.1**	20.5	24.7	4		7	53		22	C	14
		26-41	B21gt	35.9	2.3	22.0	1.6	30.8	7.9**	18.7	22.9	4		8	55		23	C	10
		41-58	IIB22g	27.3		13.6	2.0	28.8	11.9	27.0	24.2	6		4	56	1	22	C	11
G*	*Stream terraces*																		
	Nyawama N100	0-21	A1	23.1		4.2	5.5	22.8	9.7	29.1	23.8	3		9	76	2	10		
		21-31	A3	27.5		10.8	2.5	26.2	7.5**	17.9	17.6			13	72	1	11	C	3
		31-42	B21	30.6	1.1	14.2	2.2	28.0	5.5**	15.2**	15.7			10	75	2	8	C	5
		42-60	B22t	34.8	1.3	12.0	2.9	30.8	4.7**	13.3**	15.4	4		15	65	1	10	C	5
	Nyawama N71	0-11	A1	37.1		8.7	4.3	40.0	5.9	25.6	23.7	6		9	77		8		
		11-17	B1	40.7	1.1	20.2	2.0	38.2	4.9**	15.5**		5		11	77	1	6		
		17-26	B21t	47.3	1.3	13.3	3.6	42.5	3.4**	11.9**	15.0	4		11	72	3	6	C	4
		26-50	B22t	50.9	1.4	0.8	63.6**	47.8	2.8**	11.2**	15.4	5		14	72	2	7		
	Nyawama N15	0-5	A1	23.6		7.6	3.1	30.0	13.7	34.3	15.8	5		9	73	4	5	C	4
		5-14	A3	32.4		16.8	1.9	31.0	6.3**	17.0	17.8	5		7	76	4	4	C	4
		14-33	B21t	40.8	1.3	16.8	2.4	36.0	4.8**	12.6**	16.7	6		8	75	4	4	C	3
		33-50	B22t	45.8	1.4	0.4	114.5**	43.5	3.6**	12.3**	17.2	8		11	74	3	4		
	Kania N70	0-12	A1	33.4		15.4	2.2	38.0	4.1	29.1	25.6	4		12	72		12		
		12-16	A3	35.6		26.4	1.3	35.0	4.8**	11.8**	20.3	6		14	68	2	10		
		16-24	B21t	53.5	1.5	1.0	53.5**	46.2	3.8**	11.9**	18.3	4		16	68	1	8	C	3
		24-39	B22t	56.1	1.6	0.8	70.1**	48.5	3.6**	12.1**	20.0	4		11	70	2	9	C	4
		39-56	B23t	55.9	1.6	0.7	79.9**	51.5	3.9**	12.5**	15.5	3		12	71	3	7	C	4

(Footnotes given at end of table.)

Table I (continued).

Soil prov., Fig. 8	Soil series and profile no.	Depth, inches	Horizon	Clay (%)	Ratio I/E clay[a]	W.-d. clay (%)[b]	Ratio C/W clay[c]	2.5 x % 15 atm. H_2O	Me. extr. bases + Al x 100 / % clay[d]	Me. CEC x 100 / % clay[d]	Cation exch. cap., me/100g	Quartz, %	Goethite, %	Gibbsite, %	Kaolinite, %	Illite, %	Chlorite, %	Interstratified 10-14C, 10-14V Kind[e]	Interstratified %
	Tsiama	0-13	A1	35.2		10.3	3.4	30.0	11.3	40.2	23.9	4		10	52	1	23	C	10
	N101	13-31	A3g	21.5		14.1	1.5	22.2		23.2	26.7	4		6	58	1	24	C	7
		31-42	B21gt	30.7	1.4	2.2	14.0	25.0	8.2**	16.3	20.0	3		4	74	2	10	C	7
		42-63	B22gt	37.4	1.7	0.6	62.3**	31.0	8.4**	17.0	17.5	3		6	67	3	12	C,V	9
G*	*Alluvial floodplains*																		
	Pujehun	0-4	A1	20.4		3.6	5.7	28.2	6.7	31.4	21.2	5		11	69		10	C	5
	N80	4-12	A3	22.6		10.4	2.2	23.8	5.3**	20.4	17.9	6		14	70		6	C	4
		12-31	B21	16.7	0.7	10.7	1.6	18.2	4.5**	15.3**	15.0	4	4	18	66	2	3	C	3
		31-55	B22	34.7	1.5	0.7	49.6**	36.5	3.3**	12.1**	12.7	4	2	12	72	3	4	C	3
	Gbesebu	0-4	A1	49.4		20.4	2.4	64.2	4.6	29.5	28.2			14	76	4	6		
	N125	4-7	A3	59.7		36.6	1.6	66.0	3.6**	19.2	23.8	5		12	71	3	5	C	4
		7-19	B21	61.2	1.0	34.1	1.8	67.5	3.1**	13.8**	22.0			14	74	2	4	C	6
		19-25	B22b	60.6	1.0	37.2	1.6	68.2	3.5**	14.0**	23.8	4		13	73	2	4	C	4
		25-63	B23	58.6	1.0	2.6	22.5**	66.0	3.7**	13.4**	20.0	4		12	75	2	4	C	3
	Gbesebu	0-7	A1	45.8		10.4	4.4	58.2	9.6	33.5	26.1	4	2	10	71	3	6	C	4
	N13	7-42	B21	53.6	1.2	15.2	3.5	58.2	4.2**	14.8**	23.5	4	3	13	70	3	5	C	2
		42-50	B22	42.0	0.9	1.5	28.0**	38.8	4.7**	15.3**	20.8	5	3	13	69	3	4	C	3
	Mokoli	0-6	A1	57.2		32.2	1.8	70.5	5.3	32.0	21.2	4		12	70		10	C	4
	N14	6-15	A3	66.6		50.4	1.3	68.0	4.2**	17.0	20.8	5		14	71	1	6	C	3
		15-27	B21	62.7	0.9	2.2	28.5**	69.0	3.5**	13.1**	19.2	7		11	72	2	5	C	3
		27-60	B22	56.4	0.8	1.0	56.4**	64.8	3.5**	13.0**	18.5	4		12	71	3	6	C	4
J*	*Granite and acid gneiss, Makeni area*																		
	Upland and colluvial footslopes																		
	Timbo	0-12	A11	20.1		3.1	6.5	24.5	7.6	31.2		5	10	30	42	5	4	C	4
	P19	12-19	A12	28.2		6.2	4.5	28.0	6.1**	22.6			7	31	53	1	8		
		19-28	AB	30.7	1.1	9.6	3.2	31.0	3.3**	14.7**			9	38	46	3	4		
		28-43	B21	30.7	1.1	1.1	27.9**	32.0	2.5**	11.8**			10	27	55	8			
		43-70	B22	33.7	1.2	0.6	56.2**	32.8	3.1**	11.2**			11	28	61				
	Makeni	0-10	A1	33.1		6.9	4.8	39.8	13.4	35.5				11	84		5		
	P2	10-20	B21t	56.2	1.7	18.6	3.0	54.2	4.0**	14.5**		3		14	71	3	6	C	3
		20-67	B22t	51.8	1.6	1.7	30.5**	59.2	2.9**	8.9**		4	7	14	71	2	2		
	Mabassia, shallow	0-7	A11	22.9		4.9	4.7	29.2	13.6	42.0		7	4	23	58	2	4	C	2
	P71	7-25	A12	31.1		7.7	4.0	31.5	5.2**	25.4		5		23	65	2	3	C	2
		25-39	IIB1	22.9		10.4	2.2	23.2	4.8**	19.7		3	4	19	60	5	5	C	4
		39-65	IIB2	24.2		2.5	9.7	24.5	3.2**	8.7**		4	2	14	68	3	6	C	3
	Mabssia, deep	0-6	A11	19.9		5.0	4.0	22.5	13.4	34.3		4	6	19	63	4	4		
		6-13	A12	31.9		17.0	1.9	30.2	5.9**	24.8		6	5	21	60	4	4		
	P108	13-26	B1	35.3	1.1	11.5	3.1	33.2	4.2**	22.2		3	5	22	63	4	3		
		26-35	B21t	39.0	1.2	0.9	43.3**	34.5	2.6**	14.6**		4	3	19	62	4	5	C	3
		35-59	B22t	38.3	1.2	0.3	127.7**	35.0	2.4**	10.6**		3	4	20	63	3	3	C	4
	Bosor	0-9	A11	17.3		3.8	4.6	21.2	9.3	34.4				17	67	5	5	C	6
	P60	9-18	A12	24.5		6.6	3.7	25.0	5.8**	24.6			3	23	68	3	3		
		18-24	B21	24.6	1.0	10.2	2.4	24.0	4.7**	18.3			3	24	72	1			
		24-43	B22	27.8	1.1	11.0	2.5	26.0	4.4**	14.6**		5	7	20	60	3	2	C	3
		43-51	IIB23	32.1		4.8	6.7	30.8	2.7**	15.1**		5	5	24	66				
	Tubum	0-4	A11	11.8		3.6	3.3	16.2	13.4	41.9		9		14	67	6	4		
	P13	4-13	A12	18.0		5.6	3.2	20.2	8.8**	28.3		7		18	67	5	3		
		13-25	B1	20.6	1.1	8.7	2.4	22.2	9.1**	24.1		5		13	72	5	3	C	2
		25-33	B21	22.2	1.2	9.8	2.3	21.8	7.7**	21.6		5		12	71	7	3	C	2
		33-54	IIB22	21.0		12.7	1.7	22.0	6.6**	17.5		4		12	74	5	3	C	2

(Footnotes given at end of table.)

	Panlap	0-11	A11	11.0		2.3	4.8	15.5	12.8	23.5			12	80	2	6		
	P1	11-23	A12	10.7		5.7	1.9	13.8	13.0	21.7	5		14	71	4	6		
		23-37	AC	11.8		9.4	1.3	14.8	9.5**	12.1**	4		13	76	4	3		
		37-60	Cg	12.5		11.8	1.1	16.0	7.8**	10.7**	4		6	82	4	2	C	2
	Mankane	0-6	A1	12.7		4.3	3.0	18.0	8.5	23.4			13	77	5	5		
	P8	6-21	Bg	13.0		12.3	1.1	15.5	5.9**	15.7**	7		13	70	5	5		
		21-25	Cg	10.4		10.4	1.0	11.8	6.6**	15.2**	5		11	75	5	4		
	Masheka	0-16	A11	16.4		3.7	4.4	22.5	13.0	39.1			12	74	4	5	C	5
	P49	16-26	A12	25.0		7.4	3.4	23.0	7.4**	23.4	7		21	63	4	2	C	3
		26-38	B21	24.4	1.0	13.4	1.8	25.0	5.5**	16.3	5		17	73	2	3		
		54-68	IIB23	28.4		1.6	17.8	27.0	3.7**	14.0**			17	75	5	3		
	Masuba	0-7	Ap	23.4		14.5	1.6	25.2	7.7	22.7	6		10	71	5	4	C	4
	P9	7-22	B1	26.8	1.1	14.5	1.8	25.2	5.6**	14.1**	5		9	77	4	3	C	2
		22-67	B2	25.7	1.1	2.5	10.3	25.8	5.9**	12.2**	7		12	71	5	2	C	3
J*	*Alluvial floodplains*																	
	Makundu	0-8	A11	46.9		12.7	3.7	72.8	8.0	32.4			10	73	7	5	C	5
	P104	8-16	A12	46.8		9.0	5.2	72.4	3.6**	27.2	5		12	76	2	3	C	2
		16-21	AB	49.8		27.9	1.8	67.8	3.8**	23.3	3		11	75	3	4	C	4
		21-28	B1	59.8	1.2	1.3	46.0**	64.5	3.3**	15.0**	7	2	11	73	3	1	C	3
		28-43	B21	61.3	1.2	0.5	122.6**	64.5	2.2**	13.7**	5		12	76	3	2	C	2
		43-74	B22	60.4	1.2	1.0	60.4**	63.0	2.4**	6.0**	5	3	10	77	3		C	2
L*	<u>*Granite and acid gneiss in the upper Moa Basin, Kenema area*</u>																	
	Upland and colluvial footslopes																	
	Vaahun	0-6	A1	29.1		6.5	4.5	36.8	20.7	51.1			6	62	4	28		
	145010	6-20	B1	56.8	2.0	24.0	2.4	51.2	7.4**	26.4	4	1	7	72	4	12		
		20-28	B2	55.1	1.9	15.3	3.6	52.8	6.4**	30.8	3		8	74	4	11		
	Segbwema	0-13	A1	26.8		11.4	2.4	34.5	7.9	30.9	3	2	4	80	4	2	C	5
	145005	28-60	B22	34.0	1.3	0.2	170.0**	41.5	3.7**	16.5	6	4	2	82	4	2		
		60-94	C1	23.7		0.2	118.5**	35.8	3.9**	16.8	2	7	5	82	4			
	Manowa	0-10	A1	30.8		2.9	10.6	31.5	10.5	37.4		5	34	49	5	7		
	Kpuabu 1	10-21	A3	38.4		3.9	9.8	33.2	7.2**	24.2	5	6	20	55	5	9		
		35-70	B22t	47.8	1.2	0.6	79.7**	44.0	1.8**	12.6**		8	19	61	4	8		
	Baoma	0-5	A1	34.1		6.9	4.9	35.5	5.2	33.6	6	6	8	66	3	11		
	144801A	5-23	B2t	46.7	1.4	0.9	51.9**	41.8	2.2**	15.6**	4	6	9	70	3	8		
		23-43	IIB31	56.4		0.5	112.8**	50.0	1.3**	11.5**		6	9	75	3	7		
		43-67	IIB32	55.7		0.4	132.9**	53.0	1.7**	9.6**		7	10	72	3	8		
	Keya	5-11	A12	2.3		0.4	5.8	6.8	11.8	34.7	6	1	20	63	7		V	3
	145041	21-33	IIIC1g	18.2		15.4	1.8	20.5	7.4**	16.7	3	1	10	82	4			
	Pendembu	0-7	A1	19.7		2.7	7.3	22.8	16.6	41.4			14	73	6	7		
	Kpuabu 2	7-18	A3	23.8		6.8	3.5	21.8	10.8	20.1			15	75	5	5		
		37-54	B2t	30.3	1.3	0.3	101.0**	26.8	4.6**	11.6**	1		16	74	5	4		
	Kparva	0-9	A1	21.4		4.8	4.5	27.5	10.8	37.9	4		18	68	6	4		
	145042	9-39	B2t	38.6	1.8	22.1	1.7	35.8	6.7**	13.1**	5		13	73	5	4		
		39-66	B3t	37.7	1.8	0.6	62.8**	40.0	3.6**	13.2**	6		19	66	5	4		
		68-80	IIIC2	25.5		4.4	5.9	35.0	3.7**	31.6	1	6	24	52	5	3	C	9
L*	*Alluvial floodplains*																	
	Moa	0-6	A1	40.6		14.4	2.8	46.0	8.3	30.0	3		10	75	5	7		
	Kpuabu 3	6-21	B21	48.2	1.2	9.4	5.1	48.2	4.3**	16.5	4		11	77	4	4		
		31-59	B3	48.9	1.2	0.3	163.0**	51.0	3.1**	12.7**	5		12	73	4	6		

*See Section 4:1.

Diagnostic properties of an oxic horizon (69) = ≥ 20 (column with 163.0), < 10 (column with 3.1**), ≤ 16 (column with 12.7**)

[a]Ratio of clay in the illuvial horizon to the overlying eluvial horizon, where there is no lithologic discontinuity between them.

[b]Water-dispersible clay.

[c]Ratio of conventional clay to water-dispersible clay. A C/W ratio of 20 means 5% of the total clay is water-dispersible.

[d]Divisor is % conventional clay or 2.5 x % 15 atm. water, whichever value is higher.

[e]After Lucas (47). C,V and V,C are combinations of interstratified 10-14C and 10-14V, the predominant one being listed first.

Table II. Total analyses of the clay fraction (< 0.002 mm) in selected soils in Sierra Leone

Soil province (Fig. 8)	Soil series and profile number	Depth, inches	Horizon	Total analyses of clay, %				Loss on ignition, %
				K_2O	Fe_2O_3	Al_2O_3	TiO_2	
B*	*Sandy beach ridges*							
	Gbamani, T165	80-120	C	0.54	6.6	32.6	1.00	13.8
D*	*Alluvial floodplain grasslands*							
	Taso, T183	0-6	A1	0.58	7.3	33.8	0.84	13.5
		6-12	A3		7.7			
		12-22	B21		8.4			
		35-50	B23	0.47	7.9	35.6	0.80	13.1
	Gbehan, T187	0-5	A1	0.44	1.9	31.3	0.76	12.6
		5-11	A3g		2.5			
		11-14	B1g		2.8			
		23-52	B22g	0.52	4.6	38.4	0.87	15.2
G*	*Rokel River Series, Njala area*							
	Momenga, N44	0-7	A1	1.97	8.2	28.1	1.07	11.1
		15-33	B21		8.5			
		42-57	IIB23	2.22	10.6	32.4	1.29	10.5
	Mokonde, N42	0-5	A1	1.47	7.3	31.4	1.00	10.8
		39-60	IIIB23	1.76	11.7	34.0	1.11	11.7
	Bonjema, N39	0-4	A1	1.68	6.3	26.4	1.1	10.5
		25-33	IIB21		8.9			
		57-70	IIIB23	2.69	8.7	29.9	1.3	10.0
	Pelewahun, N47	0-11	A1	1.60	4.2	29.6	1.29	10.5
		17-25	B21t		4.8			
	matrix	25-41	IIB22t	2.22	8.1	29.9	1.20	10.2
		41-72	IIIB23t		5.3			
L*	*Granite and acid gniess in the upper Moa Basin, Kenema area*							
	Vaahun, 145010	0-6	A1	0.42	7.0	35.1	0.66	13.6
		6-20	B1		6.7			
		20-28	B2	0.36	6.6	40.4	0.60	14.2
	Segbwema, 145005	0-13	A1	0.41	8.3	35.5	0.58	13.2
		28-60	B22		9.5			
		60-94	C1	0.38	7.4	36.6	0.53	13.1
	Manowa, Kpuabu 1	0-10	A1	0.45	13.9	33.1	2.03	14.9
		10-21	A3		13.4			
		35-70	B22t	0.42	14.7	39.7	1.70	15.2
	Baoma, 144801A	0-5	A1	0.28	15.3	24.4	1.06	13.8
		5-23	B2t		17.9			
		43-67	IIB32	0.28	20.3	34.6	1.37	14.4
	Keya, 145041	5-11	A12	0.74	1.3	20.9	0.25	12.8
		21-33	IIIC1g	0.44	1.4	37.7	0.73	14.6
	Pendembu, Kpuabu 2	0-7	A1	0.57	7.2	34.6	1.35	13.4
		7-18	A3		7.7			
		37-54	B2t	0.48	6.6	36.2	1.31	14.6
	Kparva, 145042	0-9	A1	0.56	5.1	35.6	0.99	13.3
		9-39	B2t		5.8			
		39-66	B3t		4.2			
		68-80	IIIC2	0.52	5.4	37.9	1.06	15.2
	Moa, Kpuabu 3	0-6	A1		10.8			
		6-21	B21		10.7			
		31-59	B3		9.7			

APPENDIX D. ESTABLISHED SOIL SERIES IN SIERRA LEONE, SOIL PROVINCE IN WHICH THEY OCCUR, DIAGNOSTIC HORIZONS, THICKNESS OF GRAVEL-FREE LAYER, AND INDEX FOR SOILS DESCRIBED IN THIS PUBLICATION

Soil series[a]	Soil province (Fig. 8)	Diagnostic horizons (69) Epipedon	Subsurface	Thickness of gravel-free top layer (in.)	Index: page on which is Discussion	Classification	Management recommendations	Data
Babaibunda	I*	Ochric	Oxic or argillic	>48				
Bali	D*	Umbric	Oxic	>48				
Baoma	L*	Ochric	Argillic (or oxic)	10-48	59	69	81	98
Batiema	G*	Ochric	Argillic	10-24				
Batkanu	I*	Ochric	Argillic (or oxic)	0-10				
Belebu	G*	Ochric	Argillic	0-10				
Belia	I*	Ochric	Cambic	0-10				
Bom	I*	Ochric	Cambic	>48				
Bonganema	G*	Ochric	Argillic (or cambic)	>48				
Bonjema	G*	Ochric	Argillic (or cambic)	24-48	39	69	81	100, 102
Bosor	J*	Umbric	Argillic (or cambic)	24-48	51	69	81	104
Diabama	I*	Ochric	Cambic	10-24				
Dowjo	L*	Umbric	Cambic	>48				
Fanima	L*	Umbric	Oxic	0-10				
Gbamani	B*	Ochric	Spodic	>48	29	69	82	106
Gbehan	B*	Ochric	Oxic	>48	32	69	81	108
Gbesebu	G*	Ochric	Cambic	>48	45	69	78	110, 112
Giema	L*	Umbric	Oxic	0-10				
Gullied Land[b]	G*	Ochric	Cambic	>48				
Hahun	B*	Umbric		>48				
Kania	G*	Umbric	Argillic (or oxic)	>48	43	71	78	114
Keya	L*	Ochric		>48	62	71	81	116
Kontobe	I*	Ochric	Cambic (or argillic)	>48				
Koyema	D*	Ochric	Oxic	>48				
Kparva	L*	Ochric	Argillic (or oxic)	>48	62	72	81	118
Mabang	I*	Ochric	Argillic	>48				
Mabanta	J*	None or ochric		0-24				
Mabassia	J*	Umbric	Cambic or argillic	10-48	51	72	81	120, 122
Mabole	I*	Ochric	Oxic or argillic	>48				
Madina	I*	Ochric	Oxic (or argillic)	>48				
Magbunga	I*	Ochric	Cambic	>48				
Makeni	J*	Umbric	Argillic	0-10	49	72	82	124
Makoima	I*	Ochric	Oxic	>48				
Makoli	I*	Ochric	Argillic or oxic	10-24				
Makonte	I*	Ochric	Oxic or argillic	>48				
Makundu	J*	Umbric	Oxic	>48	56	72	78	126
Malansa	I*	Ochric	Oxic or argillic	>48				
Malinka	I*	Ochric	Argillic or cambic	0-10				
Malop	I*	Ochric	Petroferric contact	10-24				
Mamalia	I*	Ochric	Argillic or oxic, petroferric contact	10-24				
Mamu	D*	Ochric		>48				
Mandu	L*	Ochric	Cambic (or oxic)	24-48				
Mani	D*	Ochric		>48				
Mankahun	I*	Ochric	Argillic or cambic	24-48				
Mankane	J*	Ochric	Cambic	>48	55	72	81	128
Manowa	L*	Umbric	Argillic (or oxic)	0-10	59	72	82	130
Mara	I*	Ochric	Argillic	24-48				
Maroki	I*	Ochric		>48				
Masebra	I*	Ochric	Oxic or argillic, petroferric contact	24-48				
Masheka	J*	Umbric	Argillic (or cambic)	>48	53	72	81	132
Massimo	I*	Ochric	Cambic (or argillic)	>48				

(Footnotes given at end of table.)

Soil series[a]	Soil province (Fig. 8)	Diagnostic horizons (69): Epipedon	Diagnostic horizons (69): Subsurface	Thickness of gravel-free top layer (in.)	Index: page on which is Discussion	Classification	Management recommendations	Data
Masuba	J*	Ochric	Cambic	>48	54	73	81	134
Masuri	I*	Ochric	Argillic or cambic	24-48				
Matamba	I*	Ochric	Argillic or oxic	>48				
Mateboi	I*	Ochric	Cambic	>48				
Matutu	I*	Ochric	Argillic or oxic, petroferric contact	10-24				
Mayanki	I*	Ochric	Argillic or oxic	0-10				
Moa	L*	Ochric	Oxic (or cambic)	>48	64	73	78	136
Mogbondo	G*	Ochric (or umbric)	Cambic	24-48				
Mokoli	G*	Ochric	Cambic	>48	46	73	78	138
Mokonde	G*	Ochric	Argillic (or cambic)	10-24	36	73	81	140
Momenga	G*	Ochric	Cambic	0-10	33	73	82	142, 144, 146
Mosungo	G*	Ochric		Variable				
Moyambaworo	G*	Ochric	Argillic	>48				
Naba	D*	Umbric	Oxic	>48				
Ngelehun	L*	Ochric	Oxic	>48				
Njala	G*	Ochric or umbric	Argillic	0-10	36	73	81, 82	148, 150
Nyawama	G*	Umbric or ochric	Argillic (or oxic)	>48	42	74	78	152, 154, 156
Panderu	L*	Ochric	Oxic (or argillic)	24-48				
Panlap	J*	Umbric		>48	55	74	81	158
Pelewahun	G*	Umbric or ochric	Argillic	24-48	41	74	81	160, 162
Pendembu	L*	Ochric	Argillic	36-54	62	74	81	164
Pujehun	G*	Ochric	Cambic	>48	44	74	78	166
Rochin	I*	Ochric	Cambic	>48				
Rock Land[b]	G*,J*, L*	None or ochric		0-24	47, 58		82	
Rokel	I*	Ochric	Oxic (or argillic)	>48				
Rokupr	C*	None or ochric	Sulfuric or none	>48	30	74	82	168, 170
Romankne	I*	Ochric	Cambic (or argillic)	>48				
Rosinth	J*	Ochric	Argillic	10-24				
Sahama	B*	Ochric or umbric		>48	29	74	82	172
Sangama	D*	Umbric	Cambic	>48				
Segbwema	L*	Ochric	Oxic (or cambic)	>48	59	75	82	174
Seli	I*	Umbric	Oxic or cambic	>48				
Senehun	D*	Ochric		>48				
Sewa	D*	Umbric	Cambic	>48				
Tabai	I*	Ochric	Cambic	>48				
Taiama	G*	Umbric	Argillic	>48	43	75	81	176
Talia	D*	Umbric	Oxic	>48				
Taso	D*	Umbric	Oxic	>48	32	75	78	178
Timbo	J*	Umbric	Oxic (or cambic)	0-10	47	75	82	180
Tisso	L*	Umbric	Oxic (or argillic)	24-48				
Torma Bum	D*	Ochric or umbric	Cambic	>48				
Tubum	J*	Umbric	Cambic	24-48	52	75	81	182
Vaahun	L*	Ochric	Cambic	0-10	58	75	82	184
Waima	L*	Ochric	Oxic	10-24				
Wari	I*	Ochric	Petroferric contact	0-10				
Yumbuma	L*	Ochric	Oxic	>48				

a/The relationships among these soils are shown in Table 2 (pages 16 and 17).
b/Land type.