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SOILS OF THE ACCRA PLAINS

by

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SOIL RESEARCH INSTITUTE

(GHANA ACADEMY OF SCIENCES)

PREFACE

THIS report deals with the soils, vegetation and land-use of the Accra Plains, the area of south-eastern Ghana lying between the Akwapim Range, the lower Volta River and the sea.

This region was surveyed in 1950–52. A report on the survey was drafted in 1953–54 but it was decided to defer publication until adequate analytical data for the soils became available. Preoccupation with other urgent technical and administrative matters, especially following the death of the former Director of Soil and Land-use Surveys, C. F. Charter, early in 1956, subsequently prevented the report from being finalized.

In the meantime, information on the soils, vegetation and land-use of this region, or parts of it, has been given in a number of publications. The more important of these are listed below:

Reports on the Department of Soil and Land-Use Survey

Rep. Dep. for the period 5th June, 1951, to 31st December, 1955. Accra, Government Printer.

BRAMMER, H. and DE ENDREDY, A. S. 1954

The Tropical Black Earths of the Gold Coast and their related vlei soils. *Transactions of the 5th International Congress of Soil Science, Leopoldville*, Vol. 4, pp. 70–76.

BRAMMER, H. 1955

Detailed Soil Survey of the Kpong Pilot Irrigation Area. *Gold Coast Department of Soil and Land-Use Survey, Memoir* 1.

BRAMMER, H. and DE ENDREDY, A. S. 1956

The Tropical Grey Earths of the Accra Plains. Paper submitted to *The 6th International Congress of Soil Science, Paris*. To be published in *The Ghana Soil and Land-Use Survey Branch, Occasional Paper* 2 (in preparation).

BRAMMER, H. 1958

Soils of Ghana. *Ghana Soil and Land-Use Survey Branch, Divisional Paper* 6, *2nd ed.* 1959.

BRAMMER, H. 1959

The Tropical Black Earths of Ghana. *Ghana Soil and Land-Use Survey Branch, Divisional Paper* 9.

SWINSON, W. C. and EVANS, D. C. P. 1959

Development of the south-eastern coastal savannah: Accra Plains and Dawhwenya dam projects. Published for the authors by the *Ghana Soil and Land-Use Survey Branch.*

BRAMMER, H. 1960

A brief account of environmental conditions and factors affecting agricultural development on the south-eastern coastal plains. *Ghana Soil and Land-Use Survey Branch, Divisional Paper* 10.

The present report comprises the whole of Part II and an abridged version of Part I of the complete report. It is published in its present form to satisfy the immediate needs of those concerned with agricultural development and extension in the region. It is hoped that the complete report will be printed and published within the next 12–18 months.

Part I of the report gives a comprehensive geographical account of the region, that is of the physical, social and economic factors affecting present and future land-use in the region.

Part II gives a general account of the soils, vegetation and land-use of the region. This part of the report is couched in as non-technical language as the subject allows and is designed to assist administrators, advisory officers and literate farmers.

For convenience of treatment, the region has been subdivided into four physiographic subregions, *viz.*—the Akwapim Range, the Accra Plains, the Volta floodplain and Volta delta and coastal flats. These are further subdivided into a total of 16 soil tracts. These are natural units of the landscape which would normally require to be treated together for agricultural development. Within these, a total of 36 soil associations have been mapped. Soil associations are areas covering the whole or part of a soil tract within which the pattern in which individual soils occur in relation to the topography is similar.

The reader interested in a particular area of the Accra Plains should locate its position on both the soil map and the soil tracts map and identify the soil association and soil tract in which it lies. He should then refer to the section of Part II of the report in which the soil tract and the soil association are described. The description therein gives detailed information concerning the soils, vegetation and present land-use of the tract together with general recommendations regarding the utilization of particular soils and the tract as a whole; these recommendations include advice in respect of road-building within the tract. The soil descriptions given should enable the reader to identify the particular soils within the tract in which he is interested.

Part III of the complete report is aimed at the specialist. It will contain detailed descriptions of the soils together with relevant analytical data, as well as systematic accounts of the vegetation and land-use of the region. Recommendations for land-utilization in the different parts of the region, made already in Part II of the report, will here be brought together to provide, in effect, a statement of policy for the development of the whole region. A summary of the major recommendations is given in the present report.

The terms used on the Soil, Vegetation and Land-Use maps will probably be unfamiliar to many readers. The meaning of these terms is explained either in the appropriate sections of Part I of the report or in the glossary.

The account given in this report relates to conditions as they were at the time of the survey and during the drafting of the original report. Where further important information has been obtained since 1954, the account has been brought up-to-date, usually by means of footnotes. The boundaries on the Vegetation and Land-Use maps relate to conditions existing at the time of the survey.

FOREWORD

SOIL SURVEY was started in Ghana some twenty years ago to establish a relationship between soil type and the incidence of swollen shoot disease. This never yielded the desired fruits but the foundations of a country-wide soil survey were laid and the Accra Plains area was among the first to be tackled.

This area is predominantly covered by black tropical clays and although they have not been worked to any extent, similar clays elsewhere support excellent cotton and a variety of crops. Besides, the Accra-Tema area is bound to witness a massive concentration of population unparalleled anywhere in this part of Africa and it is only logical that the hinter-land of this metropolitan area should be assessed for its food production capacity.

The report is the second memoir in a series on survey regions of the country. It recommends about 608,000 acres (980 square miles) of a total of 960,000 acres (1,500 square miles) as suitable for irrigation agriculture. Now that the Volta River Project is a reality and water is bound to be available for irrigation the Accra Plains can support rice, sugar-cane, cotton, jute, tobacco, maize, sunflower and a variety of beans as recommended in the report.

The number of workers engaged in this semi-detailed survey totalled more than one hundred and fifty-seven, including about three professional officers, using methods which had been worked out here to suit the peculiar circumstances of the tropics. These methods have been adopted by pedologists working elsewhere in Tropical Africa. In Ghana itself the methods have undergone considerable modifications in recent years, aimed at reducing costs and time of survey.

This report is happily being published at a time when the irrigation possibilities of the Accra Plains are foremost in people's minds. It is, therefore, recommended to pedologists, agriculturists, administrators, and individuals who will share in the tremendous development projects which are bound to be undertaken in the region.

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Director
Soil Research Institute.

KUMASI
March, 1966

CONTENTS

CONTENTS—*continued*

DESCRIPTION OF SOIL ASSOCIATIONS

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PART 1

GENERAL

INTRODUCTION

Purpose of The Survey

THE OBJECTS of the reconnaissance soil survey of the Accra Plains were—

(i) to make an inventory of the soils of this region as part of the routine survey of the country's soil resources; and

(ii) to assess their potentialities for development, particularly with the aid of irrigation water from the proposed Volta dam.

Details of The Conduct of The Survey

The reconnaissance survey was preceded by a preliminary survey of the region whose object was to establish a mapping legend for the major survey to follow. This was undertaken between September, 1950, and March, 1951.

The reconnaissance survey commenced in April, 1951, and was completed in February, 1952. Between October, 1951, and the close of the reconnaissance survey, a semi-detailed survey was also carried out in the Kpong-Akuse-Somanya triangle in the north of the region. The findings of the latter survey have been incorporated in the present report.

These surveys were undertaken by large field parties led, for most of the time, by three professional officers. The numbers of personnel engaged in the field are shown below. These figures include administrative and other auxiliary staff.

	Reconnaissance Survey	*Semi-detailed survey*	*Total*
Soil Survey Officers	2	1	3
Asst. Soil Survey Officers	7	4	11
Soil Survey Assistants	41	42	83
Soil Grinders, Messengers	11	7	18
Drivers, Watchmen, etc.	9	8	17
Labourers (average monthly totals)	102	95	197
Totals	172	95	197
Total, all surveys			329

The reconnaissance party had to be housed under canvas for much of the survey and to be supplied with food and water.

The reconnaissance survey was carried out by sampling the soil and recording details of topography, vegetation and land-use on a regular sampling grid throughout the region. Traverse-lines were cut at intervals of 100 chains ($=1\frac{1}{4}$ miles) across the region, except in the extreme west where lines were cut $2\frac{1}{2}$ miles apart. Samples and records were taken at intervals of 10 chains (=220 yards) along the traverse-lines. In addition, samples and records were taken at 10-chain intervals along roads and major tracks. The accuracy of the traverses was checked by surveyors from the Survey Department who surveyed check-lines with theodolites at intervals of approximately 500 chains throughout the region.

On the semi-detailed survey, samples were taken on a regular $6\frac{2}{3}$-chains grid.

On both surveys, soils were examined to a depth of 4 feet at each sampling point, using small holes made by soil chisel and screw auger. Samples of the different soil layers at each site were collected in bags and brought back to the field-base technical office for examination, description and identification (after which they were discarded).

At each sampling point, vegetation and land-use were recorded within a radius of approximately 60 feet to give a sampling area of $\frac{1}{4}$-acre. Vegetation was recorded in physiognomic terms adapted from "Vegetation of Nigeria", a handbook of the Nigerian Forestry Department (1). Land-Use was recorded according to the World Land-use Survey scheme (2). Specimens of vegetation were collected for identification either at main-base, the University College Botany Department or the Royal Botanic Gardens at Kew.

During the reconnaissance survey, more than 1,500 miles of traverse-line were cut and recorded and over 250 miles of roads and tracks traversed. Approximately 500 profile pits were examined and samples from 129 of them sent for laboratory analysis. During the semi-detailed survey, approximately 180 miles of traverse-line were cut and recorded. Thirty profile pits were examined and samples taken from 4 of them for laboratory analysis. In addition, records are available for more than 100 pits dug during the preliminary and other previous surveys of and in the region as well as analytical data in varying detail for samples from 28 of these pits.

The information collected during the reconnaissance survey was originally plotted on 1-inch maps of the region; (that from the semi-detailed survey was plotted on 2-inch enlargements of the 1-inch maps). Boundaries were drawn in by interpolation between the traverse-lines with assistance from topographical maps and supplementary field investigations. It must be acknowledged, too, that in places the soil, vegetation and land-use maps owe a considerable amount of their detail to information obtained from the 1947–50 series R.A.F. aerial photographs, although these photographs were unfortunately of too variable quality for systematic use throughout the survey.

PHYSICAL FEATURES OF THE REGION

LOCATION AND EXTENT

THE ACCRA Plains region lies in the south-east of Ghana between parallels 06°–14′N. and 05°–29′N and meridians 00°–23′W. and 00°41′E. The region is roughly triangular in shape. It is bounded in the west by the watershed running along the crest of the Akwapim Range and the Weija Hills; in the north and east by the right bank of the lower Volta River; and in the south by the sea (the Gulf of Guinea) between the mouth of the Volta and the village of Lanma some 10 miles west of Accra. The total area is slightly over 1,500 square miles, or almost 1,000,000 acres.

GEOLOGY

The geology of the region has been described by Junner and Bates(3). Briefly, the major part of the region is underlain by ancient igneous rocks, but strongly-metamorphosed ancient sediments occur along the western boundary and there are important areas of relatively young, unconsolidated sediments in the south and south-east.

The main Akwapim Range in the west is formed of Togo (pre-Cambrain) quartzites with smaller amounts of phyllite, sericite schist, sandstone and shale. The Weija Hills and a number of smaller hills scattered throughout the south-west of the region (e.g. Legon Hill and the Dawhwenya Hills) are formed of Togo quartzite schist.

The Accra Plains proper are mainly occupied by Dahomeyan (= Archaen) gneisses and schists. These are divided into three belts running north-south across the region. These consist of a western and an eastern acidic gneiss belt separated by a basic gneiss belt.

The western acidic gneiss belt consists mainly of fine-grained muscovite-biotite schists and gneisses containing numerous quartz veins. There is a large intrusion of coarse-grained, pale-coloured granite (which does not outcrop) between Agomeda and Dodowa, and a few smaller intrusions of related granites further south. There are small bands of syenite and other basic rocks between Kpong and Somanya and locally further south. Pegmatite was seen near Kpong and Tema. There is a small area of Accraian (= mid-Devonian) shales and sandstones on the coast at Accra. Rock outcrops are very rare throughout this tract.

The main basic gneiss belt consists almost entirely of garnetiferous hornblende gneiss. Intrusions of pyroxenite occur in a number of places, especially in a line running north-south from 2 miles east of Krobo Hill in the north towards the Shai Hills in the centre. The basic gneiss forms a number of large inselbergs (isolated rocky hills) in the north and centre of the belt. Small rock outcrops are common in the north and near the inselbergs, but are rare in the south and south-east.

The eastern belt of acidic gneisses consists mainly of fine-grained muscovite-biotite schists and gneisses, rather richer in biotite than the rocks in the western belt and with many fewer quartz veins. In a belt broadening quickly northwards of Dawa, there are coarse-grained, biotite-rich gneisses and granite. Rock outcrops are not known in the fine-grained rocks, but there are a number of outcrops near the central axis of the coarse-grained rocks.

The Dahomeyan rocks are overlain in the south-east, and locally in the extreme south as far west as Nungua, by unconsolidated sediments, sandy clay in texture, of Tertiary age. Sediments thought to be of similar age have recently been found to occupy a number of deep narrow troughs at the foot of the Akwapim Range near Abokobi.

Recent alluvium occupies the Volta floodplain and the valleys of the major streams on the Plains. There are remnants of a 30–40 foot river-terrace along the Volta floodplain and a marine-terrace at this height along parts of the coast east of Prampram and in Accra. Extensive flats along the lower course of the Volta and around Songaw lagoon appear to represent a former delta now standing 5–10 feet above its original level.

RELIEF AND DRAINAGE

The Accra Plains proper form part of the south-eastern coastal plains of Ghana. The relief is generally gently undulating at less than 250 feet above sea-level. Slopes are widely of 2 per cent or less over the clay soils over the Dahomeyan gneisses; only the alluvial areas surrounding the coastal lagoons could strictly be called flat. Slopes may be up to 5 per cent in the north of the basic gneiss belt and over coarse-sandy soils over the acidic gneisses as well as around the edges of occurrences of the Tertiary sediments. They extend up to about 10 per cent in the extreme west of the Plains near the foot of the Akwapim Range.

Inselbergs in the basic gneiss belt rise abruptly to heights several hundred feet above the surface of the surrounding Plains. Ningo Hill (1,400 feet), Krobo Hill (1,099 feet) and the Shai Hills (948 feet) are the highest points. The majority of the rock outcrops in the eastern acidic gneiss belt rise only a few feet above the surrounding land, but there are six larger hills, the highest of which, near Dedukope, rises about 100 feet above its surroundings. The outliers of Togo quartzite schist in the south-west usually rise only slightly above the surrounding country, but Legon Hill rises to 484 feet.

The Akwapim Range and the Weija Hills rise steeply above the western edge of the Plains. The crest of the Akwapim Range lies generally at 1,250–1,400 feet north of Aburi, with Jakiti, 1,848 feet, the highest point. South of Aburi, the crest falls gradually to around 1,000 feet and then more abruptly to the Ofako gap through which the Accra-Nsawam road and railway pass. South of the Ofako gap, a discontinuous line of hills—the Weija Hills—rises generally to about 500 feet, the highest point, near Weija, reaching 641 feet.

There are no perennial streams within the region. The major streams rising in the Akwapim Range—the Okwe, Dodowa and Dakobi—flow for only a few weeks during and after the rainy seasons and dry out to pools in the main dry seasons. On the Plains proper, stream channels themselves are often discontinuous over the acidic gneisses and most valleys over the basic gneisses are streamless. Valleys draining to the Volta and the coast typically end in lagoons.

Over the Dahomeyan gneisses, many of the soils are impervious and are subject to surface run-off during heavy rainfull. Under these conditions, the whole ground-surface may be covered with a moving sheet of water which concentrates in the valleys causing extensive flooding. Such floods are generally of short duration, but during the second rainy season in the north of the region the high level of the Volta at this time of the year may impede drainage from the adjoining Plains and floods may then persist for several weeks for a distance of several miles up valleys from the edge of the Volta floodplain.

The Volta is at low water in March–April and at its highest between September and November. Flood-level varies from year to year, but there is usually a rise of some 20–30 feet (at Kpong). The river no longer appears to overtop its banks, except perhaps downstream of about Tefle, but floods its alluvial tract by backing up the creeks which penetrate the levees at intervals. A large part of the floodplain appear to be above the level of normal floods and certain parts appear unlikely to be flooded at all under present conditions. Some of the lower areas, on the other hand, are permanently flooded or subject to prolonged flooding during the rainy seasons.

The Volta is tidal as far upstream as about Tefle. The river is affected by salt below this point in the low-water season; very occasionally, the river is reputed to be saline as far upstream as Battor. During the flood season, the river is fresh almost to the mouth. At this time, fresh water enters Songaw lagoon by way of creeks linking it with the Volta, but salt water passes up these creeks at other times of the year when very high tides occur.

The Densu is subject to floods in both rainy seasons. These mainly serve to increase the size of Sakumo lagoon. In the dry seasons, the flow is often low since water is extracted from the river at Weija for supply to Accra.

Geomorphological note

Remnants of the Aya (= early Tertiary) peneplain surface occur at a height of 1,250–1,500 feet on the summit of the Akwapim Range. Mamfe soils in Mamfe-Fete Complex are associated with these remnants.

More widespread remnants of the Akumadan (= late Tertiary) peneplain surface exist at heights of 150–300 feet on the Accra Plains and account for the general summit-level at 200–300 feet. Mamfe soils in Oyarifa-Mamfe Complex and Nyigbenya soils in Nyigbenya-Hacho Complex and Nyigbenya Consociation are associated with these remnants. The inselbergs in the basic gneiss belt (but not those in the eastern acidic gneiss belt) appear to be related to this surface.

Much of the present surface of the Accra Plains appears to be that of a new peneplain. Fluctuations in sea-level during the Pleistocene have left terraces at c.100 feet and 30–40 feet and over-deepened the lower courses of valleys draining to the Volta and the coast, accounting for the presence of the lagoons. A recent fall in sea-level of 5–10 feet has been responsible for slight renewed dissection along valley bottoms and for 'raising' the Volta delta and floodplain.

CLIMATE

Climatic data for Accra, Akuse and Aburi are given in the accompanying tables. The data for Accra are believed to be representative for the greater part of the Plains, approximately the area south of a line to Dodowa to Aveime, and those for Akuse for the area north of this line. Aburi represents conditions on the Akwapim Summit.

Rainfall

Mean annual rainfall increases from around 30 inches on the coast to 45–50 inches in the extreme north and on the summit of the Akwapim Range. The greater part of the Plains probably receives less than 35 inches. Totals vary considerably from year to year, however. At Accra, where the mean is 28.83 inches, totals have ranged between 10.84 and 47.12 inches. At Akuse (mean 43.79 inches totals have ranged between 24.69 and 66.54 inches.

There are two rainy seasons, March–April to mid-July and end-September to early December. Beginnings and endings of these seasons are unreliable and storms are liable to punctuate both dry seasons. The second rainy season is less reliable than the first rainy season, and fails altogether in some years in the south of the region.

The rain typically falls in thundershowers of relatively short duration but high intensity. Rain may fall at a rate of several inches per hour for a few minutes at the onset of storms, and individual storms may give a fall of an inch or more. Prolonged heavy rain is occasionally experienced in the main rainy season: a small area around Accra received over 8 inches in one day in June, 1959. Very high monthly totals are occasionally received: both Accra and Akuse have recorded totals of 15–20 inches in a single month, May–June and October being the periods when such falls are liable to occur.

These characteristics of the rainfall are of great agricultural importance. The unreliability of the rainy seasons makes farming a hazardous occupation in this region. Periodic main-crop failures must be expected even in the better-watered northern parts, and conditions during the second rains must everywhere be considered at best marginal and in the south definitely sub-marginal. It is obvious that the provision of irrigation facilities could be of great value in this tract.

At the same time, the heavy rainfall periodically experienced requires that soils be protected against erosion and that special provision be made for drainage on heavy clays if those are cultivated. The possibility that heavy rainfall may occur on soils already saturated from a recent irrigation needs to be considered in planning drainage systems for irrigation schemes.

Temperature

So far as is known, temperatures are not of critical importance for agriculture in this region. Temperatures are highest during the main dry season and lowest during the short dry season. They average a few degrees lower on the coast and on the Akwapim Range than they do over most of the Plains. Absolute maxima and minima range between 104°F and 54°F at Akuse, but proximity to the sea in the case of Accra and higher altitude in the case of Aburi extremes less by 5–10°F in these localities.

Humidity and Evaporation

Humidities are relatively high throughout most of the year. Afternoon humidities at Akuse are generally 55–65 per cent. throughout most of the year falling to around 40 per cent. during the main dry season, with values below 20 per cent. occasionally recorded. On the coast, values are generally higher by 10–20 per cent. Humidities rise almost to 100 per cent. at night almost throughout the year throughout the Plains.

Conditions are very humid throughout the year on the Akwapim summit. Cloud enshrouds this part of the region almost every night of the year and persists into the day during the rainy seasons.

It may be noted that the term 'short dry season' is apt to be misleading. This period (July–August) is dry only in so far as little rain is usually received, but atmospheric humidity is often at its highest during this period and cloud cover greatest. This makes this dry season a less suitable period for harvesting crops than the main dry season. Drying facilities may need to be provided for crops harvested at this time.

Data available for evaporation suggest that annual losses from a free water surface may be as much as 6 feet in this region.

Wind

Winds are generally light, but there is a fresh sea-breeze by day for some miles inland from the coast almost throughout the year. Squalls of gale force may occur for a period of a few minutes at the onset of thunderstorms. Normal winds are generally south westerly, but for a few days during the main dry season light north easterly winds are periodically experienced and northerly land breezes may occur at night near the coast. Squalls during thunderstorms generally blow from a north-easterly direction.

Wind-breaks will need to be provided to protect crops against storm-damage and are desirable near the coast to reduce transpiration losses whether crops are irrigated or not.

Sunshine and cloud

The period July–August is markedly more cloudy than the remainder of the year. The main dry season is least cloudy. Cloud amounts are higher inland, especially on the Akwapim summit, than on the coast.

TABLE A

Station	Height in feet above sea-level	Mean Monthly Rainfall (inches)												Annual Total	No. of Years
		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.		
Accra (Airport)	214	0.59	1.37	2.27	3.40	5.46	7.10	1.80	0.58	1.40	2.63	1.38	0.88	28.83	70
Akuse	61	0.88	1.82	4.07	4.91	6.16	7.05	2.57	1.54	3.85	5.30	4.03	1.57	43.75	40
Aburi	1,500	1.07	1.93	4.54	4.86	6.59	7.24	3.12	1.89	4.07	5.57	4.89	2.28	48.05	40

Station	Percentage variability $\frac{\text{(Standard deviation X 100)}}{\text{Mean Rainfall}}$													No. of Years
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	
Accra (Airport)	120	99	58	49	47	73	104	104	102	93	83	127	19	39
Akuse	119	77	51	32	46	48	94	100	64	62	49	77	21	38
Aburi	101	58	59	41	46	48	62	71	59	41	36	79	14	38

TABLE A—contd.

Station	*Mean number of wet days*													*No. of Years*
	Jan.	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*	
Accra (Airport)	1.6	2.2	5.0	6.5	10.1	13.1	6.8	4.9	6.9	8.4	3.7	2.0	71.1	41
Akuse	2.3	3.3	8.2	7.3	10.5	11.7	6.5	5.3	9.6	11.5	9.9	3.5	85.0	25
Aburi	2.4	3.6	7.3	6.9	10.9	13.4	11.3	9.7	12.0	11.6	9.0	4.9	100.5	27

TABLE A—Rainfall data for Accra, Akuse and Aburi (Compiled from *Ghana monthly weather reports* 1949–59. Ghana Meteorological Department, Accra, and from additional data supplied by Ghana Meteorological Department).

TABLE B

Station		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean Annual Temperature
Accra (Airport) ...	Mean Absolute Maximum ...	92	93	92	92	91	88	84	85	86	89	90	91	
	Mean Maximum ...	88.7	89.1	89.4	89.0	87.4	83.4	80.8	81.0	83.6	85.3	87.9	88.8	
	Mean Temperature ...	80.9	81.5	81.9	81.7	80.6	77.8	75.8	75.5	77.4	78.6	80.4	81.1	79.5
	Mean Minimum ...	73.1	73.9	74.5	74.4	73.8	72.3	70.8	70.0	71.3	71.9	72.9	73.4	
	Mean Absolute Minimum ...	68	70	70	70	70	68	67	68	69	69	69	69	
Akuse	Mean Absolute Maximum ...	97	99	98	99	96	92	90	91	93	93	94	95	
	Mean Maximum ...	93.1	95.2	94.2	93.5	91.5	87.5	85.1	86.1	88.5	89.5	91.3	92.0	
	Mean Temperature ...	81.9	83.9	84.1	83.6	82.3	79.7	77.7	77.9	79.7	80.2	81.1	81.2	81.1
	Mean Minimum ...	70.7	72.7	74.0	73.8	73.1	71.9	70.4	69.7	70.9	70.9	70.9	70.4	
	Mean Absolute Minimum ...	62	67	70	70	70	68	66	66	67	68	68	65	
Aburi	Mean Absolute Maximum ...	88	90	90	90	88	86	82	82	85	84	86	86	
	Mean Maximum ...	84.5	86.4	86.2	85.6	83.6	80.7	77.3	77.8	79.7	81.5	83.0	83.6	
	Mean Temperature ...	77.1	78.4	78.2	78.0	76.6	74.5	7.20	71.9	73.1	74.3	75.4	76.2	75.5
	Mean Minimum ...	69.7	70.5	70.3	70.5	69.7	68.3	66.8	66.0	66.6	67.1	67.8	68.8	
	Mean Absolute Minimum ...	65	66	66	65	65	64	64	63	64	64	65	65	

TABLE B—Temperature data (in °F.) for Accra, Akuse and Aburi. (Compiled from *Ghana monthly weather reports* 1949–59. Ghana Meteorological Department, Accra).

TABLE C

Station	*Hour of reading*	*Jan.*	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
Accra (Airport)	1500	65	66	67	69	72	78	77	74	73	73	70	66
Akuse	1500	48	47	57	58	65	72	68	64	64	68	66	55
Aburi	0900	90	88	87	87	87	92	95	94	94	90	90	92

Table C—Relative humidity data (in %) for Accra, Akuse and Aburi. (Compiled from *Ghana monthly weather reports* 1949–59. Ghana Meteorological Department, Accra.)

TABLE D

Jan.	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Annual Total*
5.15	5.6	5.75	5.4	6.05	4.35	5.15	5.3	5.1	5.3	5.4	5.45	64.0

Table D—Evaporation data (from open tank, in inches) for Accra (Airport). (Data for 1954–55, given in Walker, H. O. 1957. weather and Climate of Ghana. *Departmental Note* No. 5. Ghana Meteorological Department, Accra).

Classificatory and mapping units

Full definitions of the various classificatory units used on the survey are given in the glossary. In brief, individual soils are recognized as *soil series*. On the scale of the reconnaissance survey this has been the lowest category normally recognized. In a few important soils, however, minor differences within the series considered to have agricultural significance have been recognized as *subseries*, *phases* or *variants*.

In mapping, where large areas are covered almost entirely by one soil series they have been shown as *soil consociations*. Over large parts of the region, however, individual soil series do not cover sufficiently extensive areas to be mapped separately on the scale of the map used. Fortunately, over any particular type of rock, a number of soil series is often found to occur in regular succession between the top and bottom of valley slopes in a pattern which is repeated on all valley slopes throughout the rock's extent. These topographically-related soils can be mapped together as a single unit known as a *soil association*, it being understood that particular soils within it will be found on particular parts of the valley slopes as defined in the description of the association in Part II of the report.

In areas of complicated geology, where a number of different rocks may underlie the topography, soils do not always occur in regular patterns down valley slopes or, if they do so, the pattern does not repeat itself over a wide enough area for it to be mapped as a separate association. In such areas, where patterns are irregular, mixed or highly intricate, soils have had to be grouped together within *soil complexes*. Such complexes have unfortunately had to be used as mapping units over much of the western part of the region.

General distribution of soils

A total of 63 soil series were identified during the reconnaissance survey. Subsequent detailed investigations in a number of areas have increased this number to over 70*. Descriptions of all these soils are given in Part II of the report.

The soils fall into seven main broad groups, *viz.*

(i) Shallow rocky soils;
(ii) Red earths;
(iii) Pallid sands;
(iv) Grey earths;
(v) Black earths;
(vi) Alluvial clays;
(vii) Levee and dune sands.

These groups are briefly described below.

(i) *Shallow rocky soils.*—These are extensively developed on the steep slopes of the Akwapim Range, the Weija Hills and the basic gneiss inselbergs, and less extensively on more moderate slopes on the outliers of Togo rocks in a line between Dawhwenya and Agomeda.

On the Akwapim Range, the soils are mainly pale and sandy with brashy quartzite occurring to the surface in most places. On the Weija Hills and on the hills between Dawhwenya and Agomeda, the scanty soil matrix is a red loam or light clay occurring amongst brashy quartzite schist. On the basic gneiss inselbergs, there may be up to a foot of heavy loam or sandy clay, black near the surface becoming brown below; these soils are related to the Black Earths.

There is a little subsistence farming on parts of the Akwapim Range particularly near the summit and the foot, but this group of soils should be regarded as unsuitable for agriculture except under very special conditions.

*Soil descriptions in Part II of the report have been allowed to stand much as they were when originally written immediately after the close of the survey. Footnotes have been added where necessary to bring the information up-to-date.

(*ii*) *Red Earths.*—This group includes soils which are red or reddish brown in colour in the subsoil. They are usually developed in old, thoroughly-weathered parent materials. (Red terrace soils occurring along the Volta alluvial tract will be discussed with the alluvial clays below).

Two major types of profile are found in the Red Earths: those with a thick layer or ironstone gravel or ironpan in the subsoil; and those consisting of fine earth throughout. The ironstone-concretionary soils occur extensively on upland sites in the west of the region but only rarely in the east of the region. They are associated with remnants of both peneplain surfaces. On the Akwapim summit they occur within Mamfe-Fete Complex; on the Accra Plains they occur within Oyarifa-Mamfe Complex, Nyigbenya-Hacho Complex and Mamfe and Nyigbenya Consociations. The non-concretionary soils are extensively developed over the Tertiary sediments (Toje Consociation, and Toje-Agawtaw Association) and in a narrow belt of piedmont colluvium bordering the foot of the Akwapim Range and the Weija Hills (Oyarifa-Mamfe Complex).

The Red Earths are typically loamy in texture near the surface becoming more clayey below. They are porous and well drained. They are rather droughty near the surface, especially where gravelly, but allow great freedom of root development and provide ample moisture storage at depth for deep-rooting plants. Nutrient supplies are concentrated in the humous topsoil, the amounts being much greater in the forest and thicket zones than in the savannah zone. Lower layers are strongly leached and store little.

These are the soils most generally used for farming at present. Farming is particularly heavy on the non-concretionary soils, except near the coast. If declared of their present vegetation, the latter soils would be suitable for mechanical cultivation, especially under a system of mixed farming. The concretionary soils are generally less well suited to mechanized cultivation. For increased crop production, nitrogenous and phosphatic fertilizers would need to be used and it would be essential to maintain an adequate supply of organic matter in the topsoil.

Middle and lower slopes below occurrences of the Red Earths often carry brown and yellow-brown soils. These are generally more sandy near the surface and less well-drained in the lower layers than the adjoining upland soils. They are generally less favoured for farming.

(*iii*) *Pallid Sands.*—This name particularly applies to pale-coloured, deep coarse-sandy soils developed extensively on gentle upland topography over granites and coarse-grained gneiss in the central parts of both acidic gneiss belts (Doyum-Agawtaw Complex). Grey-brown, medium-sandy, very gravelly soils widely developed over the finer-grained gneisses in the western acidic gneiss belt are also included (Simpa-Agawtaw Complex) as well as certain pale-coloured sands over Tertiary and Recent sediments (Agbozome series in Toje Consociation and Agbozome (Goi) Consociation).

These soils are almost barren of nutrients and are very droughty. Penetration of roots into the more clayey layers occurring at depths of 3–6 feet (except in the Teritary sediments) is prevented by a zone of impeded drainage at the base of the sandy layer.

The coarse-sandy soils are cultivated locally, mainly for groundnuts, okro and cassava. The gravelly soils are little cultivated, but the grassland they carry supports large herds of cattle in the central and southern parts of their extent. Poor crops of cassava are produced from the pallid Tertiary sands.

These are fundamentally poor agricultural soils which are unlikely to produce sustained high yields economically under any form of management. Their ultimate destiny seems likely to be to provide rough-grazing.

(*iv*) *Grey Earths.*—This group comprises soils with a foot or so of grey to brown, firm, sandy or silty loam abruptly overlying a layer of grey-brown, compact, impervious clay grading down into paler-coloured plastic clay containing lime concretions; there is usually a thin line of gravel at the base of the clay overlying the weathered rock.

These soils are extensively developed on gentle topography over some of the acidic gneiss rocks. They occupy virtually the whole of the topography within Agawtaw Consociation and throughout most of Nyigbenya-Agawtaw Association, but occupy mainly the lowland areas of Doyum-Agawtaw Association, Simpa-Agawtaw Complex and Toje-Agawtaw Association.

The Grey Earths underlie the main grazing areas of the region but they are virtually uncultivated. They appear potentially suitable for development with the aid of irrigation, but investigations are first required to discover how best they can be brought under cultivation. The presence of the impervious hardpan and appreciable amounts of harmful salts in the lower layers present serious problems. Phosphorus is particularly deficient in these soils, and fertilizers containing both this element and nitrogen are required to increase productivity, including that of the present rough-grazing.

(*v*) *Black Earths.*—These are major soils developed over the basic gneisses in Akuse Consociation and in minor expanses in several other associations. They occupy very gentle upland topography and consist of dark grey to black, heavy clays, usually 3–4 feet deep, overlying weathered gneiss. They are sticky and plastic when wet, but become hard and compact on drying and develop wide vertical cracks. Lime concretions occur in large amounts, usually only below 18–24 inches, but locally scattered throughout the profile.

Associated depression soils are deeper, much heavier and crack more widely than the upland soils. Lime concretions only occur in the deeper layers. Substantial amounts of harmful salts occur in the lower layers of the profile in many areas.

The Black Earths are virtually uncultivated at present and are subject to grazing only in the south of the region. They are considered potentially suited to development with the aid of irrigation. Their development poses serious problems, however, because of their difficult physical properties, but it is considered that with the aid of irrigation and drainage, artificial fertilizers (chiefly phosphorus and nitrogen), heavy machinery and large-scale methods of management they could become highly productive, with rice and sugarcane the major crops to be grown. Investigations to work out suitable techniques of cultivating and irrigating these soils have been carried out at Nungua Agricultural Research Station and Kpong Irrigation Research Station since 1952–53.

(*vi*) *Alluvial clays.*—The major area of alluvial clays occur along the Volta floodplain. The major area here (Amo-Tefle Association) is occupied by grey, mottled, silty clays on the relatively higher, less frequently flooded sites and grey, heavy clays in the depressions subject to regular flooding. Both these soils are highly acid, and towards the south-east they become affected by harmful salts in their deeper layers. None-the-less, the lighter, higher soils are often heavily cropped to maize and cassava at present; and, if flooding could be controlled—which does not appear to be impossible—both soils appear suitable for large-scale development.

Terrace-remnants standing above the general level of the Volta floodplain carry red and yellow silty clays of Aveime-Zipa Association. These have better nutrient and moisture-holding properties than the Red Earths and are heavily farmed.

Extensive flats around Songaw lagoon are mainly occupied by grey and red mottled, extremely acid, compact clays; but there are also red and yellow silty-clay terrace soils, dark grey heavy clays and various saline clays. Saline clays occur around the other coastal lagoons. (Ada Consociation; Aveime-Ada Association, Aveime-Zipa Association, Agbozome (Goi) Consociation, Ada-Oyibi Association, Oyibi-Muni Association, and Songaw Consociation). Some of the terrace soils are cultivated. The heavy clays are uncultivated, but some of them support rough-grazing. They are unlikely to be developed in the near future.

Alluvial clays in valleys on the Plains include black, brown and grey heavy clays, usually very acid in reaction near the surface but sometimes alkaline below. (Korle-Okwe Complex, Tachem-Okwe Complex, Tachem Consociation and Lupu Consociation). They are generally unused at present, but, with drainage control, might possibly be made highly productive.

(*vii*) *Levee and Dune Sands.*—This group comprises pale yellow-brown, deep sands along the high bank of the Volta (Amo-Tefle Association) and along most of the coast (Keta Consociation; Keta-Oyibi Association). Nutrient supplies are generally poor, except where former human settlement has enriched the site with clay and organic matter. Fresh water is often available at a depth of 2–6 feet in the coastal dune-sands, but generally at a greater depth, except at high flood, in the levee sands.

These soils are usually closely settled and heavily farmed. The usual subsistence crops are grown on the levee soils, with groundnuts important locally. Coastal dune sands typically support coconut plantations. Manuring is required to increase production.

Pedological notes

Soil conditions on the south-eastern coastal plains, of which the Accra Plains form part, are in general very different from those obtaining in the forest and interior savannah zones of Ghana. In the latter zones, the most widespread soils are developed in old, or relatively old, thoroughly-, and often deeply-, weathered parent materials. Such soils on the Accra Plains occur only on the peneplain remnants and over such easily-weathered parent materials as the Tertiary sediments. Over much of the region, soils of this kind are believed to have been stripped off during Pleistocene fluctuations in sea-level. Actively-weathering rock is found at a depth of only a few feet in most soils and the soils themselves are relatively young. The nature of the parent material is, of major importance in pedogenesis in this region.

Shallow skeletal soils (Lithosols) are associated with resistant rocks on steep, actively-eroding slopes. The trend in weathering is towards the formation of Red Earths over the Togo rocks, especially the quartzite schists, but towards Black Earths over Dahomeyan basic gneiss.

Mature Red Earths (Latosols) are generally associated with thoroughly-weathered parent materials on the peneplain surfaces and over the easily-weathered Tertiary sediments and piedmont drifts adjoining the Akwapim Range. The clay mineral is kaolinitic with an unknown, but probably small, proportion of iron and aluminium sesquioxides present. Organic matter is concentrated in the surface few inches, amounts being moderate in forest and thicket soils but low in savannah soils. Topsoils are almost saturated with bases, but lower layers are typically strongly leached.

Pallid sands are developed mainly over coarse-grained acidic gneiss or granite and over the finer-grained of these rocks where these contain numerous quartz veins. Pedogenetically, these soils appear to be related to the Grey Earths (which are mainly developed over the finer-grained acidic gneisses). The clay mineral in the clay substratum is believed to be a mixture of montmorillonite and kaolinite. This layer is affected by sodium to varying degrees, but usually sufficiently to render it impervious. The reason for the lack of ferric iron in these soils, which account for their pale colour, is not clear, but does not appear to be attributable to lack of iron in the parent rocks nor to anaerobic conditions which probably only develop temporarily and in a shallow layer over the clay substratum. Because of the lack of iron to stabilize it, however, clay is easily washed out of the upper layers leading to a relative accumulation of the coarser fractions. Organic matter contents are very low but profiles often appear humus-stained to a depth of a foot or so due to the lack of iron to mask it. Topsoils are almost saturated with bases but lower layers are moderately leached; the lower part of the clay substratum or the underlying weathered rock are usually saturated, with sodium amounting to over 10 per cent of the total bases in some profiles. Pallid sands over the Tertiary sediments seem to have been leached of their colour (iron) at a time when their parent material adjoined or lay below the 30-40-foot and 5-10-foot sea-levels.

Black Earths are associated with basic rocks wherever these underlie gentle topography. The clay mineral is montmorillonitic. The dark colour of the soils is attributable to organic matter which, under the base-saturated conditions, although present in only moderate to low amounts, is dispersed deeply down the profile as a dense stain around the mineral particles. The soils are usually base-saturated throughout with calcium carbonate accumulating in large amounts below the surface 18-24 inches; but rotational movement of the soil due to shrinking and swelling has locally pushed calcareous concretions to the surface; (actual 'gilgai' micro-relief appears to be rare). Calcium and magnesium are the dominant bases, but sodium may account for around 10 per cent of the total in the lowest layers.

Grey Earths are developed over the finer-grained acidic gneisses where these do not contain abundant quartz veins and in colluvium derived from Pallid Sands upslope. Their profile has some of the major characteristics of a solodized solonetz but they appear to differ from such soils in the much larger dimensions of the structural units in the hardpan layer and in the absence of associated saline soils (solonchak and solonetz). The clay mineral is a mixture of montmorillonite and kaolinite (4). The small amount of organic matter is distributed in two layers, one in the upper topsoil, the other in the upper part of the hardpan layer where, in well-developed profiles, it forms a dark varnish on the faces of the structural units. Topsoils and the upper layers of the hardpan are usually slightly leached, but lower layers are saturated. Calcium carbonate has accumulated below the hardpan and soluble salts (mainly sodium chloride) occur in amounts up to about 0.2 per cent in the deeper layers. Calcium and magnesium account for most of the total base content, but sodium provides from 10–30 per cent. of the total below the topsoil.

The Alluvial Clays include a number of very different soils. Very minor areas are occupied by true alluvial soils (Alluviosols) subject to significant accretions of fresh alluvium at the surface. The majority have a developed, or developing, soil profile. The trend appears to be for topsoils to become increasingly acid from the highest to the lowest sites in fresh-water areas: red terrace soils and the higher of the levee soils are near-neutral in reaction, becoming acid with depth; slough soils are very acid throughout. Towards the lower course of the Volta, the lower-lying soils contain a certain amount of sulphides in their lower layers which oxidize when the soils are sampled leading to the development of extreme acidity. This process has taken place naturally in extensive former deltaic areas surrounding Songaw lagoon where slightly improved drainage has led to oxidation of ferrous sulphide, precipitating the iron as large bright mottles, the sulphuric acid released reacting with shells to form gypsum crystals but still leaving the soils extremely acid below the surface few inches. Soils immediately surrounding the lagoons are mainly solonchak and solonetz. Heavy clays in the interior valleys are mainly very acid throughout, although sometimes becoming less so with depth. The clay mineral in most of the alluvial clays is believed to be mainly illite, but the black alluvial clays are predominantly montmorillonitic and the brown clays are believed to be partly montmorillonitic, too. Despite the strong leaching of most of the clays, they are still well provided with bases. Calcium and magnesium predominate, except in the saline soils, but sodium becomes important in the lower layers of the lower-lying soils. Soluble salts are present in appreciable amounts, usually at depth, in almost all the soils.

Levee and Dune-sands are regarded as Regosols. Both have developed profiles, however. The levee sands have a well-developed humous topsoil. The humous layer is poorly developed in the dune sands, but shells formerly present in the parent material have been dissolved out of the uppermost few feet of the profile.

It remains to add that sedentary soils, that is soils developed directly in the underlying weathered rock, are comparatively inextensive in this region. They are practically confined to the steep slopes of the Akwapim Range and the inselbergs. The majority of the upland soils are developed in a supperficial 'drift' of fine material which is often separated from the underlying rock by a stone-line of quartz gravel. The drift is of very local origin, however, and changes in the underlying geology appear to be faithfully followed by the overlying drift. There is evidence that termites, particularly those building the large, 'gothic', mounds, are responsible for creating this drift, transferring fine earth from the zone of weathering rock through the stone-line to their mounds on the ground-surface whence it is distributed over the surface as the mounds are eroded. The thickness of the drift is rarely more than 6 feet and perhaps averages 3-4 feet. It tends to be thicker on summits of the broad undulations than on slopes, and in coarse sands than in clays.

Not all drifts are of biotic origin. Normal colluvial and alluvial drifts occur on lower slopes and along valley bottoms. Piedmont drifts - special case of colluvial drift - occur at the foot of the Akwapim Range, but do not appear to be important around most of the basic gneiss inselbergs.

VEGETATION

There is a transition eastwards from moist semi-deciduous forest on the Akwapim Range through thicket near its foot to savannah over the greater part of the Plains. This broadly reflects diminishing rainfall and humidity in this direction. Within this broad zonation, however, there are considerable differences in detail due to differences in soils.

The forest occurring on the Akwapim Range and near its foot in the centre and north has been considerably disturbed by settlement and cultivation. The picture now is of more or less frequent, isolated, large trees, particularly silk cotton, standing over a mosaic of cultivated clearings, thicket regrowth vegetation and low secondary forest.

On the flanks of the Akwapim Range and over a broad belt near its foot approximately south of Dodowa, few forest trees remain and there is now a dense growth of thicket up to 15-20 feet high cleared irregularly for food-farms. In this area, the thicket is composed largely of dark and shiny-leaved species, several of them thorny: this appears to be a stable formation now and is known as 'coastal thicket'. Further north, in more humid areas, the thicket is composed of species with broader, softer and lighter-green foliage: this is known as 'forest thicket' and is not regarded as stable but merely as a successional stage in the regeneration of forest after clearing.

The thicket vegetation continues eastwards for some distance onto the Plains wherever Red Earths occur, mainly in the south, but on other soils savannah is quickly encountered. Over coarse-sandy soils and over concretionary Red Earths in the south, tall-grassland is found. On the coarse Pallid sands between Dodowa and Adomeda, this grassland is characterized by abundant Borassus palms. Over the Red Earths in the south, frequent patches of coastal thicket occur in the grassland, often in elongated clumps aligned NE-SW with the prevailing sea-breeze.

Over the Grey Earths, and the finer, gravelly, Pallid Sands, there is short-grassland with widely-scattered small clumps of thicket confined to old termite-mounds. These thicket clumps characteristically include a candelabra-like tree, *Elaeophorbia drupifera*. On the deeper sands to the north of Tema, a dense low growth of thorn thicket (of *Dichrostachys glomerata*) has developed. Low riverain woodland occurs along stream channels.

The Black Earths carry medium-grassland with *Vetiveria fulvibarbis* the major grass occurring. There is almost no woody vegetation in the south, but scattered low shrubs appear as the latitude of the Shai Hills is approached and low, stunted, savannah trees become frequent in the north. Forest and thicket occur on some of the basic gneiss inselbergs, but most carry savannah vegetation. Riverain forest or woodland border stream channels.

The Red Earths over the Tertiary sediments still carry coastal thicket over their major occurrences, but this is heavily broken by food farms and tall-grassland with thicket clumps is encroaching in the southern areas.

The Volta floodplain is mainly under tall swamp-grassland with frequent small swamp trees, but patches of thicket occur locally and there is riverain forest along the river bank and along some of the creeks.

The edges of the saline coastal lagoons are bare or scantily-covered with scrambling, succulent herbs, but low mangrove thicket occurs in some places, especially along creeks and river banks affected by tides. Sparse short-grassland with coconut palms covers the coastal sand-dunes.

Alluvial clays elsewhere mainly carry swamp-grassland, variously short, medium and tall, but the deltaic clays around Songaw lagoon support short-grassland with thicket clumps which often include the wild date palm (*Phoenix reclinate*). Medium-grassland occurs on lacustrine clays to the north of Sakumo lagoon in the south-west.

Different types of vegetation are sometimes found on different parts of the topography because of differences in soil conditions. In such areas, it has been necessary on the Vegetation Map to represent ‘vegetation associations’, a term derived by analogy from the soil associations on which they depend and not to be confused with the ecological term ‘plant association’.

CULTURAL FEATURES OF THE REGION

SOCIAL

Political Organization

THE SEVERAL administrative divisions into which the Accra Plains are organized take little or no cognizance of the well-marked physical boundaries of the region. The former Accra district, now a subregion of the Eastern Region, overlaps the Weija Hills and extends almost to Nsawam. The summit and eastern slopes of the Akwapim Range from Berekuso in the south to a point west of Somanya in the north lie within, but form only a small area proportion of, Akwapim-New Juaben district with headquarters at Koforidua. The northern part of the region forms part of the Volta River district with headquarters at Akuse; this district overlaps both the northern part of the Akwapim Range and the Volta River by considerable amounts. The greater part of the eastern half of the Plains forms part of the Ada district administered from Ada Fuah. All the districts listed above fall within the Eastern Region whose headquarters are at Koforidua. The central stretches of the Lower Volta floodplain together with a triangular slice of the Plains to the south are administered from Sogankope on the eastern bank of the Volta as part of the Tongu district. This district forms part of the Volta Region whose headquarters are at Ho.

To a large extent the administrative boundaries conform to traditional tribal frontiers. Because of a complicated history of tribal wars and migrations and the fact that much of the region is sparsely populated and little used, there is often dispute over the exact location of these frontiers, and difficulties concerning rights of ownership of land can be expected if the region is ever developed.

Briefly, the history of tribal movements in the region is one of constant clashes between Ga-Adangbe people on the one hand and Akan peoples on the other, together with frequent clashes between the component sub-divisions of these groups, too.* The original inhabitants of the region, or at least the earliest of which there is any legendary history, were the Guans or Cherepons. These people were conquered or pushed out by Ga-Adangbe-Krobo tribes moving from the east, probably from the Benin region of Nigeria, in the 15th and 16th centuries. At the same time, or perhaps shortly afterwards, Twi-speaking Akan people were moving down through the forest zone from their original homes in the northern savannah region. The earliest of the Akan people to arrive seem to have been the Akwamus who settled in the neighbourhood of Nsawam just outside the region. The Akwapims occupied the central parts of the hill range of their name.

Today, the greater part of the region is occupied by the various Ga-Adangbe-speaking tribes. The Gas inhabit the areas immediately around and to the north-west of Accra. Dangbe territory includes a large part of the south-central part of the Plains, with Ningo and Prampram the chief towns. Shai people, evicted by the Government in 1895 from their strongholds in the hills of their name in the centre of the Plains, occupy territory at the foot of the Akwapim Range between Dodowa and Agomeda, although the validity of their claim to this land has been disputed by neighbouring tribes. These tribal divisions are all administered from Accra.

The part of the Akwapim Range lying within Akwapim-New Juaben district is mainly occupied by Akwapims. The 1948 Census Report also records 11,678 Cherepons, probably the earliest inhabitants of the region. These people, speaking Cherepon and La languages are concentrated in Larteh and Adukrom.

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*Much of this history has been condensed from Ward, W. E. 1935. "*A short History of the Gold Coast*" 4th edition 1949. Longmans, Green & Co. Ltd., London; and Reindorf, C. C. 1889. *The History of the Gold Coast and Asante* 2nd edition 1951. Basel Mission Book Depot, Basel, Switzerland.

The northern part of the region, administered from Akuse as part of the Volta River district, belongs to three important tribal groups: the Krobos, Osudokus and Akwamus.

The Krobos and Osudokus occupy the north-western part of the district with the exception of a small area near Senchi. Both tribes speak languages related to Ga-Adangbe. These people were removed from their traditional strongholds on Krobo and Ningo (or Osudoku) Hills respectively in 1895 although, except in time of war, they had presumably also occupied land at the foot of the Akwapim Range and along the Volta floodplain respectively.

The Krobo people split into two divisions, Yilo Krobo and Manya Krobo, and now occupy a large area of country beyond the Akwapim Range between Koforidua and Bisa which they appear to have bought from the Akim people. They still possess important settlements along the eastern foot of the Akwapim Range between Trom and Nuaso, however, as well as the large town of Akuse at the edge of the Volta floodplain. The Krobos quickly took up cultivation of cocoa when this crop was introduced, and as it has died out in the original areas, they have tended to move on westwards further into the forest zone. The 1948 Census Report records that there was a slight decrease in population of the Volta River District during the inter-census periods preceding the Reports of 1931 and 1948, and that only 69 per cent of the Krobo people now live within their traditional territory (5).

The fate of the Osudokus is less clear; but from the fact that 34 men of the town of Osudoku are listed in the Census Report as owning cocoa farms—which could certainly not be local—it seems highly probable that many of these people, too, moved to the forest zone to take up cocoa-farming. Some are reputed also to have moved to Accra where they occupy Osu quarter.

The Akwamus, formerly occupying the southern part of the Akwapim Range, moved north after defeat in battle and now inhabit the hill-country around the Volta gorge, with their chief town at Anum beyond the Volta. Only a minor part of their tribal territory lies within the Accra Plains region, Ada district in the south-west and, less closely, to the Krobo; Shai and Osudoku people to the north-west.

The Volta floodplain downstream from Duffaw almost to the river mouth is occupied by Ewe-speaking people. These people, traditionally occupied in fishing and trading, are showing a remarkable tendency to move westwards. Their increase in the Volta River district has almost compensated for the loss of Krobo people to districts further west. The frequency of village names of Ewe origin—e.g.—kope,—kofe,—aw—within the Ada territory suggests that Ewe people have settled in this area, too, but now owe allegiance to the paramount chief of Ada and speak his language. The Ewe areas are administered as part of Tongu District from Sogankope on the eastern bank of the Volta.

POPULATION

The facts that both the administrative districts and tribal territories overstep the regional boundaries and that many of the settlements recorded in the Census Report do not appear on the available maps make it difficult to give an exact figure for the number of people living in the region. By checking through the village names listed in Table 19 of the 1948 Census Report with assistants of the Branch belonging to the various tribes, however, it is believed that a reasonably reliable estimate has been made not only of the total population of the region but of its distribution within the region.

The total population of the region is estimated to be approximately 375,000*. Of this total, the population of the Accra municipal area accounts for almost 135,000, or 36 per cent. The population of this town, the centre of government for the whole country, has almost doubled—from 70,000—since 1931.

Even leaving Accra out of account, the distribution of population about the region is very uneven. The greatest densities of population occur in the peripheral areas; the central tracts are virtually uninhabited. Approximately 40,000 people live along the crest of the Akwapim Range and a further 56,000 in the thicket and farming country at its foot. Along the narrow littoral strip (excluding Accra) there are approximately 34,000 people; and approximately 82,000 people inhabit the alluvial tract

*All the population figures quoted below relate to 1948 since figures for the 1960 census are not yet available.

along the river Volta. Less than 30,000 people inhabit the vast central tracts of the region, and, of these only 5,000 live on the Black Clays belt.

With this pattern of settlement, figures of population density are apt to be misleading. For instance, the littoral population inhabits a very narrow strip of coastal sand-dune and Tertiary deposits over which the density would appear to be of the order of 500 per square mile. These people, however, rely for their subsistence not on this narrow coastal strip alone, but on a much larger areas of sea and of lagoon in which they catch fish or make salt which they exchange for food, and, to a certain extent, on a strip of land up to five miles wide inland in which they may graze cattle and grow subsistence crops.

The 300 square miles of the Black Clays belt, on the other hand, do not actually support even as many as the 5,000 people which the 1948 Census Report records as living within the belt. This paradox is explicable by the fact that the majority of this number live in the towns of Osudoku (2,183), and Doyum (1,101) which are traditional home-towns of the Osudokus and some of the Shais respectively, to which old people retire and which younger people visit only for the celebration of traditional customs. The majority of these people are not supported by the soils on which they live but by the sale of their labour in cocoa-growing areas*. Similarly, it appears likely that many of the population of 20,000 recorded as living in the Krobo hill-foot villages must actually be supported by cocoa or food-farms in Upper Krobo, beyond the limits of the Accra Plains.

Communications

The most striking feature about the communications of the region is the system of more or less parallel roads and trails leading from the foot of the Akwapim Range to the coast, each road traversing the territory of the component divisions of the Ga and Dangbe tribes. (*See* Administrative map). Some of these trails are utilized today as dry-season motor roads; but one still frequently sees people, usually women, head-loading goods between the hills and the coast or *vice versa* on, for instance, the Ningo-Doyum road. The roads follow the spurs of higher, better-drained land so far as possible and are probably very old. They reflect the need of the coastal people for forest produce, in exchange for which they trade fish, salt and, in former days, the foreign goods landed at their coastal towns. Dodowa is the great central market in this area, from where there is a relatively easy route—by foot—up the tributary valleys of the Dodowa stream onto the Akwapim Ridge. Here forest and coastal produce are brought together for exchange. Until the end of the first World War there was an important trade in palm oil which was rolled in barrels along these trails from the foot of Akwapim Range to the coastal towns, whence it was shipped to Europe. The coastal towns remain only as fishing settlements today, for foreign vessels, in this region, only call now at Accra.**

Two other traditional routes in the region respectively follow the crest and skirt the eastern foot of the Akwapim Range; (the present motor-roads from Accra to Koforidua and Accra to Senchi do not entirely follow the old routes). The former ran from Accra through Achimota and climbed onto the Akwapim Range between Kwabenyan and Berekuso, joining the present summit road at Kitasi; another route climbed onto the Akwapim summit between Abokobi and Berekuso. The road along the foot of the Akwapim Range kept—and keeps—to the better-drained red soils, not only, presumably, because these soils are more suitable for traversing during wet weather, but also because almost all the settlements in the area are found on these soils, too.

Traffic along the coast formerly followed the coastal sand-bar and dunes, along which there is still considerable head-loading of local produce. The present Accra-Ada motor road dates only from the 1930's and connects only seven small settlements between Nungua (M.P. 10) and Tamatuku junction (M.P. 59). This road not only links Accra with Ada, but also, by means of the ferry at Tefle, with Keta, Lome and Lagos to the east. From this road, dry-season roads run south to many of the coastal towns, or to the northern edge of Songaw lagoon where salt is collected.

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*The date of the 1948 Census was deliberately fixed for February 8th "as by that time it was to be expected that most persons temporarily absent from home for the cocoa harvest would have returned to their more permanent residences" (6).

**The new port of Tema is expected to come into use in 1960–61.

Along the more closely settled Volta floodplain and delta there are no motorable tracks between Asuchuale (5 miles downstream of Akuse) and Tefle, and communication with the remainder of the region is mainly by canoe along the river or by foot along the levee-bank. The United Africa Company Limited run a shallow-draught launch between Ada and Amedica, and, in times of high flood, this launch can reach Senchi. There are North-South trails between the floodplain and the coast across the eastern acidic gneiss belt. A dry-season motor road between Sege and Aveime with an extension to Battaw has recently been made. The reconnaissance soil survey showed that motor vehicles could be run freely over the acidic gneiss soils during dry weather without benefit of roads.† The road along the floodplain between Kpong and Akuse is liable to be closed during the months of October and November when the Volta is in highest flood; and so too, for the same reason, was formerly the road to Tefle ferry until the recent construction of a causeway across the low-lying areas.

The Accra-Aburi-Mamfe, Accra-Senchi and now the Accra-Tefle, Mamfe-Larteh-Ayikuma and Mamfe-Adukrom roads as well as the scarp portion of the Trom-Adukrom road have bitumenized surfaces. The Kpong-Akuse, Somanya-Akuse, Trom-Asesieso, Dodowa-Prampram, and Tamatuku junction-Ada roads are not bitumenized and the surfaces are often badly corrugated and pot-holed. They are, however, regularly maintained either by the Public Works Department or Local Authorities, and, with the exception of the Kpong-Akuse road already noted, are motorable throughout the year. Other roads, such as those to the coastal towns—except Prampram, and now Tema—are simply dry-season tracks, and cannot be negotiated during the rainy seasons.*

Road construction over large parts of the region is made difficult by the poorly-drained nature of many of the soils, the shortage of readily-accessible supplies of suitable foundation material and the exceptional volume of run-off down valleys that has to be contended with following heavy rainfall. Because of the importance of road development in the opening up of the region, special recommendations concerning soil properties in relation to road-construction are given for each soil tract described in Part II of the Report.

In the extreme south-west, the Accra-Kumasi railway traverses a small area of the region on its ascent from the coast to the Ofako gap at the southern end of the Akwapim Range, approximately 10 miles north-west of Accra.

This line is more or less followed by the Accra-Nsawam road, the major connection between Accra and the forest zone. These communications are of little direct importance to the region as such. A branch railway-line has now been constructed between Achimota and the harbour-town being built at Tema, and will later extend by way of the Shai Hills to Kpong. A former railway-line from Accra to the Water Works at Weija is followed today by a motor-road.**

Accra was, until the recent development of Takoradi harbour, the country's major port; but since ships have to anchor off-shore and goods have to be transferred through the surf by lighter, a new deep-water harbour with four berths*** is now under construction at Tema, 16 miles to the east. It is to be expected that this port will take the whole of Accra's present traffic, as well as relieve some of the congestion at Takoradi.

The airport at Accra can handle the largest aircraft, and is served regularly by a number of international airlines as well as by inter-West African and internal services.

†The tussocky grass and the widely-cracked soils made this impracticable, even with the most sturdy vehicles, over the basic gneiss areas.

*Subsequent to the close of the reconnaissance survey, new first-class roads have been constructed from mile 11 on the Accra-Lagos road to Tema and from Tema to Kpong by way of the Shai Hills; part of the new Accra-Takoradi road traverses the south-west of the region.

**From approximately M.P.7 on this road, the new Accra-Winneba-Mankessim coastal road branches off. This has considerably shortened the road distance between Accra and Takoradi.

***It was announced in 1960 that an additional four berths were to be built at Tema.

Land-Use

The scheme of land-use classification used in this report is that recommended by a commission appointed by the International Geographical Congress held at Lisbon in 1949. Since the survey under review seems likely to have been the first on which this scheme has been utilized on a large scale, it should be acknowledged that it has been found to work very satisfactorily.

On the map-scale used, a great deal of condensation of information has been necessary. In the first place, where cultivation is practised, it is not of a fixed type so that a particular piece of land recorded as under cultivation at the time of the survey would probably not still be under cultivation a year or two later. If it were, the crops grown would almost certainly be different from those originally recorded. Further, if it were found cultivated again after a number of years, the boundaries of the cropped area would usually be different from those originally recorded—as probably would be the farmers, too. A detailed portrayal of actual land-use would only be valid for the year of mapping, therefore, and would have limited long-term value. What has been recorded on the accompanying map is, in effect, the *system* of land-use practised, indicating the type of land-use likely to be found over a number of years.

In the second place, because of different soil conditions, different types of land-use are often found on the uplands from those in the adjoining depressions. These differences have been mapped where the map-scale allows; but in most cases the mapping units are 'land-use associations' similar to the soil associations on which they depend indicating that, within the boundaries of the unit, a particular, specified, system of land-use is found on the upland soils and another on the lowland soils.

A negligible proportion of the region remains under closed forest, and only a relatively small area of secondary forest is found, mainly in the Volta River Forest Reserve. Most of the former forest area has been cleared to make way for cultivation. Fuelwood plantations at Achimota and Prampram cover approximately two square miles.

Cultivation is practically confined to the better-drained, upland soils, and accounts for approximately 30 per cent of the area. Since the general farming system is that popularly known as 'shifting cultivation', the greater part of the area at any one time is actually under fallow vegetation. The crops grown, the length of fallow practised and the character of the regrowth vegetation differ from place to place according to such factors as climate and pressure of population on the land. Small scattered cocoa plantations occur on the Akwapim summit and there are extensive coconut plantations along the coast.

Grassland covers approximately 60 per cent of the region and is particularly associated with the heavy clays over the Dahomeyan gneisses. The acidic gneiss soils provide the main grazing areas. The Black Clays belt is little grazed.

The rocky inselbergs are classified as unproductive land; and the fresh-water swamps and saline marshes, although potentially utilizable, are, in effect, unproductive at present, too.

A few hundred acres of land are under mechanical cultivation at Nungua Veterinary Farm and H.M. Borstal Institution, Accra.*

Crop husbandry

Except in Accra and along the littoral strip, the majority of the population is engaged mainly in farming. The area of land which can be cultivated by the primitive methods used is limited not so much by the rainfall as by the difficult nature of the soils. Cultivation is attempted even in the driest areas where the soils are light-textured, but heavy clays found throughout the central areas, around the lagoons and along valley bottoms are scarcely touched.

The system of farming is that familiarly known as "shifting cultivation". It is considered, however, that this term should be reserved for the primitive economy in which family units themselves shift

*Since the completion of the survey, a further few hundred acres have been brought under mechanical cultivation at the University College Agricultural Research Station at Nungua and on the Kpong Irrigation Research Station. In addition Division of Agriculture mechanized extension units have ploughed a number of areas in the south-west of the region, notably on Black Clays north of Kpong.

about clearing small plots of virgin land; when these are exhausted, then the unit moves on to new areas. In the local system, no virgin land cultivable by present methods remains, and farmers live in more or less permanent villages. Plots of land are cropped until their fertility has been exhausted and are then abandoned in favour of new plots. The abandoned plots in the meantime quickly revert to some form of natural vegetation, the leaf-fall from which restores soil fertility until, after a number of years, cultivation is possible once more. The period between successive cultivations is in reality a natural fallow; and it would seem more appropriate to refer to this system of farming as 'land rotation cultivation'.

The system of land tenure so far as current land-use is concerned does not vary significantly throughout most of the region, even though inheritance is patrilineal amongst the Ga-Adangbe, Krobo and Ewe tribes and is matrilineal amongst the Akwapim and Akwamu tribes. Except amongst the Ewes, where land is owned by the extended family, all land belongs to the 'stool', the symbol of tribal authority. Although a family may traditionally farm within a certain area of their village's land, there is no personal ownership of land as such but only of the crops growing on it. An investigation carried out at Kitasi, 3 miles south of Aburi, by four University College students* showed that, although some people regularly farmed within a definite area, many had farms on land not traditionally recognized as theirs. In the latter case, permission had been sought from the recognized 'owner'—or perhaps only the previous cultivator. This was not normally refused unless the intending farmer was a stranger to the village, when permission would require to be sought from the chief, or if a member of a different tribe, perhaps from the Paramount Chief.

At Kitasi, land is plentiful. Elsewhere, where there is greater pressure of population on the land, it might be expected that the use of family land would normally be more jealously preserved, but there is little evidence that this is, in fact, the case. There is little conception of the idea of land as personal property. Even the introduction into the economy of a perennial crop such as cocoa does not seem materially to have altered the situation. Where cocoa has died out, the land has been abandoned to bush in the customary manner and is available for others to cultivate if the 'owner' is not himself cultivating it. The idea of ownership patently extends only to improvements made to the land in the way of perennial or semi-perennial crops (or buildings). For instance, oil palms and fruit trees are often regarded as personal property, and when permission is granted to another farmer to cultivate land on which such trees are growing, these trees may be specifically excluded from the bargain and be retained for the 'owner's' use or made the subject of a rent.

Throughout the region, work on farms appears to be carried on by members of both sexes. Men are usually responsible for the heavy work of clearing the land. Planting, weeding and harvesting are usually performed by women often assisted by children; but, more particularly in the west, men often assist in such work, too.

Implements are few and primitive. A cutlass (machete) is used initially to clear the vegetation; so few trees remain that it is rarely necessary to use an axe. In savannah areas, a hoe is then used to break up the tussocks of grass, but this is unnecessary in forest or thicket areas. Subsequently, the hoe is used for weeding, although on the Akwapim summit the cultass is often used for this work, too, and hoes are rarely seen. The hoes used have a very short handle, and the blade is set at a very acute angle: a more back-breaking implement could scarcely have been devised.

Land is cleared in one or other of the dry seasons to be ready for planting at the beginning of the subsequent rainy season. In forest, some of the large trees may be felled for their timber, but less useful or more difficult-fellable trees such as silk-cotton, *wawa* and *Piptadenia***(*Dahoma*) are normally left standing. Smaller trees may be girdled and removed later when dead, or coppiced and the poles removed for fuel. The remaining vegetation is then burnt.

In forest and thicket areas, no further preparation of the land may be required after clearing and seeds or cuttings are dibbled directly into the soil. In savannah areas, tussocks of grass are hoed out. and left on the ground-surface. Hoeing of the soil to prepare a fine tilth is not required, for the majority of soils cultivated break down naturally to a fine surface tilth on clearing; heavy clays are generally

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*Report on Kitasi Village Survey. Unpublished typescript report to Director, Soil and Land-Use Survey, by Messrs. E. S. C. Amable, E. K. Ametewee, J. B. Abban and J. G. A. Renner.

**Now *Piptadeniastrum*.

avoided. The Ewe people, however, who cultivate some of the lighter clays along the Volta floodplain, sometimes prepare low raised beds on which to plant their crops. In the forest zone, too, soil is scraped together into small mounds for yam-cultivation.

The size of farms varies considerably. In the drier, savannah areas, they are usually very small, often no more than one-tenth of an acre in extent. In forest and thicket areas, they are usually an acre or so in extent, but may exceed 4 acres occasionally. Between Agomeda and Somanya, especially near Asesieso, clearings of 10 or more acres are common, but these appear to be used for cash-crop production by traders from Accra rather than by the local inhabitants.

A family often farms two or more plots in different parts of the village land, probably, it seems, with the idea that, even if crops are lost due to drought, disease or theft in one area, there is the possibility of a harvest in another. Similarly, more land is cultivated than would be necessary if good harvests were assured, and in most years some crops—mainly cassava—appear to be left unharvested. Generally speaking, a family cultivates an area of 3 or 4 acres each growing-season, but less than this where farming is supplemented by fishing or trade as a means of livelihood.

The climate of the region, with two rainfall maxima, permits two growing seasons. In forest and thicket areas, only two crops are normally taken before the plot is abandoned. Exceptionally, land is cropped for more than one year; but the extra work involved in weeding does not appear to be recompensed by the lower yields obtained in the second or subsequent years. In the south and south-east, however, where fallow regeneration is slower, land may be cropped—usually with cassava—for a number of years. Along parts of the Volta floodplain, too, land may be cultivated continuously for a number of years until weed-growth—especially speargrass (*Imperata cylindrica*)—becomes dominant. Small areas along the Volta banks and west of Ada Fuah appear to be under continuous, intensive cultivation.

The crops grown vary with the rainfall and, in a general sense, with the soils, too.—

Cocoa is practically confined to the ultra-humid Akwapim summit.

Coconuts are practically confined to the coastal sand-dune.

Cassava is a staple food-crop throughout the region, and its cultivation is even attempted on some of the heavy clays in the north. In forest areas, a white-skinned, large-tubered variety is grown. In savannah areas, the variety is mainly one with numerous, small, red-skinned tubers.

Vegetables such as *tomatoes*, *garden eggs* and *peppers* are grown in all cultivated areas, but only occupy a small proportion of the land. Onions are grown by intensive methods near Boteanaw and European *salad vegetables* by intensive methods in Accra.

Maize—cultivation is practically limited to forest and thicket areas, roughly those receiving more than 37 inches annual rainfall.

Yams, *cocoyam* and *plantains* are mainly grown on the more humid Akwapim summit.

Okro is usually produced on seasonally poorly-drained, lower-slope soils in savannah areas.

Sugarcane.—(used only for chewing and the distillation of 'gin') is grown locally in small amounts on bottom clays near the foot of the Akwapim Range, along the Volta floodplain and near Ada Fuah.

Groundnuts and *Bambara beans* (*Voandzeia*) are grown locally throughout the Plains.

Cucurbits (*gourds*, *melons*).—are grown mainly near the coast.

A more detailed account of crops grown and methods of cultivation used in particular areas is given in Part II of the Report.

Mixed cropping is the traditional practice. On the Akwapim summit, yams, maize, cocoyams and cassava are interplanted, sometimes with plantains and vegetables in addition. Elsewhere, maize and or cassava were customarily interplanted with groundnuts or Bambara beans. By this method, the soil is continuously protected against insolation and direct rainfall. It is to be regretted, therefore, that, away from the Akwapim summit, the traditional practice is giving way to monoculture, often of maize, which does not adequately protect the soil. Cassava is grown in almost pure stands in the drier south-east.

Most crops are grown for subsistence purposes, but cash-crop farming of maize is prevalent in the Krobo hill-foot areas, and sugarcane and tomatoes near Ada Fuah and onions near Boteanaw are grown for sale. Cocoa on the Akwapim summit is, of course, a cash crop, too.

The rotation of land is not so systematic as the rotation of crops familiar in temperate agriculture. The students' investigations at Kitasi indicated that the height of the thicket regrowth and the potential yield of fuelwood from this were the major criteria used by farmers in selecting land for cropping. Accordingly, fallow periods must vary with the rates of recovery of fallow vegetation on soils of different quality. Accessibility was also found to be important, the land near the village being cropped more frequently than that in more distant areas.

Under thicket, fallow periods of at least 6 years seem desirable to restore fertility even on the most favoured soils, and of more than 10 years on poorly-provided soils. These minima seem to be achieved on the Akwapim Range, except immediately around settlements; but pressure of population in the Krobo and Shai hill-foot zones has reduced fallow periods to less than 5 years over wide areas which cannot be considered adequate, especially since monoculture of maize is also prevalent in these areas.

Fallowing is less systematic in savannah areas. Natural grass follows are far less efficient in restoring soil fertility than thicket, and this is reflected in the poor quality of the crops produced. There is little cultivation in the south-west, and clearings are made on vacant land only as required: too often, of course, this leads to over-cultivation of land immediately around settlements, as can be seen in and around Accra. Over the Tertiary deposits in the south-east, cultivation is almost continuous within 1 mile of Tamatuku junction, but, although no differences in soil are apparent, fallow periods lengthen beyond this range. Because of inadequate fallow periods, thicket is being replaced by grassland in parts of the Krobo and Shai hill-foot areas, and this is happening, too, over some of the terrace soils along the Volta. There is intensive cultivation of some of the silty flood-plain soils near settlements. Fertility here might be partly maintained by the periodic floods, but it is necessary to point out that the quality of Volta alluvium can only be poor since it is mainly derived from the erosion of old ferruginous drifts, barren Voltaian siltstones and strongly-weathered soils in the upper part of its basin.

Any agricultural system which is going to be permanent must be concerned with the maintenance of soil fertility; and, to anticipate the detailed recommendations given in later sections, it may be stated here that bush-fallowing is the only locally-proven methods of maintaining fertility on the red tropical soils. Grass-fallowing and crop-rotation without the use of fertilizers are inadequate, and the value of green-manuring with legumes has not yet satisfactorily been established. The only satisfactory alternative would appear to be manuring but, again, there is as yet little experience with artificial manures in the tropics, and results have often been conflicting or disappointing. Farmyard manure, of poor quality even when available because of the poor pasturage available to stock, is unlikely to be obtainable in forest and thicket areas because the keeping of cattle is inhibited by the presence of tsetse-fly and the consequent prevalence of *trypanosomiasis.* The problem of how fertility is to be maintained has also to be taken into account when considering the question of introducing mechanized methods into peasant agriculture. This problem will be taken up in Part III of the Report.

ANIMAL HUSBANDRY

Cattle.—The prevalence of *trypanosomiasis*, an infection carried by tsetse flies which breed under forest or thicket shade, generally inhibits cattle-rearing in the coastal regions of West Africa. The open grassland over the south-eastern coastal plains of Ghana, however, is virtually fly-free, and this has become an important stock-rearing area during the present century. A census taken in 1951 estimated that of an approximate total cattle population of 395,160 in the country, 72,266 were reared on the coastal plains (7); of these, probably at least 50,000 are kept on the Accra Plains.

Cattle cannot safely be kept in the tsetse-infested thicket belt in the west. In the grassland areas which can be used there is a striking correlation between soils and cattle-distribution. The acidic gneiss soils provide the major grazing areas, both in the east and west; only one temporary settlement, inhabited by a single herdsman, is recorded over the Black Clays. Although the distribution of herding settlements does not necessarily define the limits of grazing, it is at least clear that the Black Clays are considerably less utilized than the acidic gneiss areas.

The cattle are mainly West African Shorthorns which the Animal Health Division consider "are not economic animals from any point of view" (8). In view of this, improvement is being attempted by crossing with bulls of the White Fulani breed. The cattle are mainly owned by professional or commercial men in Accra or other towns, and are regarded mainly as 'prestige capital': numbers alone count The larger herds are tended by Fulani herdsmen and smaller ones by young boys. During the day the herds have to roam over large areas because of the generally poor quality of the grazing, and water shortage is often a grave problem. At night, the stock are kraaled in cactus-fenced enclosures near villages. The animals are prone to a large number of diseases, but vaccines are available against the more serious infections. Control measures are effected by assistants of the Animal Health Division who make regular tours of inspection.

Despite the owners' attitude, the cattle have a considerable economic value. The meat-shortage in the country is such that high prices are obtained even for these poor-quality animals. In 1950–51, 4,500 cattle from the region were slaughtered, bringing prices as high as £G28 per beast. Investigations at Nungua Veterinary Farm show that the West African Shorthorn yields less than 1 lb. of milk per day in comparison with the 12 lbs. given by the White Fulani. (9) The sale of the dairy products is a perquisite taken by the herdsmen (at the expense of the calves), but these are mainly consumed in the herding settlements themselves.

Although the limits of the present grazing and water resources under the present system of husbandry have not yet everywhere been reached, with the continued rapid expansion the time is in view when these limits will have been reached and any substantial increase in numbers will then lead to deterioration in the quality of the stock, the grazing and ultimately of the soils. Disease-control measures have outstripped improvements in standards of animal husbandry. Only by a revolutionary approach to the latter problem, it is considered, can a permanently satisfactory stock-rearing economy be established in the region. Detailed recommendations in this respect will be given in Part III of the Report.

Other mammalian stock.—No estimate is possible of the numbers of other stock kept in the region. Most households have at least one or two sheep and goats. These are, respectively, of the small forest breed and the short-legged forest breed. The quality of the animals is generally poor, although, in Accra, Hausamen often keep better stock of Sudanese breeds. The incidence of disease is believed to be high. The animals live mainly by scavenging, but they may be provided occasionally with herbage (e.g. *Millettia Thonningii*) collected for them or with cassava. The animals are kept only for their meat.

Pigs are kept in small numbers, mainly in grassland and coastal areas. They are all of the indigenous, black, long-snouted breed. They are little tended and are of poor quality. They subsist mainly by scavenging, but the practice of feeding with cassava is more common than with other animals. Stewart, in 1928, reported that the animals were heavily infested with *cysticercus cellulosae*, the intermediate stage of *Taenia solium*, the most virulent tape-worm of man, and suspected that serious, recurrent epidemics causing large numbers of deaths might be swine fever (10).

No data are available to indicate the total numbers of livestock slaughtered in the region, but an idea of the economic importance of these animals can be gained from the figures available for Accra in 1950–51 which include animals brought in from beyond the Accra Plains region: cattle, 7,035; sheep, 12,627; goats, 5,465; pigs, 6,807. Prices ranged from £G2 to £G3 10s. for sheep; £G1 10s. to £G2 10s. for goats, and £G4 10s. to £G5 10s. for pigs (11).

No horses, mules or donkeys are kept on the Accra Plains proper, although there are a small number in Accra.

Poultry.—Most households have a small flock of fowls. Ducks (of the Muscovy breed) are kept locally on the Plains, and turkeys and guinea fowl are important in the Ada area. No estimate of their total numbers can be made.

With the exception of turkeys, the quality of the birds is generally poor. The fowls are in-bred and small. They live largely by scavenging, but occasionally receive a handful of maize or lump of termite-bearing earth. Losses from disease are high, and numbers are greatly reduced by an epidemic of Newcastle disease in 1950. A few eggs are used for baking, but the majority are left to produce new stock.* Current prices (1953) for chickens range from 15s. to £G1 and for turkeys upwards of £G1 10s.

COLLECTING, HUNTING AND FISHING

Throughout the region, crop and animal husbandry are more or less considerably supplemented as a source of livelihood or of subsistence foods by the collection of wild and semi-wild plant products, and by hunting and fishing.

*Since the close of the survey, there has been a considerable increase in poultry-farming, especially around Accra using imported stock.

Plants and plant products.—Oil palms are rarely deliberately planted. The nuts are disseminated by rodents and birds, and seedlings grow up amongst wild vegetation. When land is cleared for farming, these, and other useful plants, are not disturbed; in this sense only—a process usefully termed 'selective weeding'—are they cultivated. Locally, small plantations are made by transplanting seedlings from the bush or from small nurseries on farms.

Oil palms occur throughout the Accra Plains, but are more particularly associated with the thicket areas in the west. For economic, commercial production of palm oil, it is reckoned that a well-distributed annual rainfall exceeding 80 inches is required. The high humidities prevalent on the Akwapim summit, however, would appear to compensate for the deficiency in rainfall, and, indeed, at the beginning of the present century before attention was diverted to cocoa-farming, palm oil production from this area was important, with Dodowa at the foot of the Range the chief rushing and marketing centre. Large numbers of palms occur on old alluvial soils north of Ada, almost forming oil-palm thicket in places. The plants are extremely stunted—none possessing trunks were seen—and appear to be unproductive.

Palm oil today is only produced for local consumption and forms an important item in the diet, Many palms, too, are tapped for the sap obtained from the growing-point which, when fermented, makes palm-wine. Large quantities of this are consumed and provide a valuable source of vitamin B: it is also used to leaven dough. The spirit distilled from the wine—*akpeteshi*, or native gin—is widely manufactured, illicitly, and is accordingly sold for high prices.**

Mango and pawpaw must be included in this category of semi-wild plants. Mango trees are particularly common in cultivated areas in the extreme south of the region. Pawpaw is more commonly seen within villages and in regrowth vegetation in the forest and thicket belt. Oranges, grape-fruit, limes, cashew, avocado pears, coconut, soursop (*Anona muricata*), sweet sop (*A. squamosa*) and, locally, custard apple (*A. senegalensis*) occur in small numbers, usually within villages, and are probably usually planted. The castor plant exists in a wild or semi-wild state locally, usually around villages. The fruit is collected for extraction of the medicinal oil for local consumption.

It is not possible here to list the wide range of wild plants made use of by local inhabitants. Leaves and fruits of many plants are collected for food and flavourings or for medicinal purposes. Small amounts of herbage from *Milletia Thonningii*, *Griffonia simplicifolia*, *Pterocarpus erinaceous* and other browse-plants are collected to be fed to stock kept in towns. Bark-cloth, fibres and material for the making of baskets, etc. are collected from a variety of plants. Indigo dyes are obtained from *Lonchocarpus cyanescens.*

After oil palms, however, perhaps the major product obtained from the natural vegetation is fuelwood. This is obtained as a by-product when thicket is cleared for farming, but savannah trees are also coppiced; (slow-growing, close-grained savannah trees are probably more suitable for the making of charcoal). Fuelwood is scarce in the coastal areas and coconut husks and cassava stalks are used; mangroves are coppiced where they occur.

Little useful large timber remains in the region today, but poles for the construction of houses are locally-derived; bamboo is often used for the latter purpose, too. Borassus palms growing abundantly on granitic sands of *Doyum* series between Dodowa and Luum are used locally for beams—'ago beams' —and, because of their fibre—and termite-proof qualities, are a potential source of telegraph poles. (The best quality palm-wine is reputed to be made from tapping the growing-points of these palms, too, although there is no evidence that they are used for this purpose locally).

A wide variety of grasses and sedges is used for thatching and weaving. The use of the sedge *Cyperus articulatus* for the making of matresses may be particularly noted. The rhizomes of *C. esculentus* (Tiger nuts) and *C. rotundus* (Nut grass) may be collected for human food, or eaten by stock, mainly pigs. They are mainly found around the edges of the coastal lagoons.

Animals and animal products.—Few game animals remain in the region today. Hunting is quite important, however, and, at night in particular, hunters are frequently encountered out with shot guns

**Local information suggests that a kerosene-tinful (4 gallons) sells for £2–£3 where manufactured, but the price increases to £4–£6 in Accra, partly due to difficulties encountered *en route* in circumventing the law. (1953)

and headlights about their business. Cutting-grass (*Thryonomys swinderianus* Temm.) and a hare (*Lepus zechi* Matshie.) are their chief prey; but antelopes, crocodiles, monitor lizards, fruit bats, monkeys, and rodents and birds generally are taken, too.

Snails form an important item in the human diet, and are collected mainly in the forest and thicket areas. The major snail collected appears to be *Achatina fullica*, which may grow to a size of two or more inches. The snails are extracted from their shells, impaled on bamboo slivers, smoked and then cured in the sun until dry.

Sea-fishing is important along the coast,* where it is the major occupation, supporting 35,000 people (excluding the municipal area of Accra). Almost all the fishing is in the hands of Ga-Adangbe people who migrate along the coast following the seasonal movements of fish shoals. The 1948 Census Report recorded a population of 5,786 at the village of Otrowe near Ada Fuah, where it was thought that the normal population was approximately 350; the equality of numbers of males and females here suggests that women as well as men are engaged in these seasonal migrations, the men catching the fish, the women preparing and marketing it. The quantity of fish caught locally is not known. Much of the catch is smoked and despatched up-country where it has a ready sale.

Fishing is also important amongst the Ewe people living along the Volta. Their catch is normally sold only locally. The collection of oysters—*Egevia radiata* Lamark—is locally important, and seems to be particularly associated with the stretch of the river where tributary streams bring in large amounts of lime from the Dahomeyan gneiss areas. Oyster-nurseries are maintained on mid-stream sand-banks and the industry might well be termed oyster-farming. Large quantities of the molluscs are smoked, and marketed either at Accra or outside the region. The shells are burned for lime by a contractor at Amedica; and a kiln was formerly worked at Volo, near Tefle ferry. Shells in the streets of the river-bank settlements are so common as to give them the appearance of being cobbled; and they are sometimes used to make decorative patterns on house-walls.

Small, 'sugar-loaf' termite-mounds are collected locally on the Plains for the benefit of poultry. Larger—'gothic'—termite-mounds may be opened up for the extraction of the queen which is considered a delicacy in the human diet.

Minerals and associated products.—Ironstone-gravel once formed the basis of local iron-smelting industries. Iron-slag is frequently encountered on the summit of the Akwapim Range, and has been seen near Dodowa at the foot of these hills, as well as on the summit of Mwoyo, a small inselberg immediately south of Krobo Hill. No local smelting is carried on at present and the material is considered to be of too low grade for economic exploitation today.

Clays are used locally for making pottery. Silty Volta alluvium (of Amo soil series) is most widely favoured, and the making of earthenware is important along the floodplain. Plastic clays (of Tachem series) are used near Kodiabe for a similar purpose; and indeed, the Geological Survey Department in making a survey of sources of usable clays, suggested that the best pottery clays were to be found where these clays were mixed naturally with the Amo-type clays in the lower part of the Okwe stream (near the Kpong Irrigation Research Station) (13). Former lagoon clays on the northern edge of Sakumo lagoon west of Accra give rise to an important pottery-making industry employing 108 women at Oblogo (in 1948).** Garnetiferous hornblende gneiss is locally collected, crushed and the feldspar used to make a glaze.

Clays elsewhere are used locally for house-building, but the Black Clays are unsuitable both for the making of houses and pottery.

A strongly-mottled clay found immediately below the Tertiary basal pebble-bed where it outcrops on a small, isolated hill near Toje on the Accra-Lagos road is extracted from a cave which penetrates deeply into the hill-side, and used locally as a 'pigment. Both red and yellow colours are obtained.

Sand is collected locally from suitable stream and river alluvia or from the beach, more particularly near Accra, but also near other large settlements along the coast, for use with imported cement in the making of concrete, particularly concrete building-blocks.

*For details of the types of fish caught and the several methods of fishing, Irvine's book *The fishes and Fisheries of the Gold Coast* (12) should be referred to.

**These deposits have subsequently been exploited by the I.D.C. Bricks and Tile Works, *cf.* footnote 49.

The evaporation of salt is highly important around the shores of Songaw lagoon, and the product, together with that from the larger Keta lagoon across the Volta, is the major natural source of the mineral in the country. Salt is also obtained on a smaller scale around Sakumo lagoon west of Accra.*

FORESTRY

Timber exploitation in the region is negligible, and the most important forest products are fuelwood and charcoal. Besides that used locally, there is an important trade in these products between the forest (and thicket) belt and Accra. The dug-out canoes (made of *wawa*) used by the coastal fishermen are not made locally but are brought down from the forest zone, mainly from Ashanti.

The Forestry Department maintains a fuelwood plantation of approximately 1,000 acres at Achimota, and has planted one of 100 acres for the Prampram Native Authority. It has established a small nursery near Sege.**

The part of the Volta River Forest Reserve which lies within the Accra Plains region is not known to yield any economic products.

MINING

No minerals of major economic importance have been discovered in the region. The garnets which occur abundantly in the Dahomeyan basic gneisses are too shattered to be of use as gems, but where found in alluvial deposits, they may be of potential economic value as abrasives.

Togo quartzite has been quarried near Kitasi for crushing and use as concrete aggregate at the University College site on Legon Hill. A number of small quarries exist in Togo quartzite schist outliers to the west and north-west of Accra, mainly to provide crushed rock aggregate for roads construction or building foundations in and around Accra. Ballast for the Achimota-Tema-Shai Hill-branch railway lines was taken from a quarry in the acidic gneiss near Ashaiman, approximately 6 miles north of Tema. Rock for the breakwaters at Tema harbour was obtained from the Shai Hills, where the rock is garnetiferous hornblende gneiss.

The more important sources of rock for road material are Togo quartzite schist, quarried near Kpong to surface the Kpong-Akuse road, and near Dawhwenya and Afienya for the Dawhwenya-Prampram and parts of the Dodowa-Dawhwenya roads, and as a foundation to part of the bitumenized Accra-Lagos road near Dawhwenya; Dahomeyan quartz-schist extracted from a large pit near Toje, M.P.62 on the Accra-Lagos road; and acidic gneiss quarried on the watershed ridge some 6 miles north of Sege, mile 47½ on the Accra-Lagos road. The two latter sources are extensively used in the east of the region where unconsolidated floodplain alluvia and Tertiary sediments generally prevail. Local rocks are used elsewhere; but perhaps the most widely-used material is ironstone gravel, available throughout the west of the region on peneplain remnants (cf. on Soils Map, Nyigbenya Consociation; Mamfe-Fete Complex; Oyarifa-Mamfe Complex; Nyigbenya-Hacho Complex; Mamfe Consociation).

On the eastern side of Sakumo lagoon near Accra, old lagoon clays are being used for brick and tile manufacture by the West Africa Brick and Tile Works Company, Limited. The clays here are extensive but not deep—usually less than 30 inches—and require to be sluiced with fresh water to leach out the salt. The bricks and tiles made are a pleasant orange-red in colour and appear to be a satisfactory quality.† More-plastic, alluvial clays 10–15 feet deep were formerly extensively quarried near Alajo (in the broad valley south of the Achimota Fuelwood Reserve, now crossed by the Achimota-Tema railway). The bricks and tiles produced were similar in colour and apparently in quality to those just previously mentioned.

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*Salt-production is now organized on an industrial scale around Sakumo lagoon.

**An experimental plantation has subsequently been developed some 3–4 miles north of this village.

†Since the completion of the reconnaissance survey, the Ghana Industrial Development Corporation has constructed a brick and tile works near M.P. 5 on the Accra-Weija road using clays from the northern side of Sakumo lagoon.

PART II

DESCRIPTIONS OF THE SOIL ASSOCIATIONS AND COMPLEXES OCCURRING IN THE ACCRA PLAINS REGION TOGETHER WITH AN ACCOUNT OF THEIR VEGETATION AND PRESENT LAND-USE AND RECOMMENDATIONS FOR THEIR DEVELOPMENT

INTRODUCTION

BECAUSE OF the complex pattern in which the soils of the Accra Plains often occur it has not been possible on the reconnaissance survey to map individual soils. This would only be possible by the use of very detailed methods and of very large-scale maps. Even a survey on a 1-inch grid and the production of a map on a scale of 1:5,000 scarcely served to show the full detail of the soil complexity occurring on the site of the Kpong Irrigation Research Station. In the present report, therefore, it has been necessary to use larger mapping units than the soil series.

The mapping units used, known broadly as *Soil Associations*, are based on the fact that differences between soils can be brought about not only by differences between the parent materials in which they are developed but often also by differences in drainage conditions between the topographical sites on which these materials occur. Thus, in the simplest case, over any particular rock underlying a tract of undulating country, there might be developed a well-drained soil on the hill tops and slopes and a poorly-drained soil in the valley bottoms. A traverse across such a piece of country would show that the two soils always occurred in the same position on the relief. It would be possible, therefore, to map the area as one unit, since it would be understood that within it the uplands would be occupied by the one soil and the lowlands by the other.

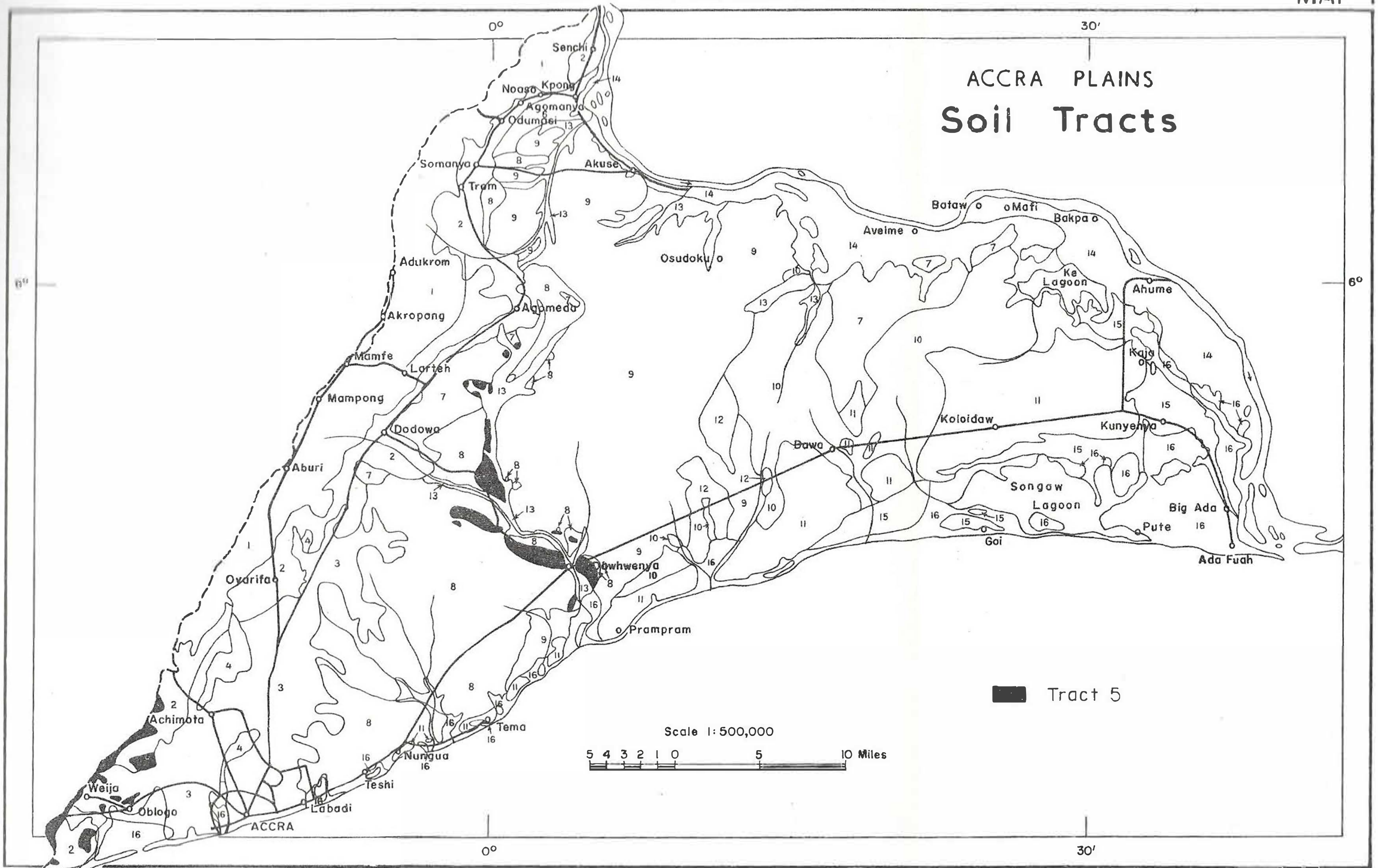
The patterns in which soils occur in nature are not always so simple, and associations often include several soils. Where the soil pattern is irregular, usually because of complicated geology, the area is mapped as a *Soil Complex*. On the other hand, where one soil covers almost the whole of a tract of country, this is mapped as a *Soil Consociation*.

The region has been divided into four physiographic subregions. Within these, 36 soil associations have been mapped. Wherever practicable, a number of associations occurring together within a natural unit of the landscape have been treated together in the descriptions which follow. This has been done not only to reduce the need to repeat desciiptions of soils found in more than one association, but also because it has the practical advantage in connection with the recommendations regarding land-use that such tracts of country will normally require to be developed as a unit. Sixteen such tracts have been distinguished and are indicated on the accompanying map.

These tracts, together with their component soil associations and complexes, and these, in tune, with their component soils, are listed below and later described. In this list a distinction is made between soils always present in a complete topographical sequence and those occurring only sporadically within the association. The former category is subdivided into principal and subsidiary and the second into important and minor according to the areal significance of the soils.

ACCRA PLAINS:—COMPONENT SOILS OF MAPPING UNITS

Name of Association	Soils Always Present: Principal	Soils Always Present: Subsidiary	Soils not Always Present: Important	Soils not Always Present: Minor
SUB-REGION I (AKWAPIM RANGE)				
Tract 1.				
(*a*) Mamfe-Fete Complex	Mamfe Fete	—	Abotakyi Salom	Midie Jakitii Aburi Kitas
(*b*) Fete Consociation	Fete	—	Salom	Kitasi Sesemi
SUB-REGION II (ACCRA PLAINS)				
Tract 2.				
(*a*) Oyarifa-Mamfe Complex ...	Mamfe	Kweman Beraku Krabo	Oyarifa Korle	Fete Salom Papao
(*b*) Beraku-Krabo Association ...	Beraku Krabo	—	Doyum	—
Tract 3.				
(*a*) Nyigbenya-Hacho Complex ...	Nyigbenya	Hacho Papao Adentan	Toje Korle Alajo	Fete Chichiwere Tefle
(*a*) Chuim-Gbegbe Association ...	Chuim Gbegbe	— —	— —	— —
(*c*) Mamfe Consociation	Mamfe	—	—	—
Tract 4.				
(*a*) Danfa-Dome Complex	—	—	Danfa Dome Mamfe Simpa Hacho Papao Alajo	Otinibi Nungua Akuse Bumbi
(*b*) Danfa-Otinibi Association ...	Danfa Otinibi	—	—	—
(*c*) Alajo Consociation	Alajo	—	—	Nungwa Dome Akuse Bumbi
Tract 5.				
Korle Consociation	Korle	—	Nyigbenya Adentan	Mamfe Toje



Drawn by the Drawing Office Staff, Soil Research Institute (Ghana Academy of Sciences)

Kumasi. July, 1960

ACCRA PLAINS: COMPONENT SOILS OF MAPPING UNITS—*contd.*

Name of Association	*Soils Always Present*		*Soils not Always Present*	
	Principal	*Subsidiary*	*Important*	*Minor*
Tract 6.				
Korle-Okwe Complex	—	—	Korle Mamfe Okwe Beraku Hacho Krabo Papao	Fete (Kpong) Simpa Tepanya Akuse Agawtaw
Tract 7.				
Doyum-Agawtaw Association ...	Doyum Agawtaw	—	Koni	Mamfe Kenya Lota Hwapan
Tract 8.				
(*a*) Simpa-Agawtaw Complex ...	Simpa Agawtaw	— —	Nyigbenya	Toje Agbozome Doyum Korle Miny Koni Kenya Hawap Akuse Ashaimaa
(*b*) Nyigbenya Consociation ...	Nyigbenya	—	—	Toje Korle
(*c*) Akuse Consociation	Akuse	—	Ashaiman Nungua Bumbi	—
(*d*) Ashaiman Consociation ...	Ashaiman	Osudoku	—	Nyigbenya
Tract 9.				
(*a*) Akuse Consociation	Akuse	Bumbi Lupu	Kloyo Tepanya Tetedwa	Ashaiman Nyigbeny Bundasea Shai Muete Yongwa Osudoku
(*b*) Kloyo Consociation	Kloyo	—	—	Osudoku Yongwa
(*c*) Osudoku Consociation ...	Osudoku	—	—	—

Name of Association	*Soils Always Present*		*Soils not Always Present*	
	Principal	*Subsidiary*	*Importaut*	*Minor*
Tract 10.				
Agawtaw Consociation	Agawtaw	Hwapa	—	Doyum Simpa Minya Dawsi Bumbi Tachem Lota
Tract 11.				
(*a*) Toje Consociation	Toje	—	Agbozome Alajo	Koliodaw
(*b*)Toje-Agawtaw Association ...	Toje Agawtaw	—	Agbozome (Goi)	Minya Koloidaw Koni Kenya Hwapa
(*c*) Nyigbenya Consociation ...	Nyigbenya	—	—	—
Tract 12.				
Nyigbeya-Agawtaw Complex ...	Nyigbenya	—	Agawtaw Akuse	Tepany Minya Simpa
Tract 13.				
(*a*) Lupu Consociation	Lupu	—	—	Bumbi Tefle
(*b*) Tachem Consociation	Tachem	—	Bumbi	—
(*c*) Tachem-Okwe Complex ...	—	—	Tachem Okwe Bumbi Lupu	Akawle
SUB-REGION III (VOLTA FLOOD-PLAIN)				
Tract 14.				
(*a*) Amo-Tefle Association	Amo Tefle	Chichiwere	Lupu	Aveim Zipa
(*b*) Aveime-Zipa Association ...	Aveime Zipa	—	—	—

Name of Association	Soils Always Persent		Soils not Always Present	
	Principal	*Subsidiary*	*Important*	*Minor*
SUB-REGION IV (VOLTA DELTA AND COASTAL FLATS)				
Tract 15.				
(*a*) Ada Consociation	Ada	—	—	—
(*b*) Aveime-Zipa Association ...	Aveime Ada	Zipa	Songaw	Oyibi Agbozome (Gbi)
(*c*) Aveime-Zipa Association ...	Aveime Zipa	—	—	—
(*d*) Agbozome (Goi) Consociation	Agbozome (Goi)	—	Zipa	—
Tract 16.				
(*a*) Ada-Oyibi Association	Ada	Oyibi	—	Truku
(*b*) Songaw Consociation	Songaw	—	—	Oyibi
(*c*) Oyibi-Muni Association ...	Oyibi Muni	— —	— —	Truku
(*d*) Keta Consociation	Keta	—	—	—
(*e*) Keta-Oyibi Association ...	Keta	—	Oyibi Muni	Truku

DESCRIPTION OF SOIL ASSOCIATIONS

SUB-REGION I. (AKWAPIM RANGE)

TRACT 1

General

THIS TRACT, covering approximately 120 square miles (76,800 acres), includes the whole of the Akwapim Range occurring within the Accra Plains region. Soils on small areas of relatively gentle relief on the highest parts of the range are developed mainly in ironstone-concretionary clays. On the steep slopes which occupy most of the tract, shallow soils are developed over quartzite or, less commonly, phyllite. There are only small areas of alluvial soils. All soils are well drained, some excessively so. Semi-persistent streams only occur in the larger valleys; over most of this tract, small streams flow only after heavy rainfall.

The Akwapim summit enjoys a distinctive climate. Aburi has a mean annual rainfall of 48·05 inches falling on an average of 100·5 days per year; the coefficient of variability is 14 per cent.* Throughout the year, cloud usually envelopes the summit at night; it often persists for much of the day, too, between June and August. Under these conditions, copious amounts of moisture collect on the forest vegetation and drip to the ground, keeping the soils moist throughout the year. The flanks of the range, except in the north, receive less rainfall and do not benefit to the same extent from cloud-water. At the foot of the range, the mean annual rainfall increases from around 35 inches in the south to 45–50 inches in the north.

The summit carries broken secondary forest and thicket with frequent small cocoa plantations and clearings for subsistence crops. The flanks of the range generally carry thicket but, in the north, secondary forest occupies the Volta River Forest Reserve, and in three localities there are extensive patches of savannah. Clearings for cultivation are generally infrequent and small except near settlements, but they are extensive on the slopes above and between Asesieso and Somanya.

The soils have been grouped within two associations: *Mamfe-Fete Complex* along the highest part of the Akwapim summit; and *Fete Consociation* on the remainder of the summit and on the flanks of the range. The boundary drawn between the two associations is necessarily rather arbitrary since the slopes on which Fete soils occur on the summit merge with those forming the flanks of the range.

SOILS

Mamfe-Fete Complex

This association comprises a number of different soils occurring over the highest parts of the Akwapim Range and cover an area of approximately 35 square miles (22,400 acres). It includes the following soils which are described in turn below†:—

1. *Mamfe series*
2. *Midie series*
3. *Jakiti series*
4. *Fete series*
5. *Salom series*
6. *Abotakyi series*
7. *Aburi series*
8. *Kitasi series*

Mamfe series comprises red concretionary clays occurring extensively on gentle to moderate upper slopes on the highest parts of the Akwapim summit.

The topsoil consists of dark greyish brown humous sandy loam or light clay, often including a moderate amount of ironstone and quartz gravel. This grades at 6–12 inches into brownish red to red

*This figure indicates that in two years out of three, rainfall totals between approximately 41·32 and 54·78 inches may be expected to occur, i.e. 48·05 inches + 14 per cent.

†The Akwapim Range was not examined in great detail and it seems probable that within this complex any disturbed area there may exist more soils than are indicated below, although none would be expected to be very different in their agricultural properties from those described.

light clay or clay full of spherical ironstone gravel and varying amounts of quartz stones and gravel together with small pieces of reddish decomposed quartzite and phyllite. At 2–6 feet this is underlain by red, often mottled yellow, crumbly decomposed rock; this is usually quartzite, but sandstone so phyllite occur locally. Former settlement has often disturbed the upper layers: soils on such siter may contain pottery fragments and be blackened with charcoal to 30 inches or more.

Soil dug *Odumasi sub-series* differ from the normal soils in that they have a sandy loam texture throughout. They occur patchily amongst the normal soils but are only rarely encountered.

Mamfe soils are well drained and in this tract retain moisture satisfactorily throughout the year. They are easily hand cultivated. The gravelly sub-soil and, in shallow profiles, the underlying weather rock are rarely sufficiently compact to interfere with root-penetration. Under present farming conditions there is little erosion hazard, but if arable cropping is intensified it will be advisable to cultivate on the contour and to ensure that the ground-surface is protected by vegetation or mulch at all times.

Almost all the soils' nutrient supply is contained in the topsoil organic matter. Under present conditions, fertility is generally moderate and on arable land a natural fallow of 6–8 years appears to be adequate to restore fertility to a level satisfactory for renewed cultivation. Former settlement sites, except those recently abandoned, may be much more fertile than the normal soils.

For more intensive cropping, whether of arable or tree crops, it will be necessary to use manures. Phosphorus and nitrogen are likely to be the major needs, but potash may also need to be added in later years. Former settlement sites are often well supplied with phosphorus and potash, but crops grown on them may occasionally show deficiencies in some of the minor elements: these deficiencies, after diagnosis by agronomists, can usually be corrected by appropriate leaf sprays.

Moisture relationships are generally satisfactory but the underlying weathered rock may impede the penetration of tree roots. Nutrient reserves appear to be low, except on old settlement sites. Contour cultivation is required to minimize soil erosion.

Jakiti series differs from Midie series in that its soils are developed over phyllite and so are clayey in texture. They occur patchily in similar sites to Midie soils. The topsoil consists of a few inches of dark brown or grey-brown, crumbly, humous light clay and overlies 1–2 feet of orange-brown to reddish brown, rather stiff, light clay which becomes recognizable as weathered phyllite towards the base. Ironstone and quartz gravel may occur in the clay at 6–12 inches.

These soils appear unlikely to differ very much from Mamfe soils in their agricultural characteristics and potentialities. The old cocoa plots in Aburi gardens occur partly on disturbed soils of this series.

Fete series comprises excessively well-drained, pale-coloured, sandy soils containing little-weathered brash of Togo quartzite (or, less commonly, sandstone) at a shallow depth in the profile. Within the present complex these soils are extensively developed amongst frequent rock outcrops on the steep sides of valleys cutting into the Akwapim summit, and may contain loose ironstone concretions and quartz gravel in the surface 12 inches. They have often been disturbed by former settlement and are sometimes black with charcoal down to 18–30 inches. These soils are more fully described under Fete Consociation below (page 60).

Salom series includes pale-coloured soils generally resembling Fete soils but more clayey in texture due to their being derived from phyllites, shales and sericite schists. They occur locally amongst Fete soils on the steep sides of valleys on the Akwapim summit, but they occupy a much smaller area. They are more described under Fete Consociation below (page 61).

Abotakyi series comprises dark brown, sandy light clays or sandy clays, sometimes rather poorly drained in the lower horizons, developed in slopewash material. These soils cover small areas where relatively gentle slopes occur in the upper parts of valley starting on the Akwapim summit.

Where not recently disturbed, the topsoil consists of approximately 6 inches of dark grey-brown to very dark brown, humous, friable, sandy loam to heavy loam. This grades downwards into dark brown to slightly reddish-brown, rather friable and porous, sandy light clay to sandy clay which sometimes becomes faintly mottled orange below 30 inches. The base of the profile is usually marked by a thin layer of quartz and ironstone gravel overlying iron-stained, crumbly, weather quartzite or sandstone. In shallower profiles, the gravel layer may be a foot or more thick. Former settlement sites are indicated by the presence of pottery fragments and charcoal blackening to depths up to 30 inches.

These soils absorb and retain moisture satisfactorily. Drainage may be slightly impeded in the lower horizons, but otherwise it is good. Hand tillage is easy, but occasional rock outcrops would interfere with mechanical tillage. Terracing would be required if extensive permanent clearings were to be made for annual crops.

Although the soils are strongly leached, their nutrient status still appears to be slightly higher than that of the other soils of the complex. Nonetheless, the bulk of the nutrients is held by organic matter which is quickly decomposed when the soils are exposed, and manuring—particularly to supply phosphorus—would be required for more intensive cropping. Fertility is normally higher on old settlement sites.

Aburi series comprises soils with a pale-coloured sandy layer overlying orange-brown concretionary clay. The soils occur patchily on moderate slopes immediately below the Akwapim summit-level. The profile consists of a dark grey-brown humous sandy topsoil overlying from 3 inches to as much as 3 feet of grey-brown to pale-brown sand; this is followed by 1–2 feet of orange-brown light clay or clay full of iron-stone gravel underlain by pale-coloured, little-weathered quartzite or sandstone.

These soils are of minor agricultural importance. They are easily cultivated and generally have good moisture relationships; where the sandy layer is thick, however, the soils may suffer from draught. Nutrients are concentrated in the humous layer. These would need to be supplemented by manuring for more intensive cultivation.

Kitasi series includes soils patchily developed along valley bottoms. In profile, they consist, below a dark grey-brown, humous sandy topsoil, or from 2–6 feet of pale grey-brown to pale yellow-brown, loose sand overlying rather iron-stained and brashy, quartzite or sandstone.

These soils cover too small an area to be of much agricultural significance. They are free-draining but because of their valley-bottom site and their occurrence near the ultra-humid Akwapim summit they are not subject to severe droughtiness. They are easily handled, and afford unrestricted root-development. The nutrient is likely to be low and contained wholly in the topsoil organic matter.

Fete Consociation

This soil association, consisting predominantly of soils of *Fete series*, occupies the whole of the steep flanks of the Akwapim Range and covers an area of approximately 85 square miles (54,400 acres). The following soils, described in detail below, occur in the association:—

1. *Fete series*
2. *Salom series*
3. *Sesemi series*
4. *Kitasi series*

Fete series comprises excessively well-drained, pale-coloured, brashy soils developed extensively on steep slopes over quartzite or, less commonly, sandstone. The profile consists of a shallow, sandy, humous topsoil, often containing small pieces of rock, merging directly into pale grey-brown to pale yellow-brown sand, sandy loam or sandy light clay containing abundant pieces of rock. Where the rock is sandstone; this usually crumbly and rather iron-stained; in the case of quartzite, the rock is hard and little-weathered and rock outcrops are frequent.

Because of the variable nature of the parent rock and disturbance due to former settlement, Fete soils vary in character from place to place.

Larteh sub-series comprises soils in which there is a foot or more of pale-coloured sand overlying the brashy weathered rock. These soils appear to occur only locally.

Kpong sub-series includes minor soils developed under bush-regrowth and savannah vegetation on moderate to gentle slopes at the foot of the Akwapim Range near Kpong. The profile consists of almost a foot of very dark grey-brown to black, loose, sandy loam, often containing small amounts of quartz gravel, underlain by about 6 inches grey-brown loose sandy loam containing moderate amounts of quartz gravel which rests on slightly iron-stained, brashy, quartzite schist.

Aplisi sub-series is the name given to very shallow quartzite soils occurring under savannah vegetation. The profile consists of an inch or two of humus-stained sand occurring over and amongst pale-coloured, hard, unweathered quartzite. The soils are extensive on steep slopes above Agomeda and occur patchily further north on the slopes above Somanya and Odumasi.

Fete soils near the summit of the Akwapim Range may contain moderate amounts of iron-stone and quartz gravel in the surface layers. Soils here are also frequently blackened by charcoal and contain pottery fragments down to as much as 30 inches. Other local variants occur in which the bedrock is more deeply weathered and clayey or the rock brash is iron-stained giving a somewhat reddish appearance to the soil.

Fete soils are excessively well drained and normally dry out quickly on exposed cultivated plots, becoming droughty during prolonged dry periods. They are less droughty, however, under the more humid climate near the Akwapim summit. Rock outcrops, except on very steep slopes and in Aplisi sub-series, are rarely too frequent to interfere with hand cultivation. The bedrock, except in Aplisi sub-series, is usually sufficiently broken to allow adequate root penetration.

These soils have low nutrient reserves. Fallow periods of 10 years or more appear to be needed between successive periods of cultivation and the nutrients accumulated in the topsoil organic matter under bush fallow are rapidly lost when the soils are again cleared for cultivation. Larger amounts of nutrients are sometimes found on old settlement sites.

Salom series comprises soils closely resembling those of Fete series in appearance. They differ in that they are developed over Togo phyllites, shales and sericite schists and accordingly are clayey rather than sandy in texture. They occur locally on the flanks of valleys cutting into the Akwapim summit as well as on the main slopes of the range, but cover a much smaller area than Fete soils. Their most extensive occurrence is in the neighbourhood of Asesieso where phyllite occurs on the slopes of the Akwapim Range and on small outliers at its foot.

The surface few inches consist of dark brown to dark grey-brown, humous, friable loam to light clay; this layer may locally contain a high proportion of sand and gravel washed in from adjoining soils. Below this, the soil becomes paler and more clayey, and can be seen when dry to merge at 6–12 inches into brashy weathered rock. With clay-shale, this part of the profile is pale grey-brown to peal yellow-brown in colour, and heavy and stiff when moist; with sericite schist, which is only rarely encountered, the colour tends to be more yellow or even pale red, and the clay rather softer and more friable; with phyllite, which is most commonly encountered, the colour is usually pale orange-brown to pale red, and the weathered rock more brashy.

Despite their clayey texture, the soils are usually well drained. Near the Akwapim summit, moisture retention in the clayey sub-soils is generally satisfactory, although less so where brashy phyllite occurs. Elsewhere, the soils are more liable to drought during the main dry season, except near the foot of Yogaga Hill where the sub-soils show signs of slower drainage and probably retain moisture more satisfactorily. Hand tillage is not difficult. Mechanical cultivation would generally be impracticable except near the foot of Yogaga Hill where soils developed over clay-shales occur on more gentle topography.

Potash reserves appear to be good, but nitrogen and phosphorus supplies vary with the amount of organic matter present. The soils are generally very acid below the humous topsoil, and it might be necessary to add lime as well as nitrogenous and phosphatic fertilizers for more intensive crop production.

Sesemi series consists of pale-coloured sandy light clays containing abundant stones and boulders of various Togo rocks. They are formed in talus accumulations which occur locally on the lower slopes of the Akwapim Range.

The surface few inches consist of dark grey-brown to dark brown, humous, sandy loam or light clay. This grades into about 6 inches of grey-brown to brown, sandy light clay. These layers may contain scattered stones and boulders of various Togo rocks, some of which may project above the ground surface. Below this, there may be up to about 5 feet of brown to pale brown, sandy light clay containing abundant stones and boulders of various Togo rocks, overlying moderately-weathered, brashy Togo rocks, clayey and rather iron-stained where phyllite, but sandy and pale-brown to pale orange-brown in the case of quartzite or sandstone.

These soils are well drained, and under present practices readily absorb moisture which they appear to retain relatively satisfactorily through the dry seasons where they are deep or overlie clayey rotten rock. Hand-cultivation is not difficult and there is no impedence to root-penetration. Erosion control measures would be essential if more intensive cropping were to be attempted. The bulk of their nutrient supply is contained in the humous topsoil. Fallow periods of 10–15 years appear to be used except in the heavily-farmed Krobo areas and immediately around settlements elsewhere. Fertilizers would need to be used for more intensive cropping.

Kitasi series is of limited extent in this association. The soils occur mainly in drainage-grooves near the Akwapim summit. They consist of 30 inches or more of pale grey-brown to pale yellow-brown loose sand which is humus-stained for a few inches at the surface and overlies brashy quartzite or sandstone. The soils in the present association do not differ significantly in their agricultural characteristics or potentialities from those described above under Mamfe-Fete Complex.

VEGETATION

The northern part of the Akwapim Range is protected by the Volta River Forest Reserve. Within the reserve, there are areas of broken high-forest near the summit, but low secondary forest 20-40 feet high prevails on the flanks.

Further south, the Akwapim summit is closely settled. The vegetation between villages consists of mixed broken secondary forest and forest-type thicket above which project widely-scattered high-forest trees, but low bush-regrowth occurs immediately around most settlements. Oil Palms occur abundantly amongst the fallow vegetation. Much of the broken secondary forest shades cocoa plantations, and the thicket vegetation is frequently broken by food-farms. Because of the ultra-humid environment, trees often carry such plants as fens, mosses, lichens, orchids and mistletoe.

Dense thicket covers most of the flanks of the Akwapim Range south of the Volta River Forest Reserve. In the north this is of the forest type, 10-20 feet high, containing frequent oil palms and with *Mallotus oppositifolius* the most conspicuous species. Relict high-forest trees are numerous on the higher parts of the range. There are extensive clearings for cultivation between Asesieso and Somanya. Towards the south, oil palms and *Mallotus* are less common, and the thicket—known as coastal thicket—is characterized by the dominance of numerous dark, shiny–leaved species growing 10-20 feet in height. Very few forest trees remain except in narrow, uncultivable gullies. Clearings for cultivation are infrequent, except near hill-top or hill-foot villages.

To the west of Somanya and Agomeda, and to the south-west of Abokobi, extensive patches of savannah occur on the flanks of the range. These carry a few, small, gnarled, fire-resistant trees amongst tussocky medium grassland. These occurrences appear to be associated with outcrops of particularly resistant quartzites which provide only very shallow, droughty soils.

PRESENT LAND-USE

The major forms of land-use in this subregion are cocoa-farming and land-rotation cultivation with thicket fallows. A considerable area on the Akwapim summit is occupied by settlement, too.

It was on the soils of Mamfe-Fete Complex only a few yards beyond the boundary of the region that the present era of cocoa-farming in the country began when, in 1879, Tetteh Quashie introduced the crop to his farm at Mampong. From here, cocoa-farming spread along the entire Akwapim Range and gradually moved westwards into the then-largely-untouched forest belt, little of which now remains to be exploited for this crop.

Cocoa was probably tried originally on all the soils of the subregion, but failed sooner or later on those not inherently suited to its production. It is today found only on the Akwapim summit, particularly on Abotakyi, Mamfe and Jakiti soils, on which, especially in the case of Abotakyi series, the trees are often found in good conditions. Relatively minor amounts, often strikingly impoverished in appearance, survive on other soils. None of the soils can be considered good cocoa soils since they have only low nutrient reserves, and the fact that cocoa production has persisted is attributable to the perennially humid environment and the satisfactory soil-moisture relationships associated with the latter. The lower temperatures, the greater degree of cloudiness, and the continuously moist conditions in the topsoils maintained by the nightly precipitation of cloud-water reduce the rate at which organic matter is destroyed, and, in soils where adequate numbers of shade trees have been preserved, a satisfactory nitrogen and phosphorus status appears to exist under such conditions. The clay soils derived from Togo rocks, even where strongly leached, appear to contain moderate amounts of exchangeable potash throughout the profile. Since little is known yet of the nutrient requirements of cocoa, however, the contribution of these factors cannot be assessed. The enrichment of the soils on former settlement sites may perhaps partially explain the survival of cocoa on some of the shallower brashy soils.

Generally speaking, cocoa production suffers from the low standards of husbandry practised: trees are too-closely spaced—sometimes less than 6 x 6 feet; inadequate shade trees are preserved; and old and diseased trees are not replaced. The humid climate (as well as irregular and incomplete harvesting) encourages Black Pod disease, and a few outbreaks of Swollen Shoot disease are known to occur. No data on yields are available.

Elsewhere on the Akwapim summit, land-rotation of subsistence crops with thicket fallows is the rule. Clearings are usually less than 2 acres in extent. Mixed cropping of maize, cassava (the white-skinned forest variety) and cocoyams is practised, with yams or plantains included in many cases. Tomatoes, peppers, garden eggs and bananas occupy small areas.

Farms are normally prepared during the main dry season, although some clearing is also carried out during August–September. In the former case, yams—where grown— are normally planted first, in March–April, on low mounds spaced approximately 4 x 4 feet. Maize is next interplanted in April, and then cassava and cocoyams in May. If plantains are grown they are planted in June. Little weeding is necessary because, in the first place, weed species have been eliminated during the preceding thicket fallow, and then, later, the cover provided by the crops themselves is able to suppress weed-growth.

Maize is harvested in August and yams in September–January. Thereafter, little attention is paid to the farm, and cocoyams, cassava and plantains continue to grow amongst the regenerating thicket vegetation. Cocoyams are harvested after two years. Cassava may be lifted at any time between 6 months and three years, and, in fact, may not be completely harvested since it appears often to be grown to provide a reserve supply of food in case other crops fail. Plantains mature at between 1 and 2 years.

Maize is the major crop grown if land is first cleared in the second growing season. It is then planted in September to be harvested in December, and is usually interplanted with cassava.

Tomatoes, peppers and garden-eggs may be grown on small separate patches of land in the corner of a farm devoted to other crops, or may be interplanted irregularly with these crops. They may be planted in either April or September to be harvested 2–3 months later.

One or two small pineapple plantations have been observed on Fete soils, but more usually, the fruits are collected from plants which grow semi-wild in the thicket and secondary forest. Bananas, too, are rarely cultivated today, but the fruits are collected from plants which continue to regenerate from old stock.

Oil palm seedlings found growing wild may occasionally be transplanted to form small plantations; but this practice is uncommon, and the fruit—or the sap, for palm-wine—is usually collected from wild palms growing in the thicket or secondary forest. These palms are only cultivated in the sense that they are protected by selective weeding when clearings for cultivation are made. Citrus are occasionally planted, but occur most commonly around compounds.

There are no yields data for any of the subsistence crops, but production appears to be relatively satisfactory due to the adequate fallow periods generally provided, the practice of mixed cropping which shades and protects the soil, the more reliable rainfall experienced and the perennially humid environment. Cassava 'mosaic' and, in recent years, maize 'rust' are prevalent, but in the absence of yields data their influence cannot be reliably estimated.

With one or two conspicuous exceptions, there is little farming on the steep flanks of the Akwapim Range. In the north, the greater part of the Range has been retired from cultivation in favour of the Volta River Forest Reserve. Southwards from Asesieso and Agomeda, mixed cropping of maize and cassava, occasionally with yams, is normally practised. Farms are small and fallow periods appear generally to exceed 10 years. The savannah patches are unfarmed.*

However, on the slopes above and between Asesieso and Somanya, and locally near such towns as Dodowa, there are extensive clearings. Fallow periods appear probably to be inadequate for the maintenance of soil fertility and probably even of the soil itself. In the neighbourhood of Asesieso,

*This has, in fact, occurred on the slopes above Asesieso since the completion of the survey.

where Salom soils are widespread, almost the whole flank of the Akwapim Range was under simultaneous cultivation in the second rainy season of 1952, and to maize, a crop which offers little practice in this area. Clearings tend to be larger than in the case of subsistence farming, and crops are usually grown in pure instead of in mixed stands.

Maize is the major cash crop produced. Seed may be sown—three seeds to a hole, spaced approximately 2 x 3 feet—in either March–April or in September to be harvested in July–August or in December respectively. Ideally, such a crop is followed by cassava which is lifted over the following one to three years. There is evidence, however, that successive crops of maize are sometimes taken from the land in this area, although how general this practice is has not been established. Cash-crop production of tomatoes and peppers has been observed at Mpeduasi on the Accra–Aburi road and may occur elsewhere.

In cash-crop farming areas, fallow periods appear to be generally less than 5 years. This cannot be regarded as adequate, and there would seem to be a danger that savannah will invade these hill-slopes shortly. There are no yields data for the crops produced in these areas, but failures due to drought are reported to occur occasionally.

RECOMMENDATIONS REGARDING LAND-USE

The greater part of this tract is occupied by land of low agricultural value. The areas of better agricultural land fortunately occur on the Akwapim summit where most of the people live. The soils included are particularly those of Mamfe, Abotakyi and Kitasi series, but some of the deeper and less steeply sloping areas of Midie, Jakiti, Aburi and Salom series and of Larteh and Kpong subseries of Fete series are also suitable for cropping. The area of good agricultural land is small relative to the population, however. The aim in improving agriculture in this tract, therefore, must be to intensify crop production in the areas of better soils.

Areas of suitable soils nearest the villages and along valley bottoms might best be given over to intensive garden-culture of quick-growing vegetables for consumption by the grower or sale in the local market. Tomatoes, garden-eggs, peppers, okros, onions, sweet potatoes, various beans and spinach would be suitable crops. As a precaution against soil erosion, these crops would need to be grown in narrow beds running along the contour. Large amounts of organic matter would need to be added to the soil: household and village refuse together with crop residues from the farm, properly composted, could supply these requirements. Mineral fertilizers would also need to be added for intensive cropping: phosphorus, nitrogen and, perhaps later, potash would be the major requirements, and some of the areas already heavily farmed would probably benefit from the addition of small quantities of lime occasionally.

In the humid environment of the Akwapim summit production might be possible on a year-round basis, although water might occasionally need to be supplied from domestic sources (or springs or streams in the case of valley-bottom sites) during unduly dry spells. Mulching would help preserve moisture in the soil as well as provide protection against soil erosion.

Under this form of continuous cropping under the very humid conditions of the Akwapim summit there would undoubtedly be a build-up of pests and diseases—such as eel-worms, fungal and bacterial wilts, insects and caterpillars—and regular inspection and treatment by specialist entomologist and pathologist staff would be required in the early years of this development until the farmers had learnt to diagnose and treat the more common pests and diseases themselves.

The remaining soils around villages which are unsuitable for intensive vegetable growing either because of shallowness or steep slope could usefully be planted to fruit trees. Pawpaw, mango, avocado pear, orange, cola, cashew, custard apple (*Anona squamosa*), soursop (*A. muricata*), sweetsop (*A. reticulata*) and guava would suit the conditions. Guava and custard apple would tolerate the more droughty soils better than the other crops. Pawpaw in particular would benefit from the addition of organic manure.

For satisfactory production, crops would need to be grown from selected planting material set out at the appropriate spacing recommended by the Division of Agriculture. Weed competition would need to be reduced by regular slashing, especially in the first year following establishment. The slashed weeds should be left on the ground to provide a mulch: the soils should never be left bare. On steep, rocky soils, it would be advantageous to collect loose boulders to form low walls along the contour, thus helping to make terraces on which the trees might be planted.

For commercial fruit production, the natural vegetation would need to be cleared and scrambling over crops planted to protect the soils; (*Centrosema* would provide a suitable cover crop and, perhaps mixed with Guinea grass, might usefully provide grazing for sheep). Fertilizer requirements could only be determined by experiment, but phosphorus and potash seem likely to be needed. Pest and disease control would require the advice of entomologists and pathologists of the Scientific Services Division.

Other areas in and around villages which it is not desired to cultivate could be used, as they often are today, for rough-grazing for sheep and goats. Production could be improved by fencing off the grazing areas and grazing them on a rotational basis. The grazing could be improved by the sowing of the paddocks to Centrosema and Guinea grass, if this were considered economic. These fodder crops would undoubtedly respond to the addition of phosphatic and perhaps nitrogenous manures, but the economics of such applications would first need to be examined. Watering points would need to be supplied in the paddocks.

Mamfe, Abotakyi and the deeper soils of Jakiti and Midie series are suitable for cocoa and coffee production. Increased production depends on improving present standards of husbandry. Old and diseased stock need to be replaced by improved varieties now available from the Division of Agriculture. New stock should be planted at recommended spacing. Fertilizers will almost certainly be shown to give responses on these soils, except perhaps on old settlement sites; phosphorus seems likely to be the major requirement for cocoa. In the humid environment of the Akwapim summit, 'black pod' is prevalent on cocoa and regular inspection is needed to remove diseased pods as well as for harvesting irregularly-ripening cocoa pods. Regular spraying against capsid and other pests is needed.

Small oil palm plantations could be maintained on some of the deeper soils on the Akwapim summit or along valley bottoms away from the summit to supply local requirements. Suitable high-yielding stock should be obtained from the Division of Agriculture and planted at their recommended spacings.

For arable cropping, there is much to commend the present practice of mixed cropping on small plots using bush fallows to restore fertility. This is an admirable method of soil conservation. The system could be improved by issuing seeds and planting material of higher-yielding varieties of maize, cassava, etc. and by substituting more efficient and more easily cleared fallow vegetation—e.g. pigeon pea—in place of the present natural regrowth. Before there can be any major increase in production, however, it will be necessary for farmers to own their own land. Farmers may then become more interested in adopting improved methods, including the use of fertilizers, to increase soil productivity.

With more intensive cropping it would be desirable for fields and crop rows to be aligned along the contour. On moderately sloping land, it would additionally be desirable to throw up earth banks or plant thick-growing hedges along the contour at intervals of 50–100 feet down the slope.

There is little scope for large-scale mechanization of agriculture because of the patchy nature of the soils, the frequency of rock outcrops or stony soils, and the sloping nature of much of the land. Where mechanical tillage is adopted, stumping of the land will first be required; fields must be aligned along the contour and protected by earth bunds along their lower edge; crops should be grown on contour ridges; the soils should be tilled as little as possible; and the ground should be protected at all times by a cover of mulch (from previous crop residues), growing crops or fallow vegetation.

The steep slopes of the Akwapim Range are unsuitable for arable cropping and this form of cultivation should be discouraged forthwith. (This need involve little hardship: they are, in fact, little farmed except locally near one or two hill-foot villages and, particularly, near Asesieso). The more accessible areas might be planted to tree crops: fruit trees such as guava, custard apple and cashew might be grown, or fuelwood (cassia, nim, teak) plantations established. In both cases, plantations should be laid out in blocks parallel with the contour for each of access and for soil protection. Quick-growing, scrambling, leguminous, cover crops might be required to protect the soils during establishment (and after coppicing in the case of fuelwood plantations). Fuelwood plantations might perhaps be maintained by local authorities.

There is no shortage of road-building materials in this tract. Sites occupied by Fete series provide quartzite brash suitable for road foundations and Mamfe soils provide a ready source of 'laterite' gravel. Under-drainage is generally very good. The main problem in building roads in this tract is that presented by the prevalence of steep slopes.

SUB-REGION II (ACCRA PLAINS)

TRACT 2

General

THIS IMPORTANT tract occupies a narrow belt of country along the foot of the Akwapim Range and the Weija Hills. It covers an area of approximately 76 square miles (48,640 acres).

Two soil associations have been mapped within this area: *Oyarifa-Mamfe Complex*, covering by far the greater part of the tract; and *Beraku-Krabo Association*, occupying a small area near Dodowa. The former consists predominantly of red concretionary and non-concretionary loams and clays on the uplands, but with minor, erratic, occurrences of a number of brashy soils, too; and associated pale-coloured, middle and lower-slope soils developed in sandy and clayey slopewash material. Beraku-Krabo association consists predominantly of imperfectly-drained, pale-coloured sands and clays found over the Dodowa alluvial fan, but includes a small area of pale-coloured, coarse-sandy, upland soils developed over granite.

The tract occupies gently-rolling country at a height of 0–500 feet above sea-level. It is drained mainly by intermittent streams, although the Okwe, Dodowa and Abokobi streams, which rise in valleys deep within the Akwapim Range are semi-perennial. Mean annual rainfall increases from around 30 inches near the coast to around 45 inches in the north, but there are great variations from year to year, especially in the south. Temperatures are higher and humidities lower than on the Akwapim summit, and the southern part of the tract at least is exposed to moderate sea-breezes during the day. Thicket vegetation covers most of the area. Clearings for cultivation are abundant.

The boundary between Oyarifa-Mamfe Complex and Korle-Okwe Complex (Tract 6)* between Noaso and Senchi in the north of the region is not distinct, but has been drawn so as to exclude, as far as possible, the possibility of pale-coloured sands or grey and black calcereous clays associated with Dahomeyan crystalline rocks in the latter association occurring within Oyarifa-Mamfe Complex.

SOILS

Since the major soils of Beraku-Krabo Association also occur in Oyarifa-Mamfe Complex it will be convenient, after discussing the disposition of the soils within each association, to give soil series description for the whole tract together.

Oyarifa-Mamfe Complex

This complex covers an area of approximately 70 square miles (44,800 acres). It consists of two major soil associations which because of the map scale employed could not be mapped separately.

The first, which is most important in the area north of Dodowa, occupies the gently foot-slopes of the Akwapim Range where slopewash from the hills above has accumulated. This association varies in width from almost nil to more than half a mile. It is most extensive in embayments cutting into the Range, such as that below the Aburi scarp road. In the slopewash material, deep, red, well-drained loams of *Oyarifa series* predominate associated with pale-coloured lower-slope and bottom soils of *Beraku* and *Krabo series*, the former sandy and seasonally ill-drained, the latter clayey and almost perennially ill-drained.

The second component association, which is most widespread in the southern half of the complex, occupies the western part of the gentle-undulating surface of the Accra Plains at 0–300 feet and only occasionally abuts directly against the steep slopes of the Akwapim Range. There is a greater complexity of soils in this association. The predominant upland soils are red, well-drained, concretionary clays of *Mamfe series;* these are developed over a variety of highly-weathered rocks. These soils are locally

*The greater extent of these soils occurs within the adjoining Korle-Okwe Complex (Tract 6).

displaced by red brashy light clays of *Korle series* developed over Togo quartzite schist, usually on rather higher and steeper slopes than those on which Mamfe soils occur. On the steep slopes of a few isolated hills there occur pale-coloured, brashy soils of *Fete* and *Salom series*, sandy or clayey respectively as they are developed over Togo quartzite or phyllite. The associated middle-slope soils of *Kweman series*, developed in local slopewash, consist of orange to yellow-brown sandy loams overlying poorly-drained, gravelly and concretionary clay at a variable depth. Lower-slope and bottom soils of *Beraku* and *Krabo series*, as described in the previous paragraph, complete the association, except locally where small patches of savannah have invaded and give rise, in similar parent materials to those of Beraku series, to soils of *Hacho series*.

Beraku-Krabo Association

The soils of *Beraku* and *Krabo series* which together dominate this association are identical with those described above under Oyarifa-Mamfe Complex, but have been mapped separately because of their more extensive development over the Dodowa alluvial fan. A small area near the junction of the Cheku and Dodowa streams is known to be occupied by pale-coloured, excessively well-drained, coarse-sandy soils of *Doyum series* similar to those occurring more extensively in the adjoining Doyum-Agawtaw Association (Tract 7). This association covers approximately 6 square miles (3,8400 acres).

The soils of the tract are described below in the following order:—

1. *Oyarifa series*
2. *Mamfe series*
3. *Korle series*
4. *Fete series*
5. *Salom series*
6. *Kweman series*
7. *Beraku series*
8. *Krabo series*
9. *Hacho series*
10. *Doyum series*

Oyarifa series includes important soils developed in deep slopewash deposits at the foot of the Akwapim Range. The profile consists of a dark grey-brown, humous, loamy top-soil grading at 6–12 inches into several feet of orange-brown to bright red, porous, sandy light clay to sandy clay which becomes mottled with yellow below a depth of 3–5 feet. The bedrock is not usually encountered within 5 feet. It may be either Togo quartzite or phyllite or Dahomeyan acidic gneiss. Shallower profiles near the foot of the Range are underlain by ironstained quartzite or sandstone at 2–3 feet.

The soils are uniform in appearance over wide areas, but are rather more clayey in some areas than others. Soils disturbed by former settlement occur locally and show pottery fragments and charcoal blackening down to as much as 30 inches in the profile. The soils are typically bright red in colour but they become more brown in colour towards the lower slopes where they grade into Beraku series.

Oyarifa soils are well drained and retain moisture satisfactorily in the subsoil. Topsoils become droughty if left bare for long. Under such conditions they also absorb rainfall less readily and are then liable to surface run-off and erosion.

These soils are highly favoured for hand cultivation. They could also easily be mechanically tilled if cleared of their present woody vegetation, but this would need to be done with due regard to the principles of soil conservation (discussed below under 'recommendations regarding land-use').

It is upon their favourable moisture relationships, texture and consistency rather than any inherent fertility that they might possess that the present relatively high productivity of the soils depends. Analyses show that the soils are strongly leached, and, once the nutrients concentrated in the humous topsoil during a thicket fallow have been exploited, the body of the soil itself has very little to offer. The use of phosphatic, nitrogenous and, probably eventually potassic fertilizers will be necessary if production is to be intensified. Topsoils are near-neutral in reaction but lower layers are very acid.

Mamfe series comprises upper-slope soils in which a humous loamy topsoil overlies red clay containing abundant ironstone concretions: this, in turn, overlies ferrugnized and decomposed rock of various kinds, usually at a depth of more than 30 inches. These soils have been described in detail above under Mamfe-Fete Complex (p. 56).

The soils within the present association differ from those described in Tract 1 in that there is occasionally up to 30 inches of red non-concretionary loam at the surface and that generally the concretionary layer contains more quartz gravel and has locally become cemented, too, to form ironpan.

A variety of weathered rocks is found at the base of the profile in different areas, but the majority of these are Dahomeyan acidic gneisses, schists or granite, and Togo rocks are only occasionally encountered. Because of their occurrence under thicket rather than secondary forest, the humous topsoil is usually thinner than on the Akwapim summit.

Two subseries have been recognized. *Odumasi subseries* has a sandy loam instead of a clay subsoil. It only occurs very locally. *Pantan subseries* occurs mainly in the neighbourhood of Oyarifa (Mile 14½, Accra-Aburi road), and differs from the normal soils in that the red clay subsoil contains fewer ironstone concretions and that the whole profile is coarsely gritty.*

The soils are less well watered than on the Akwapim summit, but moisture relationships appear to remain fairly satisfactory. The soils are everywhere used for hand-cultivation. Except where ironpan occurs, they might also be suitable for mechanical cultivation. Immediately north of Agomeda, soils were encountered in which the concretionary clay hardens to form ironpan on exposure. These soils should be disturbed as little as possible in tillage lest the whole subsoil should become permanently cemented, with adverse effects on moisture relationships and root-penetration.

The nutrient supply is almost wholly contained in the humous topsoil. Since in this association the soils only carry thicket and the environment is less humid, less organic matter accumulates than on the Akwapim summit. The soils are accordingly less well provided with nutrients. Phosphorus, nitrogen and, perhaps eventually, potash will require to be applied for more intensive cropping. Topsoils vary from moderately acid to neutral in reaction; lower layers are usually very acid.

Korle series consists of red, well-drained, light clays which contain brashy Togo quartzite schist at a shallow depth in the profile. These soils usually occur on moderate slopes on small hills rising above the general level of the surrounding plains. Rock outcrops are common in the south. Normally, the soils are found under grassland; but those within the present association occur under thicket or bush-regrowth in the neighbourhood of Kpong in the north and on some of the hills south of the Ofako gap.

Drainage is usually excessive and the soils become very droughty after a short rainless period, especially in the south. Moisture relationships are locally rather better where patches of deeper soils occur in the north. Larger areas in the south are too shallow for cultivation. Where the underlying rock is sufficiently broken, hand cultivation can be practised, but mechanical tillage would not generally be practicable.

The soils suitable for cultivation appear to be moderately well provided with nutrients, but are likely to need additional nitrogen and phosphorus if more intensive cropping is to be practised. Their topsoils are near-neutral in reaction with lower layers becoming very acid. The shallow soils in the south are likely to be much less fertile.

Fete series consists of pale-coloured, sandy brashy soils developed over quartzite. They have been described in full under Mamfe-Fete Complex (p. 60). Within the present complex the soils occur only locally in the steep slopes of small isolated hills. They do not differ materially from those previously described.

Salom series occurs on some of the small outlying hills near the root of the main Akwapim Range, especially in the neighbourhood of Asesieso, where the rock is Togo phyllite. This rock gives rise to pale-coloured shallow, brashy light clays similar to those described above for Salom series in Mamfe-Fete Complex (p. 61).

Kweman series comprises orange-brown to yellow-brown sandy loams to sandy clays containing abundant ironstone concretions and quartz gravel in the rather mottled lower horizons. These soil are found on gentle to moderate middle slopes and are developed in slopewash from the ironstone-concretionary upland soils of Mamfe series. They occupy a transitional position, usually rather narrow, between Mamfe series on the upper slopes and Beraku series on the lower slopes. The depth to the gravelly clay layer increases downslope from 12–18 inches where the soils adjoin Mamfe series to more than 30 inches where they grade into Beraku (or Hacho) series.

These soils are well drained in the upper part of the profile but are poorly drained in the lower horizons following heavy rainfall, particularly towards the lower slopes. They absorb rainfall readily,

*Later experience suggests that this soil should be recognized as a distinct series.

except when left bare, but especially towards the lower slopes where the sandy upper layer is deep, they are inclined to be droughty during dry spells.

Hand cultivation is widely practised on these soils at present. They could readily be mechanically tilled, but if extensively cleared for this purpose they would need to be protected against erosion. The gravel-concretionary layer does not appear to be sufficiently compact to impede root-development.

The soils are strongly leached and have little inherent fertility. They depend for their productivity at present almost wholly on fertility accumulated in the humous topsoils during fallow periods. Nitrogenous, phosphatic and probably also potassic fertilizers would need to be used for more intensive cropping. Topsoils are likely to be near-neutral in reaction and lower layers very acid.

Beraku series comprises seasonally ill-drained pale-coloured sands occurring on gentle lower slopes and developed in slopewash derived from Oyarifa and Mamfe soils and from the adjoining Akwapim Range. They are extensive in the Dodowa alluvial fan.

The topsoil consists of approximately 6 inches of dark grey-brown to dark brown, humous sandy loam which grades downwards into a few inches of grey-brown or brown, less humous, sandy loam. Below approximately one foot there is pale brown or pale yellow-brown, porous, sandy loam which gradually becomes slightly mottled with orange and more clayey in texture below approximately 30 inches. This layer may extend to depths of 15 feet or more. Towards its base, it includes a layer of quartz gravel. Locally, seepage ironpan may be encountered at the base of the profile, but nowhere in this complex is it known to occur within 30 inches of the surface. The underlying bedrock, if encountered, may consist of moderately—to highly-weathered Dahomeyan gneisses or schists or of Toto quartzites or phyllites.

Rainfall is readily absorbed under natural conditions, but the soils lose their tilth rather quickly when left bare and are then liable to lose water surface fun-off. Semi-perennial water-tables exist at depth in some of the larger valleys, but most soils dry out rather deeply during the main dry season.

The soils are easily hand cultivated and could easily be mechanically tilled once cleared of trees. The topsoils 'pack' rather badly when left bare and precautions against erosion would be needed if the soils were extensively cleared.

These soils are almost barren of nutrients below the humous topsoil, and the use of fertilizers would be essential under more intensive cropping. Some of these should preferably be in organic form. Topsoils are near-neutral in reaction and lower layers very acid.

Krabo series comprises grey-brown, silty clay bottom soils associated with Beraku series. They are usually less extensive than the latter soils.

The topsoil consists of dark grey-brown, humous, silty loam, rather firm and porous, and rather powdery for an inch or so near the surface when dry, but sticky when moist; root channels are iron-stained. Below this, the soil becomes grey-brown faintly mottled yellow or brown, but when completely dry, it may appear almost white. When moist, this layer is easily penetrated, but when dry, it is very hard—almost indurated—although markedly porous. The texture may remain silty loam for 1 or 2 feet at the top before becoming clayey, or silty clay may occur immediately below the topsoil. Seepage ironpan or gravel have only rarely been encountered at depth. The clays almost always extend to below 6 feet.

Krabo soils are waterlogged, and periodically flooded, during the rainy seasons but dry out deeply during the dry seasons except near semi-perennial streams. The topsoils are readily cultivated by hand and, if cleared of trees, could readily be mechanically cultivated. Control of drainage would be required before large-scale development could be attempted.

The greater part of the soils' nutrient supply is found in the humous topsoil, but the soils appear to have better nutrient-retaining properties than adjoining soils. Fertilizers would still need to be used, however, for more intensive cropping. Phosphorus and nitrogen are likely to be the major nutrient requirements. Reaction varies between profiles, some being slightly to moderately acid throughout, others being very acid below a near-neutral topsoil.

Hacho series comprises soils developed in similar parent materials and possessing a similar profile morphology to those of Beraku series described above but which, since they occur under grassland, have a less well-provided humous topsoil. They occur only locally within the present complex since the boundary between this and the adjoining Nyibgenya-Hacho Complex, where the soils are more widespread, has been drawn so far as possible to coincide with the boundary between thicket and savannah vegetation. The soils are described more fully below under Nyigbenya-Hacho Complex (Tract 3).

Near Agomeda, soils of this series were encountered in which seepage ironpan occurred within 30 inches, and locally, within 12 inches, of the ground-surface.

Doyum series consists of deep, pale-coloured rather loose, coarse sands developed on upper slopes of gentle undulations over weathered granite. The soils support a characteristic vegetation of tall-grass savannah with numerous Borassus palms. Within the present association they may not appear to be very different from Beraku (or Hacho) soils in the upper 2–3 feet of the profile, but, where the soils occur together, Doyum soils would normally occupy the upper parts of the very gentle topography and consist largely of coarse sand rather than medium or fine sand. They will be more fully described below under Doyum-Agawtaw Association (Tract 7).

VEGETATION

Only scattered high forest trees remain on the upper and middle-slope soils. The latter are now covered in the north with forest-type thicket, characterized by *Mallotus oppositifolius* and frequent oil palms, and in the south by coastal thicket, characterized by dark and shiny-leaved species. Clearings for food-farms are frequent. Because of the poor drainage, Krabo and, to a lesser extent, Beraku soils are less frequently cultivated, and often carry broken secondary forest. Bamboos are frequently found growing on these soils, and raphia palms may occur locally.

Near Agomeda and in the Krobo areas, tall-grass savannah is invading and displacing this vegetation. Tall-grass savannah with Borassus palms covers the small area of Doyum soils occurring within Beraku-Krabo Association.

PRESENT LAND-USE

The complex is entirely under-land-rotation cultivation. In the north, the upper and middle-slope soils are extensively cleared and cash-crop farming is the practice. Very large areas of Oyarifa soils between Asesieso and Somanya were under a pure stand of maize in 1952. This crop is grown in either or both of the rainy seasons, planted in March-April or September to be harvested in July-August or December respectively, when it may be followed by cassava. Smaller areas devoted to groundnuts are found, too: this crop may be sown in April or September for reaping in July or December and is usually grown in pure stands, too.

There are only minor amounts of other crops. With the extent of land under cultivation in 1952, fallow periods in this area cannot be adequate to main fertility, and there would seem to be a real danger that the thicket vegetation will quickly be replaced by savannah, a far less effective soil renovator.

In the area between Agomeda and Dodowa (approximately), cash-crop farming on Oyarifa soils is widely practised, but clearings are far less extensive and fallow periods appear generally to be adequate, except in the immediate neighbourhood of Dodowa and Agomeda. Clearings are frequently not of the square or irregular shape found elsewhere, but are in long rectangular plots of 2 to 4 acres perpendicular to the foot of the Akwapim Range. Maize is the major crop in this area, and is grown in pure stands in one or other of the rainy seasons, to be followed by cassava harvested over the succeeding 1–3 years. Subsidiary cash-crops of groundnuts and vegetables are grown to a lesser extent. Yams, planted on low mounds, are grown on a small scale, probably only for local subsistence.

Between Dodowa and the Ofako gap, cash-crop farming of maize, and to a lesser extent groundnuts and vegetables, is again practised on the upland soils, but there is more mixed-cropping of maize, cassava and yams for subsistence purposes than in the other areas. Methods of production are similar to those in areas already discussed. Fallow periods appear generally to be adequate. Between the Ofako gap and the sea, the thicket vegetation is little disturbed by cultivation, and cassava and subsidiary vegetables are probably the only crops grown.

Throughout the complex, most of the lower-slope soils of Beraku series are farmed in a similar manner to the upland soils. On the lower-lying, less well-drained sites, however, together with the adjoining soils of Krabo series, they are only infrequently cleared of their forest vegetation. Single stands of maize are often grown, and cocoyams and okro are also grown on these sites, but the most characteristic crop is sugarcane: (this crop is not grown for the extraction of sugar, but for chewing and the distillation of cane spirit). Cane setts are planted on newly-cleared land in December or January and the crop reaped during the following September to November. The farm is then again burned and a ratoon crop taken the following year. The setts are planted on the flat and are spaced irregularly at approximately 4 x 4 feet. Occasionally in the first season, maize or okro may be interplanted for reaping before the sugarcane has become fully developed.

No yields data are available for any of the crops. However, production appears generally to be satisfactory, although periodic crop failures, especially of maize, are liable to occur due to the unreliability of the rainfall, more particularly in the second growing season. Maize rust has been prevalent in recent years, but its influence on crop yields is not known.

RECOMMENDATIONS REGARDING LAND-USE

This is a relatively heavily-populated tract, densities being particularly high in the north. It is surrounded by tracts with soils considerably less suitable for farming. The aim must be to intensify cropping on the soils of the tract, therefore. The more important soils are capable of giving high crop yields, but they are also liable to suffer catastrophic erosion if improperly handled. A permanently successful farming system in this tract is especially dependent on due attention being paid to the principles of soil conservation. The principles involved will be discussed in Part III of the report.

Of the upland soils, Fete, Salom and the greater part of Korle series are unsuitable for arable cropping. Under acute population pressure they might be turned over, on clearing, to rough-grazing for sheep, or planted to fuelwood or to fruit trees such as guava, cashew or custard apple. This is unlikely to be necessary or economic in the near future, however.

The major upland soils of Oyarifa, Mamfe and Kweman series are suitable for arable cropping. Oyarifa soils in particular are suitable for mechanical cultivation (using either tractors or bullocks). Mamfe soils could also generally be mechanically cultivated, but wear and tear on tillage implements would be greater because of their gravelly nature. Kweman soils are less suitable because of the rather steeper slopes on which they occur and their greater susceptibility to erosion.

The present thicket vegetation would need to be cleared and the stumps removed if mechanical cultivation were to be practised. This would undoubtedly be an expensive undertaking. Large termite-mounds, which are common on these soils, would also need to be demolished where they occurred within fields. The soils over demolished mounds and over old down-graded mounds are usually infertile and plants grown on such areas are usually stunted in growth.

On all soils mechanically cultivated, fields must be laid out on the contour and vegetated bunds for allow strips left between them. Cultivation within the fields should be on the contour.

The farming system adopted should be one which provides adequate amounts of organic matter to maintain a good topsoil tilth or which keeps the ground protected with a continuous cover of vegetation or mulch at all times. Farm-yard manure and compost are unlikely to be available in sufficient amounts to provide the required organic matter over the whole tract, but they should certainly be used when they can be obtained. Organic matter will more likely have to be provided by putting the land under cover crops for part of the rotation: pigeon pea appears to be the most effective fallow crop which could be used at present. Crop residues left on the soil can themselves contribute much organic matter, but care needs to be taken that these do not harbour pests and diseases which could harm succeeding crops.

Farm-yard manure, compost or cover crops (green manures) will not by themselves be sufficient to maintain soil fertility under intensive cropping. For this, mineral fertilizers will be the main nutrient requirement, but nitrogen and, later, potash will be needed for most crops in the years following first clearing of the present thicket vegetation. Lime might need to be added occasionally to correct acidity, but on such soils it needs to be used sparingly; it might perhaps best be added to the cover crop. The amounts of fertilizers to be used can only be determined by investigation.

Crops suitable for cultivation on these soils are the present staples maize, cassava and groundnuts; to these might be added sorghum and millet, if varieties suited to the more humid environment of the Plains can be found, especially for use in the south and during the second rainy season; finger millet might also be tried; and the cultivation of various beans should also be encouraged. Tomatoes, tobacco, pineapples and sisal could in addition be grown as cash-crops, the two latter crops being perhaps more suitable for Mamfe and Kweman soils.

So long as the present system of hand-cultivation on temporary farms continues, farmers should be encouraged to follow the traditional practice of mixed cropping: maize (or sorghum and millet, if found suitable) could be interplanted with groundnuts, cowpeas or other crops providing good ground cover, and later with cassava. They should be encouraged to make their farm clearings in strips parallel with the contour and to plant their crops in rows parallel with the contour. Yam cultivation should not be encouraged because of the excessive disturbance of the soil it requires and the risk of soil erosion it entails. Fallow periods between successive periods of cultivation should be as long as possible, preferably not less than five years after the cassava crop has been harvested.

Where there is insufficient land available to permit natural fallows of five years or more, farmers must be encouraged to make use of fertilizers (mainly nitrogenous and phosphatic) on their crops and eventually to adopt a fixed form of agriculture. In the Krobo hill-foot areas which are closely farmed, it may be necessary to make use of powers available under the Land Planning and Soil Conservation Ordinance to ensure that the soils are adequately protected against erosion.

The lower-slope soils of Beraku series (as well as the upland Doyum soils) are suitable for small-scale oil-palm plantations to meet local needs. Arable crops such as maize, groundnuts and cassava can be grown on these soils, but yields are likely to be relatively lower and less reliable than on the red upland soils. Mixed cropping and contour cultivation are desirable to protect the soils against erosion. Sisal and pineapples could be tried on the rather better-drained sites. On the less well-drained sites, sweet potatoes and okros would be suitable crops. Tomatoes and vegetables could be grown, too, if local water supplies were available for irrigation (by hand) during dry spells. These crops, as well as sweet potatoes, would need to be planted on raised beds, parallel with the contour. For continuous cropping, large amounts of organic matter as well as mineral fertilizers would need to be added. Doyum soils are likely to remain mainly given over to rough-grazing.

Krobo soils in the bottoms are suitable for local production of chewing cane and rice. They are never sufficiently extensive to make large-scale cane or rice production with the help of irrigation practicable. On sites that could be protected from flooding, tomatoes, sweet potatoes and vegetables could be grown; they might perhaps most conveniently be grown as dry season crops.

Domestic water supplies have been improved in the Krobo hill-foot areas by means of a piped supply from Kpong, but the situation further south remains bad. Drilling has recently been in progress on the Accra Plains to attempt to locate suitable sites for wells or pumped supplies, but results to-date have given little cause for optimism.* Better use must be made of existing sources by the use of adequate roof-catchments and tanks and of properly maintained wells and ponds; the lining of some of the latter with bitumen might be considered. The situation in this respect would be improved if water from the Volta dam became available.

The red loams of Oyarifa series respond very well to water and the possibility of pumping water from the proposed main irrigation canal to land higher than the 200-foot contour requires to be considered since these soils lie mainly above this level. Investigations would be required to discover how, under irrigation, fertility and tilth might best be maintained and what crops might be grown. Sprinkler irrigation would be most effective on these soils.

Road construction presents few problems on the upland soils of this tract but difficulties are often experienced on the lower-slope and depression soils. Unsurfaced roads are quite practical on the main upland soils, although use may need to be restricted for a few hours following heavy rainfall to prevent rutting. Alignment of roads along summits and provision of side-drains and culverts would improve serviceability. Where roads go down slopes, side-drains need to be prevented from turning into gullies by the provision of occasional stone checks and more frequent lateral drains to lead the water safely away from dispersal over the adjoining land. Road surfaces should be well cambered. It is of particular importance to ensure that when road surfaces are repaired humous topsoil material from the road-sides is not thrown onto the roads; red soil only should be used.

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*Successful boreholes were drilled at Dodowa, Abokobi and Agomeda but not elsewhere in this tract. See Rep. Geol. Survey, Gold Coast 1953–54, pp. 2–4.

There are no difficulties in the construction of major roads. 'Laterite' gravel supplies are readily available from Mamfe soils. Additional foundation material could be obtained, if required, by opening up quaries in the quartzite schist ridges carrying Korle soils or on the flanks of the adjoining Akwapim Range.

Beraku and Krabo soils provide difficulties because of their poor drainage. Unsurfaced roads become impassable during the rainy season unless they are built up on causeways (preferably built with red soil) and provided with ample culverts and side-drains. Major roads also need to be built up and protected in the same manner.

Lower-slope soils similar to Beraku series create difficulties wherever they occur throughout the forest zone, bitumenized roads over these soils almost invariably collapsing after a short time into a series of transverse swells and hollows. A solution to this problem does not yet appear to have been found. The difficulty probably arises from the fact that these are sandy materials occurring in a zone where water seeps along the lower layers (from soils upslope or out of the rock) during the rainy seasons. An improvement would be expected if the sandy material were to be excavated to a depth of 3 feet or more and replaced by red soil from the uplands and the foundations kept well drained by the provision of side-drains penetrating, where possible, to below the gravel layer at the base of the profile as well as deep cross-drains (or culverts) to intercept the seepage from upslope.

TRACT 3

General

This tract occupies a roughly triangular-shaped piece of country based on the coast in the neighbourhood of Accra, where it is approximately 15 miles wide, and extending northwards to within a few miles of Dodowa. *Nyigbenya-Hacho Complex* occupies the greater part of this area. *Chuim-Gbegbe Association* covers a small area to the west of Accra, and small outliers of *Oyarifa-Mamfe Complex* occur locally.

Because of the very different nature of their soils, inliers mapped as Danfa-Dome Complex, Danfa-Otinibi Association and Alajo Consociation have been excluded from this tract and will be discussed separately below. Similarly, Songaw Consociation, Oyibi-Muni Association and Keta-Oyibi Association which occur around the coastal lagoons have been excluded, and so have the major occurrences of Korle Consociation. A minor outlier of Simpa-Agawtaw Complex will be discussed within Tract 8. With these areas excluded, the tract under review covers approximately 170 square miles (108,800 acres).

The major soils of *Nyigbenya-Hacho Complex* are formed in similar parent materials to those of Oyarifa-Mamfe Complex in Tract 2, but have developed under a drier climate and support only savannah vegetation. *Chuim-Gbegbe Association*, consisting of red and yellow-brown clays containing a lot of pebbles, is associated with remnants of marine-terrace deposits found on a ridge to the west of Accra. The outliers from *Oyarifa-Mamfe Complex* comprise red concretionary soils of Mamfe series occurring under thicket vegetation. It is possible that small areas of soils of *Danfa-Dome Complex* or of *Simpa-Agawtaw Complex* have escaped the traverse-line grid and may be found locally; such soils as may occur will be found described under Tracts 4 and 8 respectively below.

The mean annual rainfall over the complex increases from less than 30 inches near Accra to around 35 inches in the north and west, but the totals vary considerably from year to year. Rainfall during the second rainy season is particularly unreliable. At Accra airport, the mean rainfall is 28·83 inches falling on an average of 71 days per year; the coefficient of variability is 19 per cent.

The tract occupies gently-undulating to gently-rolling country at 0–300 feet and is mainly underlain by Dahomeyan gneisses and schists; but this relief is occasionally broken by slightly higher ridges, such as Legon Hill, of Togo quartzite schist. Accra town itself is partially underlain by Accraian shales and sandstones. With the exception of the Densu, which rises outside the region, there are no permanent streams in the area.

Nyigbenya-Hacho Complex

This complex covers almost 165 square miles (105,600 acres). The major component soils are developed in similar parent materials to those of Oyarifa-Mamfe Complex, but occur under a drier climate and under savannah vegetation. Under these conditions there is less leaf-fall from the scanty vegetation which is, in addition, burned annually. Little organic matter can accumulate, therefore, and the humous topsoils are poorly provided in comparison with those of similar soils occurring under thicket or forest.

The major upland soils, corresponding to those of Mamfe series is thicket or forest environments, are those of *Nyigbenya series* which consist of red loam overlying ironstone-concretionary clay or ironpan. Red, non-concretionary loams to clays similar to Oyarifa soils are known as *Toje series* but occur only locally within the present complex. Red, brashy light clays of *Korle series* and pale-coloured, sandy, brashy soil of *Fete series* developed respectively over Togo quartzite schist and quartzite, occur only locally too.

On middle slopes, orange-brown to yellow-brown, sandy loams or clays with mettled, concretionary and gravelly lower horizons are included in *Adentan series* and correspond to slopewash soils of Kweman series in thicket areas. Deep, pale-coloured, sandy, lower-slope soils of *Hacho series* and grey-brown, mottled, silty-clay bottom soils of *Papao series* correspond to Beraku and Krobo series. In broad valley bottoms towards the south there sometimes occur grey-brown, heavy, plastic clays containing lime concretions in the subsoil; these are recognized as *Alajo series* and have no equivalent in Oyarifa-Mamfe Complex.

The residential areas of Accra are predominantly underlain by Nyigbenya soils but Toje soils occur locally, too. On lower slopes, Hacho soils are extensively developed. All soils have been highly disturbed by settlement. Limited areas immediately behind the coastal cliffs appear to possess brown to reddish-brown sandy clays, rather sandy near the surface and with pebbles and ironstone concretions at a moderate depth overlying horizontally-bedded Accraian shales or sandstones. These soils have not been specifically investigated nor has a series name been attached to them. Very minor scattered patches of black clays similar to Akuse series (cf. Tract 9) occur in the Giffard Camp area.

Very small areas along the Densu in the extreme south-west are occupied by pale-coloured, river-bank sands of *Chichiwere series* and blue-grey, heavy, bottom clays of *Tefle series*. No occurrences of Amo soils, which are extensive on the Volta floodplain, have been recorded here.

In the west and north, the boundary between Nyigbenya-Hacho Complex and Oyarifa-Mamfe Complex has been drawn so far as possible so as to coincide with the boundary between thicket and savannah vegetation since the soils of the two complexes are differentiated according to the vegetation they support. Savannah appears to be encroaching on the thicket areas by way of the lower-slope soils and penetrates deeply up some valleys, with the consequence that topograpical sequences of soils in the west may include soils of Oyarifa-Mamfe Complex on the uplands and soils of Nyigbenya-Hacho Complex in the valleys. Similarly in the east, spurs occupied by Nyigbenya soils project deeply into Simpa-Agawtaw Complex the soils of which under these circumstances occupy the lower slopes.

The boundary between the present complex and Danfa-Dome Complex is indefinite since some of the component soils are common to both associations. It has been drawn, so far as the limitations imposed by the map-scale and the method of survey employed permit, so that none of the distinctive soils of Danfa-Dome Complex should be included in Nyigbenya-Hacho Complex.

The soils of Nyigbenya-Hacho Complex are described below in the following order:—

1. *Nyigbenya series*
2. *Toje series*
3. *Korle series*
4. *Fete series*
5. *Adentan series*
6. *Hacho series*
7. *Papao series*
8. *Alajo series*
9. *Chichiwere series*
10. *Tefle series*

Nyigbenya series includes soils similar to those of Mamfe series described under Tracts 1 and 2 but differing visibly in possessing only a shallow, and less darkly stained, humous horizon.

The topsoil, usually less than 6 inches thick, consists of brown or dark reddish-brown sandy loam. There may then follow as much as 2 feet of red loam or light clay; but most commonly, red sandy light clay to sandy clay containing abundant ironstone concretions and variable amounts of quartz gravel is reached with 1 foot of the surface. The concretionary layer usually extends to below 3 feet; it continued to a depth of 15 feet in one profile observed. This layer has locally become cemented to form ironpan. Where rock has been encountered, it has been found thoroughly decomposed to a red, rather mottled and usually gritty clay. Generally, the complex is underlain by Dahomeyan crystalline rocks; but in Accra, the underlying rocks are Accraian shales and sandstones, and locally elsewhere, Togo quartzite schists occur.

The soils are well drained and absorb water freely during normal rainfall except when left bare. The topsoils dry out thoroughly during dry periods, but the clay subsoils appear to retain moisture more satisfactorily. Moisture relationships are less favourable where ironpan occurs, especially when this occurs within a few inches of the ground-surface.

The soils are generally suitable for hand-cultivation by present methods. In many cases they could also be mechanically cultivated, except where ironpan occurs. On exposure, the topsoils tend to lose their tilth and puddling is liable to occur during heavy rainfall. Root-penetration is only seriously impeded where ironpan occurs.

The soils are less acid than Mamfe soils but contain less organic matter and retain lower amounts of plant nutrients. Lime has accumulated locally in and below old termite-mounds. Manures containing nitrogen and phosphorus are likely to be essential for increased crop production, but it is also essential to ensure that adequate organic matter is added to or maintained in the topsoil.

Toje series comprises soils with more than 30 inches of red sandy loam to light clay. In the present tract this layer may overlie red ironstone-concretionary clay or ironpan at depth or directly overlie ferruginized weathered rock, mainly Togo quartzite schist, but locally, in Accra, Accraian shales or sandstones. These soils occur patchily amongst soils of Nyigbenya series, but are more extensive around quartzite schist ridges such as Legon Hill.

Toje soils are very well drained and absorb water readily except when the surface is left bare. The surface horizons become parched during the dry seasons, but moisture is retained more satisfactorily at depth. Tillage either by hand or machinery is easy but the numerous large termite-mounds would require to be demolished before there could be extensive development. Crop growth is likely to be patchy where termite-mounds have to be cleared since the soil of the mounds is harder and more compact than the inter-mound soils and sometimes excessively rich in lime.

The soils are only slightly acid but have low nutrient reserves. The bulk of their nutrient supply is held in the organic matter accumulated in the topsoil during fallow periods. Nitrogen and phosphorus appear likely to be deficient and the level of organic matter in the soils needs to be raised and maintained for better crop production.

Korle series consists of red light clays containing brash of Togo quartzite schist at a shallow depth. These soils occur amongst frequent small rock outcrops on the moderate to steep slopes of small hills, such as Legon Hill, which locally project above the general level of the Plains.

The soils within the present association are similar in appearance and agricultural characteristics to those described above under Oyarifa-Mamfe Complex (p. 76) but their moisture relationships are poorer and their humous topsoils are thinner and contain less nutrients.

Fete series comprises pale-coloured sandy soils containing brash of Togo quartzite at a shallow depth. They occur on the steep slopes of low hills where quartzite outcrops, but occur only rarely in this complex.

These soils have been described in full under Mamfe-Fete Complex (p. 60). Within the present complex they occur under savannah vegetation and consequently possess thinner topsoils holding considerably less nutrients.

Adentan series is the equivalent under savannah vegetation of Kweman series described under Oyarifa-Mamfe Complex (p. 77). The soils are developed fairly extensively on gentle middle slopes in slopewash derived from the concretionary and gravelly upper-slope soils (which are sometimes thicket-covered near the foot of the Akwapim Range.) They occupy a transitional position between the red upland soils and pale-coloured, loose, sandy, lower-slope soils. They consist of orange-brown to yellow-brown, sandy loams to sandy clays passing downwards into mottled sandy clay containing abundant ironstone concretions and quartz gravel and usually overlying weathered crystalline rocks at depth.

Drainage is seasonally impeded in the lower horizons, especially towards the lower slopes. Water is readily absorbed except on bare plots, but the soils have poor retentive powers and tend to be droughty during the main dry season. The soils offer no obstacle either to hand or mechanical cultivation, but if extensively cleared for the latter purpose, numerous, large, compact, dome-shaped termite-mounds would require to be demolished and anti-erosion devices would require to be provided. There is no hindrance to root-development.*

These soils are less acid than those of Kweman series, but their clay content is low in the cultivation layer and the little fertility they possess is contained in the small amount of organic matter which can accumulate under savannah-regrowth fallows. Lime may accumulate locally in the large termite-mounds. Intensified crop production would require the addition of nitrogen and phosphorus fertilizers and the provision and maintenance of more organic matter.

Hacho series, corresponding to Beraku series in thicket areas, is fairly extensively developed in seasonally ill-drained, lower-slope, slopewash material. The soils consist of several feet of pale brown sand increasing to sandy clay with depth, humus-stained near the surface and slightly mottled orange in the subsoil, but occasionally found with seepage ironpan at a depth exceeding 2 feet.

Rainfall is readily absorbed under the natural vegetation, but the soils 'pack' on exposure and the ground-surface then becomes hard and impermeable. Internal drainage is seasonally impeded, and perched water-tables may exist at the base of the profile during the rainy seasons. The soils have little retentive power, however, and dry out rather deeply during the main dry season.

Hand-cultivation is easy, and provided that the frequent large termite-mounds were removed, the soils could readily be mechanically tilled. Ironpan is only rarely likely to occur at a depth where it might seriously interfere with root-penetration or mechanical tillage. Ante-erosion devices would be required if extensive clearings were made.

Hacho soils have low nutrient contents. Topsoils are generally slightly acid in reaction and lower layers very acid. Relatively heavy manuring would be required to produce high crop yields. It would be essential to maintain a satisfactory level of organic matter in the topsoils.

Papao series is the savannah equivalent of Krabo series. The soils consist of poorly-drained, grey-brown, silty clays developed fairly extensively over valley-bottoms which are frequently streamless.

The topsoil consists of a few inches of dark grey-brown, humus, porous, silty loam, rather powdery at the surface but firm below when dry, and sticky when moist; root-channels are ironstained. Below this there are several feet of grey-brown, weakly mottled brown, porous, silty light clay to clay, easily penetrated when moist, but very hard—almost indurated—when dry. When completely dry, the soil is much paler in colour, often appearing whitish grey. A few soft, red (ironstone) and black (manganese) concretions may occur scattered almost throughout the profile. Bedrock has not been encountered within 6 feet of the surface.

During the rainy seasons, the soils remain more or less waterlogged and are periodically flooded, but they have poor retentive properties and dry out rather thoroughly during the dry seasons. Hand cultivation is practicable on these soils because of the light texture of the surface few inches of the profile. Mechanical cultivation would also be practicable, although clay brought to the surface might bake into hard clods, and numerous very large, compact, dome-shaped termite-mounds would first require to be demolished. In their moist state, the soils permit ample freedom of root-development.

These soils are moderately acid and their low nutrient supply is concentrated in the humous topsoil. Liberal manuring, particularly with lime, nitrogen and phosphorus, would be required for intensified cultivation.

Alajo series occurs in some of the broader, streamless valleys downstream of Papao soil sand consists of grey-brown, rather ironstained, heavier, more plastic clays containing small amounts of lime in the lower part of the profile. Sheetflood occurs over the soils—usually only covered with short grasses and sedges—during and immediately following heavy rainfall, but there is no evidence that they remain flooded for long periods.

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*A definite tendency towards the development of hardpan subsoils has been observed in some profiles investigated since the close of the survey, but the extent of soils showing this feature is not known.

These soils appear not to be developed in every valley within the complex, and do not in total cover a large area. They are more fully described below under Alajo Consociation (Tract 14).

Chichiwere series comprises deep, pale brown or pale yellow, loose sands overlain by a dark grey-brown, humous topsoil. These river-banksoils have only a very limited and sporadic development along the Densu within the present tract. A full description of the series is given below under Amo-Tefle Association (Tract 14).

Tefle series comprises grey, variably-mottled, heavy clays developed under swamp grassland in bottom-lands along the Densu which are flooded for long periods of the year and may remain more or less perennially moist. These soils cover only a very small area within the present association but are extensively developed along the Volta floodplain. They are more fully described below under Amo-Tefle Association (Tract 14).

Chuim-Gbegbe Association

The presence of the component soils of this association has only definitely been established in a narrow strip along the summit and flanks of a 100–150-foot ridge to the east of Sakumo lagoon (west of Accra), but it suspected that they may perhaps be more extensively developed in the area between the occurrence mapped and Accra. The association consists of red gritty loams to clays of *Chuim series* and similar, but yellow, soils of *Gbegbe series* developed respectively on upper and middle slopes of a ridge carrying remnants of a marine-terrace pebble bed. As mapped, the association covers an area of approximately 4 square miles (2,560 acres).

Chuim series is developed on gentle upper slopes and consists of soils with 1–3 feet of red or reddish-brown, gritty loam to clay overlying a thick bed of quartz pebbles in a matrix of red, or red and yellow mottled, gritty light clay or clay which tends to harden into ironpan on exposure. Bedrock has not been encountered, but is expected generally to consist of Togo quartzite schist. Lime concretions are occasionally found patchily in the subsoil.

The lower part of the profile appears to retain moisture satisfactorily except where hardened to ironpan, but the upper layers become parched during the dry seasons. The soils are hand-cultivated at present, but would not generally be suitable for mechanical cultivation because of the general occurrence of the pebble-bed at a shallow depth in the profile.

The nutrient status of these soils is low at present and complete fertilizers would require to be added for intensified production. Some of these should be in organic form. Excess lime found locally in old termite-mounds might induce minor-element deficiencies.

Gbegbe series is developed in similar parent materials to Chuim series but occurs more extensively on less well drained, gentle, middle and lower slopes. The soils have a similar profile to Chuim soils but are brown or yellow-brown in colour, rather more sandy near the surface and do not harden to form ironpan in the subsoil when exposed.

Moisture relations and cultivation characteristics are similar to those of Chuim series, although subsoils appear to retain moisture for a longer period after the rainy seasons. The nutrient status is similarly low.

Mamfe Consociation

This mapping unit has been used to define the position of outliers of *Mamfe* soils (from Oyarifa-Mamfe Complex) which occur in the predominantly savannah-covered Nyigbenya-Hacho areas. The occurrences are restricted to rather small patches on upper slopes of the gently-undulating relief, and altogether cover only approximately 1·5 square miles (c. 1,000 acres).

Mamfe series consists of soils with a thicket-type, humous, loamy topsoil, overlying red clay containing abundant ironstone concretions and variable amounts of quartz gravel, with highly-weathered and ironstained rock usually Dahomeyan in the present case—at depths greater than 3 feet. Ironpan is occasionally encountered at the top of the concretionary layer in the present area. The soils have been described fully under Mamfe-Fete Complex (Tract 1) and further details given under Oyarifa-Mamfe Complex (Tract 2). They will accordingly not be further described here.

VEGETATION

With the exception of the small areas of Mamfe soils which carry coastal thicket and the banks of the river Densu which locally carry low riverain forest, the tract everywhere occurs under savannah vegetation.* The valley-bottom clays typically occur under short grasses and sedges with a few scattered small trees (*Mitragyna inermis*), but old termite-mounds frequently carry Guinea grass of medium height surrounding a clump of thicket. Very small areas of floodplain along the Densu occur under tall swamp-grassland.

Elsewhere, the savannah consists of open tall grassland, or locally, medium grassland which on the uplands includes numerous bushes and small trees characteristically occurring in long, narrow, thicket clumps markedly aligned north-east to south-west. Spear grass (*Imperata cylindrica*), a troublesome weed on cultivated plots, has invaded Hacho soils in some places. Settlement is encroaching over this vegetation-type in the vicinity of Accra. In Accra itself the grassland in the parks and gardens is artificially maintained.

PRESENT LAND-USE

Land-rotation cultivation with savannah regrowth predominates over this tract, but lower-slope and bottom soils in the south-east are used for grazing, and the limited occurrences of Mamfe soils are under land-rotation cultivation with thicket fallows. Settlement—with gardens in the residential suburbs occupies a large area in Accra, and is rapidly encroaching on land used for rotational farming and grazing to the north and north-east.

There are conspicuously smaller amounts of cultivation in this tract than in the adjoining thicket areas except in the immediate neighbourhood of villages and, particularly, Accra. Subsistence farming is the general rule. Farms are generally less than an acre in extent. Cassava (red-skinned variety) and okro are the major crops. There are smaller amounts of sweet-potatoes, groundnuts, peppers and tomatoes. Maize is only a minor crop in this tract.

Land is normally prepared for cultivation during the main dry season and crops then planted in April; lesser amounts are cleared for planting in September. Cassava is usually grown on the red upland soils, and okro (of an early-maturing variety) on the lower-slope soils; (okro is sometimes plantted, too, on large, down-graded, termite-mounds on the valley-bottom clays). These crops are usually grown in single stands, but are occasionally found interplanted with peppers, tomatoes or garden-eggs, although the two former crops in particular are themselves usually grown in pure stands. Groundnuts (or Bambara beans) and sweet-potatoes are only locally important, the latter more particularly to the north and west of Achimota.

With the exception of sweet-potatoes, which are grown on irregularly-spaced mounds, all crops are planted on the flat at a spacing of 3 x 3 feet or less. Under savannah conditions, more weeding is necessary than on plots under thicket, although once cassava in particular is established, little attention is given to the crop and tubers are lifted as the weeds arise. Tomatoes and peppers are harvested after 2–3 months, okro and groundnuts after 3-4 months, sweet-potatoes after 5 months, and cassava from 6 months to 3 years after time of planting.

No yields data are available for any of the crops. Production, however, can scarcely be satisfactory. Cassava in particular is conspicuously less vigorous in appearance than in the thicket areas. Yields of all crops may be expected to suffer in many years because of drought, particularly in the second rainy season. Conditions in this tract must, in fact, be regarded as definitely submarginal for agriculture using present techniques.

Little use is made of valley bottom soils over most of the tract but, in the south-east, lower slope and bottom soils are used for grazing by large herds of cattle. The value of the grazing is satisfactory only by local standards.

RECOMMENDATIONS REGARDING LAND-USE

Little increase in productivity from this tract can be expected with the aid of irrigation from the Volta dam. The major red upland soils are above the 200-foot limit of irrigation, and the frequent

*A further exception may be noted in the area covered by the Achimota Fuelwood Plantation.

shallowness of their loamy topsoil or the occurrence of ironpan would restrict their value for development by this means. The lower-slope soils of Adentan and Hacho series are too free-draining and barren to be generally suitable for this form of development. Only Papao and Alajo soils might be considered suitable, but these are of limited extent. With improved cultivation methods, they might produce rice, cotton, cereals, pulses and fodder crops, as well as traditional local food crops and vegetables, but their development in this manner is unlikely for a considerable period because of their remoteness from the main irrigation areas and the limited value for irrigation of the neighbouring soils. It might prove possible to develop some areas by means of local irrigation schemes, however, if suitable small dam sites can be found.

Increased productivity must come from improvements in present techniques. As in Tract 2, it is important to maintain a satisfactory amount of organic matter in the topsoil and to protect the soil surface against direct rainfall and sunshine. In mixed cropping, this can be achieved by growing cereals in mixed stands with scrambling legumes or cucurbits and by providing adequate fallow periods. In the latter respect, the use of natural bush or pigeon pea fallows might not be practicable in this tract because of the risk of such vegetation harbouring tsetse flies to the danger of cattle in nearby grazing areas. Investigations are required, therefore, to discover suitable fallow vegetation which will not harbour tsetse fly but at the same time will be more effective than the present grassland in restoring soil fertility. It should, if possible, too, have an economic value such, for instance, as grazing or fodder for stock since these are, or adjoin, cattle-grazing areas. For significant increases in productivity it will also be necessary to add fertilizers, particularly phosphorus and nitrogen. Kraal manure and compost should be used where available.

Farmers should be encouraged to clear their land in strips along the contour and to plant their crops in rows along the contour. Where mechanical tillage is used, fields should be ploughed along the contour and earth bunds thrown up (or uncultivated strips left) every 50-100 feet down the slope. Crops should then be planted on contour ridges.

Sorghums and millets might be suitable cereals to grow if varieties tolerant of the humid conditions can be bred; ground-cover be provided by Bambara beans or pulses of low stature, or by cucurbits. Finger millet might usefully be tried on the upland soils particularly for use in the second rainy season.

Trials with sisal and pineapples should be made on Adentan and Hacho soils: it was mainly on these soils, it is believed, that sisal was successfully grown during the 1920's. Plantation methods of production would be required for success with these crops today, using mechanical methods of cutting in the case of sisal. Water for retting might be available from the irrigation scheme: otherwise, bitumen lined excavations in the valley-bottoms would be required.

Where water for irrigation can be provided, vegetables can be grown for sale on the Accra market. For successful intensive production, large amounts of kraal manure of compost should be dug into the soil; mineral fertilizers and lime might need to be added for particular crops as experience proves necessary.

Mango, cashew and guava are suitable fruit crops for the tract. They would grow satisfactorily, on all soils except Papao, Alajo and Tefle series and those areas of Nyigbenya and Mamfe series with ironpan subsoils. Pawpaws could be grown where irrigation is possible. Coconuts could be grown on Hacho, Adentan and Chichiwere series.

The drier, exposed, southern and south-eastern parts of the tract are likely to remain used for rough-grazing. Ultimately, it is probable that stock-rearing will become the major form of land-use over most of the tract. Pasturage at present is poor and more water-holes are required for domestic and animal needs throughout this tract. Improvements should be made along similar lines to those recommended for the adjoining Tract 8.

Conditions in respect of road-building are similar to those described for Tract 2 and the account given there (pp. 85–86) can be referred to for details. Briefly, road-construction presents few problems on the upland soils but difficulties arise on Hacho, Papao, Alajo and perhaps the lower parts of Adentan series due to their poor drainage. Ample sources of road-gravel and foundation material exist in this tract in Nyigbenya, Korle and Chuim series.

TRACT 4

General

The three soil associations described below form enclaves within Nyigbenya-Hacho Complex, but are treated separately because their characteristic soils are entirely different from those of the later complex. Together, the three associations cover less than 10 square miles (6,400 acres).

The largest of the mapping units, *Danfa-Dome Complex*, has very indefinite boundaries with adjoining associations. Some of the normal soils of Nyigbenya-Hacho Complex and of Oyarifa-Mamfe Complex occur throughout, but within the boundaries mapped are displaced locally by areas of varying extent in which occur a number of soils developed over granite and chloritized granitic gneisses and schists: these include soils of *Danfa, Otinibi, Simpa, Nungua, Dome, Bumbi, Akuse* and *Alajo series.* In *Danfa-Otinibi Association*, only the soils indicated in the title occur. In *Alajo Consociation*, although *Alajo* soils predominate, there are small occurrences of *Dome, Nungua, Akuse* and *Bumbi series.*

The tract receives a mean annual rainfall of 30–35 inches, but the totals vary considerably from year to year. Danfa-Otinibi Association is found on the summit and slopes of a small ridge at 250–350 feet. Danfa-Dome Complex occupies gently-rolling country at 50–200 feet and Alajo Consociation an extensive depression at approximately 50 feet above sea-level. Some of the upland soils occur under thicket, but the greater part of the area is under savannah. There is generally little cultivation.

SOILS

Since some of the soils are common to the three associations, unnecessary repetition of descriptions will be avoided if these are given for the tract as a whole. The disposition of the soils within each association will first be described, however.

Danfa-Dome Complex

This complex occupies approximately 6 square miles (3,840 acres) in an irregularly-shaped area to the north of Achimota College. Within the boundaries mapped, the soil pattern is too complicated to be shown on the scale used or to have been fully established by the method of survey employed.

Soils of *Mamfe series*, outliers from Oyarifa-Mamfe Complex, occupy some upland areas, and *Hacho* and *Papao* soils of Nyigbenya-Hacho Complex occupy some lower-slope and valley-bottom sites. The distinctive soils of the complex appear to occur in three associations: *Dome-Bumbi Association; Danfa-Otinibi Association;* and *Simpa Consociation* (or perhaps *Simpa-Alajo Association*).

The soils of Mamfe, Hacho and Papao series appear to occupy important areas within the complex. Mamfe soils consist of red concretionary clay and occur on thicket-covered uplands; *Hacho series* consists of pale-coloured sands, slightly mottled (or sometimes with seepage ironpan) at depth, occurring on seasonally-ill drained, savannah-covered, lower slopes; and *Papao series* includes associated depression soils consisting of grey-brown slightly mottled, rather acid, silty-clays.

The largest areas covered by the tentatively-recognized Dome-Bumbi Association appear to be in the east and south-east of the Complex, associated with highly-chloritized granitic gneisses. The association consists, on the uplands, of small areas of *Nungua series*—brown plastic clays containing ironstone concretions; on the middle slopes, widespread occurrences of *Dome series*—brown or yellow-brown, plastic clays with lime concretions at depth; and smaller areas of black plastic clays in the depressions, identified as *Akuse series* where calcareous and as *Bumbi series* where non-calcareous. There is a possibility that grey and red mottled, heavy plastic clays of *Tachem series* may occur locally along depressions, too: if required, a description of this series will be found below under Tract 13 (p. 189).

Danfa and Otinibi series have only been recorded in the northern half of the complex but may well occur elsewhere. They are associated with occurrences of a coarse-grained hornblende gneiss: *Danfa series* on uplands consists of pale red or orange-brown, gritty, gravelly loam; *Otinibi series* includes associated yellow-brown, coarse-grained, slopewash soils.

On upper and middle slopes, more particularly in the west, there occasionally occur patches of soils of *Simpa series* consisting of a variable depth of pale-coloured overlying brown, perhaps mottled, gravelly clay. Soils of *Alajo series*—grey-brown, rather plastic clays, calcareous at depth—occur in depressions, more particularly in the west, and may prove to be related topographically to Simpa soils in this area.

Danfa-Otinibi Association

This mapping-unit occupies an area of approximately 1 square mile (640 acres) on a small-thicket-covered ridge at a height of 250–350 feet between Kweman and Otinibi (to the east of the road up the Aburi 'scarp'). It includes only the soils of *Danfa* and *Otinibi series* described above under Danfa-Dome Complex. Outwards, the soils of Otinibi series may be expected to grade into pale, coloured, imperfectly-drained, sandy soils of *Hacho series*.

Alajo Consociation

This mapping unit extends over a grass-covered flat immediately to the south of the Achimota Fuelwood Plantation and covers an area of approximately 2 square miles (1,280 acres). The greater part of this area appears to be occupied by grey-brown, heavy clays of *Alajo series;* but small, patchy occurrences of black clays of *Akuse* and *Bumbi series* have been observed, as well as of brown clays of *Dome* and *Nungua series* on the bounding slopes to the north. Lowland soils of the surrounding Nyigbenya-Hacho Complex may overlap the boundaries locally in the south.

The soils of these associations are described below in the following order:—

1. *Mamfe series*	4. *Nungua series*	7. *Bumbi series*	10. *Simpa series*
2. *Hacho series*	5. *Dome series*	8. *Danfa series*	11. *Alajo series*
3. *Papao series*	6. *Akuse series*	9. *Otinibi series*	

Mamfe series comprises soils with a thicket-type, humous, loamy topsoil overlying red clay containing abundant ironstone concretions and variable amounts of quartz gravel, with highly-weathered and ironstained rock—usually Dahomeyan in the present area—occurring at depths greater than 3 feet. Ironpan is occasionally encountered at the top of the concretionary horizon. These soils occur fairly extensively on some of the upland sites.

No further description of the soils will be given here since they have already been fully treated under Mamfe-Fete Complex (Tract 1) and Oyarifa-Mamfe Complex (Tract 2).

Hacho series comprises soils developed in several feet of pale brown sand going down to sandy clay at depth, humus-stained near the surface and slightly mottled below a depth of 30 inches, but occasionally found with seepage ironpan at or below this depth. They are developed in seasonally ill-drained slopewash on lower slopes of undulations under savannah vegetation.

These soils have been discussed under Nyigbenya-Hacho Complex (Tract 3) above and will not be described in further detail here.

Nungua series occurs patchily on summits of undulations where the complete suite of soils in the tentatively-recognized Dome-Bumbi Association is found. The soils consist of up to 12 inches of brown or dark brown, friable, sandy heavy loam to light clay, humus-stained near the surface, overlying 2–3 feet of grey and brown mottled plastic clay containing abundant, ochreous, ironstone concretions and variable amounts of quartz gravel. Rock, if encountered, may be expected to consist of rather ironstained, brashy, weathered, chloritized gneiss or schist.

These soils absorb water moderately well and retain moisture satisfactorily in the lower horizons. The topsoils are sufficiently light-textured to be hand-cultivated but no cultivation has actually been observed on them within the present tract. Improvements in internal drainage and aeration of the subsoils would encourage the development of a better agricultural tilth.

Nungua soils are rather variable in reaction: topsoils are usually near-neutral, but some profiles become slightly to moderately acid in the subsoil whilst others remain neutral or become alkaline at a moderate depth. Lime and potash are plentifully provided, but the phosphorus and organic matter status is moderate to low.

Dome series consists of soils with a dark grey or dark brown, friable clay topsoil overlying brown or yellow-brown, heavy, plastic clay which grades at 3–4 feet into greenish, loamy, weathered gneiss.

There are often a few lime concretion in the lower part of the profile. These soils are fairly extensively developed on middle and lower slopes where chloritized granitic gneiss occurs.

The soils are externally well drained, but rather poorly drained internally, especially towards the lower slopes. The topsoils are relatively absorptive, but the lower horizons become impervious during heavy rainfall, and the soils are then subject to surface run-off. Moisture retained by the clay may not be readily available to plant roots. No hand-cultivation has been recorded, but the soils appear well suited to mechanized irrigation agriculture. Improvement of internal drainage and aeration would improve the tilth and encourage deeper root-development.

The soils contain relatively small amounts of organic matter, nitrogen, phosphorus and potash under natural conditions, but are well provided with lime. The topsoils are slightly acid but lower layers become slightly alkaline and may possibly be affected by harmful amounts of soluble salts. With satisfactory provision for drainage and erosion control, however, these soils appear suitable for continuous cropping with the aid of fertilizers and might be expected to give high yields.

Akuse series includes dark grey to black, heavy, plastic, cracking clays which contain lime concretions below a depth of 18–24 inches. Within the present complex they are underlain at a depth of 3–4 feet by a variety of schists and gneisses. They are of minor importance within the present tract, occurring only very patchily on lower slopes and in bottoms in association with Dome series. A fuller description of the soils is given under Akuse Consociation (Tract 9) below.

Bumbi series includes soils superficially similar to the black clays of Akuse series briefly described above, but in this case the profile is slightly to moderately acid in reaction to a depth of at least 30 inches and only become calcareous, if at all, at great depth. They occur patchily as lower-slope or bottom soils, and, within the present tract, are slightly more extensive in occurrence than Akuse soils. These soils, too, are more fully described under Akuse Consociation (Tract 9) below.

Danfa series comprises very well drained, pale red to orange-brown, gritty or gravelly loams to clays developed on upper slopes over ironstained slabby granite. Soils occurring under thicket and savannah vegetation have not been recognized separately.

To a depth of approximately 6 inches there is brown to grey-brown, humous, rather loose, loamy sand, often containing large amounts of fine gravel and sometimes loose ironstone concretions. There follows a transitional layer of similar composition in which the colour changes through pale-brown or yellow-brown to that of the main body of the soil below. From a depth of approximately 1 foot there is pale red to orange-brown, rather loose loam becoming more clayey with depth; this layer contains large amounts of quartz grit, gravel and stones throughout. The underlying rock becomes recognizable at or about 3 feet, and is ironstained and clayey at first, with large amounts of quartz stones and gravel incorporated, but becomes more yellow and loamy below. Rock outcrops occur locally and soils nearby may then be more brashy.

These soils are very well drained. They absorb rainfall well but have poor retentive powers. Hand-cultivation is possible but mechanical tillage would not be practicable because of the gravelly nature of the soils and their occurrence, often amongst rock outcrops, on relatively steep slopes. There is usually no impedence to root-development.

The nutrient status is low. Little organic matter accumulates during fallow periods, especially where the soils occur under savannah vegetation, and this is rapidly lost when the soils are cleared for cultivation. Topsoils are near-neutral but lower horizons are moderately to very acid in reaction. Potash may be present in satisfactory amounts but phosphorus and nitrogen contents are low.

Otinibi series comprises brown to yellow-brown gritty or gravelly loams to clays developed on gentle middle and lower slopes in slopewash derived from Danfa soils. The topsoil, approximately 6 inches thick, consists of dark brown to greyish-brown, humous, rather loose, gritty or gravelly sandy loam to light clay. Below this, the soil becomes brown to yellow-brown in colour and rather mottled below 30 inches, and consists of gritty or gravelly loam to light clay; the mottled horizon may harden on exposure to form seepage ironpan. Weathered coarse-grained granite is only encountered at depths of 6 feet or more.

Rainfall is readily absorbed and moisture retention is probably satisfactory at depth, except where hard seepage ironpan occurs, but topsoils are rather droughty. Internal drainage is seasonally impeded in the lower horizons. Hand-cultivation is practicable, but mechanical cultivation would not be possible because of the limited extent and coarse texture of the soils. Ironpan does not occur within a depth where it might seriously impede root-development.

The nutrient supply is predominantly held in the ephemeral humus of the topsoils, but only small amounts of organic matter accumulate under the natural fallow vegetation. The body of the soil has little capacity to retain nutrients. Potash may be present in satisfactory amounts but the phosphorus and nitrogen contents are very low. Topsoils are near-neutral in reaction; lower horizons are slightly to moderately acid.

Simpa series, where present occurs on savannah-covered upper and middle slopes of gentle undulations and consists of a variable, but usually shallow, layer of grey-brown and overlying brown, often mottled, very gravelly clay which in turn overlies weathered schists and gneisses at a moderate depth. The upper part of the profile is free-draining and becomes droughty during the dry season. Drainage is impeded in the clay horizons and the upper part of the weathered rock and these layers have moderate retentive powers.

Simpa soils are fully described below under Simpa-Agawtaw Complex (Tract 8) and will not be further discussed here.

Alajo series consists of grey-brown, heavy, plastic clays containing calcareous concretions at depth. They are extensively developed on broad, grass-covered, valley-bottoms.

To a depth of 2–3 inches, the profile consists of dark grey or dark grey-brown, humous clay, hard when dry and plastic when wet; in association with adjoining sandy soils, this horizon may be rather lighter-textured, and firm and porous. Below this there is dull grey or grey-brown, heavy, plastic clay, hard and compact when dry, usually faintly ironstained throughout and occasionally mottled pale grey and orange at depth. Scattered lime concretions occasionally begin to appear within 30 inches of the surface, but more usually occur only below a depth of 4–5 feet. The clay extends to a depth of 6 feet or more, but in other areas has been observed to overlie loose, mottled sand or sandy clay; such a layer may underlie the present soils at greater depths.

The soils occasionally become waterlogged during the rainy season but are never completely flooded. Except in the lowest-lying areas, much of the rainfall they receive is lost by surface run-off and the soils fairly quickly become dry during the dry seasons. Water-tables have not been encountered, but because of the highly impervious nature of the clays, excavations retain water very well.

These soils are too heavy for hand-cultivation but appear very suitable for mechanized irrigation farming if sheet-flood water can be controlled. Internal drainage would require to be improved to encourage the development of a more desirable structure for root-development and to leach harmful salts from lower horizons.

Alajo soils contain little organic matter and are low in phosphorus and nitrogen. They are slightly moderately acid in reaction near the surface but gradually become less acid and eventually slightly alkaline with depth. Complete fertilizers would be needed for intensive crop production.

VEGETATION

Upper and middle slopes where soils of Mamfe series, and sometimes Danfa and Otinibi series are found usually support coastal thicket. Mixed open stands of medium and tall grasses with frequeci scattered small trees and clumps of thickets cover most of the remaining area, but Alajo soils characteristically support short and medium grasses with scattered clumps of thicket which are associated with old termite-mounds.

PRESENT LAND-USE

The grassland over Alajo Consociation is regularly grazed by herds of cattle kept in villages of the north of Accra, but that within Danfa-Dome Complex is ungrazed.

There is little cultivation over many of the soils of the tract, and none has been recorded on Dome, Alajo, Bumbi and Akuse soils. The small amounts of cultivation recorded on other soils have been for subsistence purposes, and usually consist of mixed stands of cassava with local vegetables. Maize may perhaps be grown in the thicket areas, particularly over Danfa-Otinibi Association, and okro may be expected to occur on small plots over Hacho and Krabo series. There are no yields data, but crops in savannah areas generally appear to be of low quality.

The heavy clays of this tract would be very suitable for development by irrigation, and might, by the use of large-scale mechanized methods and artificial fertilizers, produce a wide range of crops, including rice and sugarcane. Their development in this manner, is likely for a considerable period, however, because of their remoteness from the areas of the Accra Plains most conveniently situated for early irrigation development. Dry-land farming techniques would doubtfully be effective because of the low and very unreliable rainfall the soils receive. Only in Alajo Consociation is the grassland used for rough-grazing; and, even here, the risk to cattle of infection with trypanosomiasis carried by tsetse fly inhabiting nearby thicket areas must be considerable. Alajo soils in this area have been used on a large-scale for brick and tile-making; their use might again be considered for this purpose at some time in the future. Dome soils must probably for long remain undeveloped, however, although they might be suitable for mechanized farming of sorghum, millet and finger millet if varieties suitable for the area can be bred.

On the upland soils of Mamfe, Nungua, Danfa and Otinibi series, it is desirable to continue the present system of land-rotation cultivation. Sorghum and millet would be more reliable cereals to grow instead of maize if suitable varieties can be bred. They could be mixed with Bambara beans or cowpeas to be followed by cassava. Finger millet and pineapples might be tried on these soils. The soils are unsuitable for extensive development, but where large clearings are made, they should be aligned and cultivated along the contour. Eventually, large parts of these soils might need to be set aside for fuelwood production. Fruit trees such as guava, cashew and mango could be grown on these soils.

Simpa soils in this tract are too droughty and barren to provide a sound basis for agricultural development. The only crops suitable for the conditions are cassava, drought-tolerant varieties of beans, finger millet and cucurbits, but high yields cannot be expected. These soils would better be relegated to rough-grazing for livestock.

Mamfe soils provide a source of laterite gravel for road-building. Similar gravel in Nungua series would be suitable only if washed free of its plastic clay matrix. Danfa and Otinibi soils might provide alternative supplies of gravel if required.

Poor drainage leads to problems in road-construction on Dome, Akuse, Bumbi, Simpa and Alajo soils (as well as on Hacho and Papao soils discussed under Tract 3). Where possible, roads should be diverted round exposures of these soils. Unsurfaced roads are practical, particularly on Simpa and Alajo soils, but only if their use is strictly limited to dry periods: they do not support wheeled vehicles when wet. Major roads need to be built up on causeways provided with ample culverts. On Dome, Akuse, Bumbi and Simpa series, it would be desirable to excavate the soil to a depth of 3 feet and replace it with non-cracking clay (e.g. from Mamfe series).

TRACT 5

Korle Consociation

General

The soils of this mapping unit cover a number of detached areas in two separate localities. One group is found near and along the south-western boundary of the region; the other along the line of the Jawpa-Dechidaw streams near the western boundary of the Black Clays tract. Together these occurrences cover a total area of approximately 17 square miles (c.11,000 acres).

The soils are associated with outliers of Togo quartzite schist which form isolated hills or ridges rising above the surrounding gently-undulating surface of the Accra Plains to a height of 200–300 feet in the east and up to 650 feet in the west. *Korle series*, which covers almost the whole of the consociation, consists of red light clays containing quartzite schist brash at a very shallow depth and occurs mainly under savannah. Small areas on some of the lower hills are covered with red concretionary clays: these predominantly occur under savannah, and are recognized as *Nyigbenya series;* but in the west, they may locally carry thicket, when they are identified as *Mamfe series*. Slopewash from the hills locally accumulates to give rise to orange-brown to yellow-brown, gravelly loams to clays, similar to those described under *Adentan series* above. More commonly, the accumulated slopewash takes the form of deep, well-drained, red loams to light clays of *Toje series*, the greater extent of which has been included in Nyigbenya-Hacho Complex described above. Under thicket at the foot of some of the western hills, red loamy soils of *Oyarifa series* may perhaps occur under similar conditions to Toje series, but this has not been definitely established.

Mean annual rainfall is 30–35 inches, but near the coast in particular the value of this precipitation is considerably reduced by the exposure of the sites on which the soils occur to the fresh sea-breeze.

SOILS

The soils of Korle Consociation are described below in the following order:—

1. *Korle series*
2. *Nyigbenya series*
3. *Mamfe series*
4. *Adenta series*
5. *Toje series*

Korle series comprises soils with a shallow, humous, loamy topsoil overlying red light clay containing abundant brash of Togo quartzite schist. These soils occur amongst frequent small rock outcrops on the moderate to steep slopes of isolated hills. They normally support savannah vegetation, but relatively small areas in the west occur under thicket. Drainage is excessive, and the soils quickly become droughty. Nutrient supplies are generally low.

A fuller description of the soils is given above under Oyarifa-Mamfe Complex (Tract 2). The soils in the present tract are generally shallower and more rocky than elsewhere, and fall mainly within Weija subseries.

Nyigbenya series consists of soils with a shallow brown or dark reddish-brown loamy topsoil overlying red sandy light clay to clay containing abundant ironstone concretions and variable amounts of quartz gravel; ironpan is commonly encountered in the subsoil in the present association. These soils occur at an approximate height of 150–250 feet above sea-level: they may therefore be found at the foot, on the flanks or capping the summit of different hills according to their height. They occur under savannah vegetation.

A full description of Nyigbenya series is given above under Nyigbenya-Hacho Complex (Tract 3).

Mamfe series consists of red concretionary clays differing from Nyigbenya soils in their occurrence under thicket vegetation which leads to the development of a better-provided humous topsoil. Similar soils have been discussed above under Mamfe-Fete Complex (Tract 1) and Oyarifa-Mamfe Complex (Tract 2).

Adenta series includes orange-brown to yellow-brown (predominantly the former in the present areas) sandy loams to sandy clays overlying mottled grey and orange sandy clay which in the present tract, contains abundant quartz gravel, quartzite brash and variable amounts of ironstone concretions. The soils occur locally in drainage groves on the slopes of, but more extensively at the foot of, the hills covered with Korle series, more particularly in the more easterly of the two belts.*

A full description of Adenta series is given above under Nyigbenya-Hacho Complex (Tract 3).

Toje series occurs only to a limited extent within the present association. In profile, the soils consist of more than 30 inches of friable red to orange-brown loam becoming more clayey with depth overlying either red ironstone-concretionary clay or ironstained weathered rock at depth. They may very locally displace Korle soils where hill-slopes are gentle, but are likely to occur most commonly in drainage grooves and at the foot of the hills amongst Nyigbenya and Adenta soils.

A detailed description of the series is given above under Nyigbenya-Hacho Complex (Tract 3).

VEGETATION

With the exception of relatively small areas on some of the western hills which occur under coastal thicket, the consociation is found under stunted medium or tall grassland with scattered bushes and trees which, near the coast, characteristically occur in linear thicket clumps.

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*Subsequent detailed investigations carried out near Dawhwenya have shown that the soils here are harder near the surface and more compact in the lower layers than normal Adentan series, and are neutral to slightly alkaline in the lower layers. These soils have been recognized as ***Dawhwenya series.*** Dark brown soils with a prismatic hardpan in the upper subsoil and definitely alkaline in the lower layer occur on the piedmont slopes adjoining the Togo quartzite schist ridges in this area and have been recognized as ***Hanya series.***

PRESENT LAND-USE

In the occurrences to the east of Accra the soils of the consociation are frequently grazed, despite the poor quality of the pasturage they provide. There are only very minor amounts of cultivation, mainly of very impoverished cassava (red-skinned variety), and the greater extent of the soils in the west appears to be unused.

RECOMMENDATIONS REGARDING LAND-USE

Very little increase in productivity can be expected from this tract. Korle soils here are unsuitable for agriculture, and the remaining soils are of too limited extent to provide a basis for systematic utilization. In cattle-grazing areas they might be made to grow browse-shrubs. The eastern belt of hills would provide suitable settlement sites if the adjoining Tracts 8 and 9 were developed, so long as supplementary water supplies were provided.

The Togo quartzite schist is generally too broken to be of use as building stone, but it provides one of the major sources of road-foundation material in the region. Its quality varies considerably on a local scale, and the more schistose bands should be avoided where possible since the clay is plastic and micaceous making it unsuitable as foundation material.

The chief obstacle in road-building in the tract is that presented by steep slopes. It is usually possible to find an easy route through valleys or around the foot of the hills, however.

TRACT 6

Korle-Okwe Complex

General

This complex occupies an area of complicated geology and topography in the northern part of the Accra Plains in which, due to the methods of survey used, it has been impossible completely to unravel the soil pattern. The boundaries as mapped are indefinite, but have been drawn so as to exclude, so far as possible, the characteristic soils of the complex from Oyarifa-Mamfe Complex to the west and to exclude those soils of the latter which occur within Korle-Okwe Complex from the Black Clays belt (Akuse Consociation) to the east. As mapped, the complex covers an area of approximately 5 square miles (3,200 acres).

Within this area, there are known to be occurrences of Togo quartzite schist, Dahomeyan acidic gneisses and schists, Dahomeyan basic gneisses (albite—and nepheline-syenite, as well as the more widespread garnetiferous hornblende gneiss), and instrusive pegmatites. There are ironstone-concretionary cappings to some of the hills, and slopewash from the Akwapim Range and from the Black Clays tract has accumulated in depressions in different areas.

The complex occupies gently undulating to gently-rolling country between the foot-slopes of the Akwapim Range and the Volta floodplain near Kpong rapids. There are extensive streamless depressions in the east of the area. The mean annual rainfall is approximately 45 inches. Upland areas in the west are predominantly under thicket or bush-regrowth, although savannah appears rapidly to be encroaching. Where stream channels exist, there is broken fringing forest, but the greater part of the low-land areas is under savannah.

Of the numerous soils developed in this complex, *Mamfe*, *Beraku*, *Krabo*, *Hacho* and *Papao series* overlap from Oyarifa-Mamfe Complex (Tract 2) to the west. The most widespread soils are upland soils of *Korle series* and depression soils of *Okwe series*. The former consist of red brashy light clays over Togo quartzite schist; the latter include brown, slightly mottled, plastic clays containing lime concretion in the lower part of the profile. Elsewhere there are local occurrences of *Fete* (*Kpong*), *Simpa*, Tepanya, Akuse and Agawtaw series. Because of the complicated geology, it is possible that other soils, so far unidentified, occur, but these seem unlikely to cover significant areas.

The soils of the complex are described below in the following order:—

1. *Korle series*	5. *Tepanya series*	9. *Beraku series*
2. *Mamfe series*	6. *Okwe series*	10. *Hacho series*
3. *Fete (Kpong) series*	7. *Akuse series*	11. *Krabo series*
4. *Simpa series*	8. *Agawtaw series*	12. *Papao series*

Korle series is extensively developed on higher ground in the west of the complex, but this relief is more gentle than that on which the soils are typically developed further south and rock outcrops are uncommon. Here, the profile consists of approximately 6 inches of very dark grey-brown sandy loam overlying orange-brown to reddish-brown, porous light clay containing quartz stones and gravel to a depth of 12–18 inches below which red light clay containing brash of quartzite schist is found. The nutrient status of these soils appears to be much higher than in the soils from the south of the region, and they benefit from a higher rainfall.

Full descriptions of the soils are given above under Oyarifa-Mamfe Complex (Tract 2) and supplementary information is given under Korle Consociation (Tract 5).

Mamfe series includes soils with a humous loamy topsoil overlying red ironstone-concretionary clay. They occur under thicket vegetation on well-drained upper slopes. They occur only locally throughout this complex. Full descriptions of these soils are given above under Mamfe-Fete Complex (Tract 1) and Oyarifa-Mamfe Complex (Tract 2).

Fete series (Kpong subseries) consists of soils with almost a foot of very dark grey-brown to almost black, humus-stained, loose, sandy light loam grading downwards, into 6 inches or so of mid-grey-brown, loose sandy loam including moderate amounts of ironstained quartz stones and gravel; below this there is brashy, slightly ironstained, Togo quartzite schist. These soils cover only a limited area on gently rolling upper-slopes to the north of Kpong, and are found under both bush-regrowth and savannah vegetation.

They absorb rainfall freely, but are excessively well drained and become droughty during dry periods. They offer no obstacle either to hand or mechanical cultivation and allow free root-development. They have little inherent fertility and would need liberal manuring for increased crop production.

Simpa series comprises soils with a foot or so of pale brown or grey-brown loamy sand at the surface overlying several feet of brown, often mottled, very gravelly sandy loam becoming sandy clay with depth; this overlies Dahomeyan acidic gneiss, schist or, in one instance north of Kpong, pegmatite. The soils occur patchily on upper slopes under savannah. The upper part of the profile is free-draining and becomes droughty during dry spells, but drainage is impeded in the more clayey horizons. The soils are of low fertility.

A full description of Simpa series is given below under Simpa-Agawtaw Complex (Tract 8).

Tepanya series consists of soils with a variable, but typically shallow, thickness of black or dark grey, sandy clay, hard, compact and cracked when dry, heavy and plastic when wet, overlying grey, or grey and yellow mottled, plastic clay containing very abundant, small, spherical, ironstone concretions. The underlying weathered rock is usually garnetiferous hornblende gneiss, but in the present complex various crystalline rocks may be expected to occur. Lime concretions sometimes occur in the lower horizons.

These soils occur patchily amongst Akuse soils on some of the lower upland sites in the east and south-east of the complex. A full description of the soils is given below under Akuse Consociation (Tract 9).

Okwe series comprises dull brown, or yellow-brown weakly mottled orange, plastic clays containing lime concretions in the lower part of the profile and overlying a layer of quartz pebbles at depth. These soils are developed in broad, seasonally ill-drained depressions in the east of the complex where they extend into Okwe-Tachem Complex along the Okwe floodplain. They are found under swamp grassland.*

*Some of the occurrences on slightly higher ground near the Kpong-Akuse road seem to be associated with a calcareous conglomerate which locally forms bouldery outcrops: these might now be recognised as *Agomeda series*. Except where cultivated, they carry thicket or secondary forest, although all grassland seems to be encroaching. See footnote on Table 7.

Over small areas, usually near stream channels, the pebble bed may be met within 30 inches of the surface. In such areas the soils are differentiated as *Okwenya subseries*.

Towards their western extent, profiles without lime concretions occur, although reaction tests show them to be at least neutral or slightly alkaline at moderate depths. These soils frequently contain large amounts of very small ironstone concretions scattered throughout the profile, but neither a pebble-bed nor bedrock has been encountered. Such soils have been recognized as *Noaso subseries*.

All these soils become very wet during the rainy seasons and may be temporarily flooded after heavy storms. On the other hand they appear to dry out thoroughly during the main dry season and little moisture may then be available to plants.

Similar soils in Tachem-Okwem Complex are known to be hand-cultivated. These clays are suitable for continuous cropping and there are no obstacles to mechanical cultivation, except where shallow Okwenya soils occur. Improvements in internal drainage would encourage the development of a better tilth for root-development and would be essential to leach out large amounts of salts occurring in the lower layers.

Under present poorly-drained conditions the soils accumulate moderate amounts of organic matter, but under continuous cultivation the nutrients this contains would be quickly exhausted. The body of the soils is well supplied with lime and potash, but is poorly provided with phosphorus.

Akuse series includes dark grey to black, heavy, plastic, cracking clays containing lime concretions below a depth of 18–24 inches in the profile. Within the present complex there are often moderate amounts of small ironstone concretions throughout the profile, although less than in Tepanya soils, and the soils are often relatively shallow, with greenish, loamy, weathered rock occurring at 1–2 feet. In the east of the area mapped, where they extend into Akuse Consociation, the soils are developed over granetiferous hornblende gneiss, small outcrops of which may be encountered locally. Small, isolated occurrences nearer the centre of the complex are likely to be developed over a variety of basic igneous rocks of which there are usually no outcrops. The soils occur on all slopes of gently undulating topography, but towards the west they are more likely to be found on middle and lower slopes. They everywhere occur under savannah vegetation.

A more detailed description of the series is given below under Akuse Consociation (Tract 9). Many of the soils in the present area fall within Prampram subseries (described on page 81).

It is probable that associated bottom soils of *Bumbi series* may occur locally, but this has not been definitely established. Such soils, if encountered, would consist of heavy black clay similar to that of the Akuse soils, but non-calcareous to at least 30 inches from the surface. This series is fully described below under Akuse Consociation (Tract 9).

Agawtaw series comprises soils with the following characteristic profile: at the surface, 3–6 inches of grey-brown, porous, sandy loam; below this, to approximately 18 inches, dark brown or dark grey-brown, slightly mottled yellow and brown, very compact, sandy clay cracking vertically into large 6-sided blocks when dry; below this, for a variable depth, pale grey-brown, pale yellow-brown or pale brown sandy clay containing lime concretions; at the base of the profile, a thin layer of quartz or ironstone gravel embedded in slightly mottled clay overlying weathered Dahomeyan acidic schist or gneiss. In the present area, these soils occur mainly on middle and lower slopes in association with Simpa series. They occur most frequently in the south and west of the complex, but cover only a small area. They occur only under savannah vegetation.

A full description of the series is given below Agawtaw Consociation (Tract 10).

Beraku series comprises pale brown sands to sandy clays, dark grey-brown with humus near the surface and slightly mottled orange at depth, developed in seasonally ill-drained, lower-slope, slope-wash material under thicket or forest. The soils cover small areas in the west where they overlap from Oyarifa-Mamfe Complex. A full description of the series is given above under this Complex (Tract 2).

Hacho series consists of soils developed on similar sites and in similar materials to Beraku soils but, since they occur under savannah vegetation, possessing less well-provided humus topsoils. They appear to occur most commonly in the northern part of the complex. A full description of this series is given above under Nyigbenya-Hacho Complex (Tract 3).

Krabo series comprises poorly-drained bottom soils developed under thicket or forest in association with Beraku series. In profile, the soils consist of a dark grey-brown, humus, porous, loamy topsoil overlying grey-brown, rather mottled, porous, silty clay. A full description of the series is given above under Oyarifa-Mamfe Complex (Tract 2).

Papao series is developed in similar parent materials to Krabo series but under low savannah vegetation. In consequence, the soils have only a shallow and less well-provided humus topsoil. They are fully discussed under Nyigbenya-Hacho Complex (Tract 3) above.

VEGETATION

Over the lighter-textured soils in the west, thicket vegetation appears to be being replaced by low bush regrowth and eventually by tall-grassland with numerous small gnarled trees; this has already occurred over the greater part of the area around and to the north of Kpong. Okwe soils occur under swamp-grassland, with tall, medium and short grasses in different localities, and with frequent small trees. Fringing forest or thicket occur along stream channels. The remaining savannah areas are found under medium and tall grasses with frequent shrubs and small trees.

PRESENT LAND-USE

The lighter-texured soils in the west, especially those of Korle, Fete (Kpong) and Mamfe series, are closely farmed, especially near the main roads. Cashcrop farming is the general practice, with maize the major crop grown. Sugarcane is produced locally on bottom soils. No cultivation of Okwe soils has been recorded, but they are known to be used for maize and cassava in the adjoining Okwe-Tachem Complex. Methods of production are similar to those described for the Krobo areas in the adjoining Oyarifa-Mamfe Complex, and fallow periods appear similarly inadequate; large areas of Korle series are, in fact, found only under low bush regrowth or savannah, and are used now mainly for subsistence crops of cassava and vegetables.

The grassland areas over the heavy clays do not appear to be cultivated, nor are they grazed.

Recommendations regarding land-use

The recommendations given for Tract 2 apply equally to those areas of the present tract occupied by soils of Korle, Mamfe, Fete (Kpong), Beraku, Hacho, Krabo and Papao series. Briefly, these consist of ensuring an adequate amount of organic matter in the soils, keeping the soils protected at all times with a cover of vegetation or mulch, and cultivating on the contour. In small-scale hand cultivation there is much to be said for continuing the traditional practice of mixed cropping with maize, groundnuts (or cowpeas) and cassava. Chewing-cane and rice might be grown on Krabo and Papao soils; production could be increased by the use of fertilizers and by more attention being paid to weeding.

Okwe, Akuse and, to a lesser extent, Tepanya series are suitable for development with the aid of irrigation. Such a form of development including Okwe soils would require the provision of dams, dykes and sluices to control flooding from the Okwe river and its tributaries. Sugarcane would appear likely to be the major crop that could be grown; but the soils are also suitable for maize, and trials could be made with cotton, tobacco, tomatoes (and other vegetables) as well as various pulses. Rice production on Okwe soils would depend on whether flood irrigation could be practised without bringing salt to the surface; this requires to be investigated.

Heavy machinery would be needed for the initial breaking-in of the soils, but lighter equipment could probably be used thereafter, more particularly on Okwe soils. Preliminary investigations into their cultivation and manurial requirements could conveniently be carried out from the nearby Kpong Irrigation Research Station. Detailed soil and topographical maps would need to be prepared in advance of development to indicate areas suitable for cropping and to serve as a basis for field layout. Drainage would need to be effected by a close system of field drains to encourage better aeration and the development of a better agricultural tilth, to increase the absorption rate of water and, in Okwe soils, to control the level of harmful soluble salts in the profile.

Without irrigation, large-scale development of Okwe soils might still be possible but would again require flood-control measures along the river Okwe which might be expensive to effect. With such protection, it might still be possible to grow sugarcane, as well as maize; sorghum, millet and finger millet might be more suitable crops for the second rainy season of suitable varieties can be bred.

Without flood-control, cropping of Okwe soils might only be possible during the early part of the first rainy season and after the recession of the floods at the end of the second rainy season. Maize (of a quick-maturing variety) or upland rice could be grown in the first season; okro, tomatoes and other vegetables would be suitable for the second season. A similar cropping system would probably suit any areas of Akuse and Tepanya soils brought under cultivation.

Whatever form of development is used, crops (except rice) would better be grown on raised beds or high ridges to provide better drainage and improve the tilth of the soil. Such beds and ridges should where possible to aligned slightly off the contour to provide for adequate surface drainage during heavy rainfall. Drainage channels need to be protected against erosion by a grass cover or the provision of occasional stone checks.

Agawtaw soils are not considered very suitable for agriculture at present. They might produce subsistence crops of cassava, okro, peppers, etc., and upland rice might suit some of the lower-lying soils. Yields might be increased by growing the crops (except rice) on raised beds aligned slightly off the contour and using fertilizers, especially those providing nitrogen and phosphorus. These soils would also benefit from the addition of organic matter, whether by way of farmyard manure, compost or a green manure crop. Mechanized cultivation would be possible and so would irrigation, but it would require to be investigated whether these aids would be economic on these soils.

The presence of the tsetse-infested thicket belt in the west would probably prevent the keeping of cattle within the tract. Sheep and goats could usefully be herded in the grassland areas, however. Eventually, they might be brought into the farming system and kept on planted leys. Eventually, too, if a more intensive stock-rearing system is developed in neighbouring parts of the Plains, fodder crops could be produced within this tract, mainly from the heavy clay soils.

The Togo quartzite schist underlying Korle soils is the major source of road-foundation material in the north-west of the Plains. Mamfe soils provide 'laterite' gravel, but no extensive deposits were located within the tract during the survey although supplies are readily accessible in the neighbouring Oyarifa-Mamfe Complex. The ironstone concretions referred to in Tepanya and Okwe (Noaso) soils would only be suitable for use if washed free of their plastic clay matrix.

Road-building presents no special problems on the upland soils and, so far as possible, roads in the tract should be aligned along them. If roads have to cross the lowland soils (i.e. virtually all soils except those of Korle and Mamfe series), they must be built up on broad, high, well-consolidated causeways of non-cracking material (e.g. from Korle soils) provided with deep drains and adequate culverts and bridges. This especially applies to Okwe and Akuse soils.

TRACT 7

Doyum-Agawtaw Association

General

This association consists predominantly of deep, free-draining, pale-brown, coarse sands of *Doyum series* developed on the upper slopes of broad, gently undulations and grey-brown or pale brown, impervious, sandy or silty clays of *Agawtaw series* found over the very gentle slopes of the broad, intervening depressions. There are relatively minor occurrences of other soils. The upland soils are developed over coarse-grained, pale-coloured granites and gneisses, but it is not clear whether the lowland soils are developed wholly in fine material washed out of the upland soils or are developed in material derived predominantly from the underlying rocks, often found to be schistose. These soils occur almost entirely under savannah vegetation and receive a mean annual rainfall of about 35 inches.

The association is found over two widely-separated areas, one in the west, the other towards the east of the region. Because there are certain differences between the soils of these areas which may perhaps eventually prove to be agriculturally important the two areas will be treated as separate tracts in the section of Soils below.* Together, the two areas cover approximately 60 square miles (38,400 acres).

*Subsequent experience with similar soils on the Ho-Keta Plains has led to the differentiation of the soils in these two tracts into separate series and associations. The western association remains known as Doyum-Agawtaw Association The eastern tract would now fall within Ziwai-Pejeglo Association.

Western area

In this area the association occurs in a broad belt immediately to the east of the Accra-Senchi road from just south of Dodowa to just south of Agomeda. In the south, this belt is broken by the soils of the Dodowa alluvial fan. To the north of the main belt there is a small outlier of the upland soils of the complex near the village of Luum, east of Agomeda. The south-eastern boundary of the association is indefinite since in this direction the soils merge into the component soils of Simpa-Agawtaw Complex. As mapped, this area covers approximately 22 square miles (c.14,000 acres).

This area is characterized by the presence of large numbers of Borassus palms on the deep sandy soils of Doyum series which cover the extensive uplands. These soils are underlain by granite, but there are no rock outcrops. Where bedrock has been encountered beneath the lowland soils, Dahomeyan acidic schists have occurred. Small areas of red ironstone-concretionary clays of *Mamfe series*, outliers from Oyarifa-Mamfe Complex, occur on some of the thicketed uplands. A very minor occurrence of shallow black clays developed over an unidentified basic rock was seen a short distance to the north of the Aiyikuma-Doyum road near Asabe, but will not be further discussed below.

The soils occurring within this western area are described below in the following order:—

1. *Doyum series*
2. *Mamfe series*
3. *Agawtaw series*

Doyum series, in the western tract, consists of pale-brown (locally pinkish-brown) to pale yellow-brown coarse sand, 2-5 feet deep, humus-stained for almost a foot at the surface and underlain by a thin layer of strongly-mottled, gritty, gravelly clay at the base of the profile overlying mottled, highly weathered granite. Locally, the mottled clay layer is replaced by orange, or orange and black, ironpan. These soils are extensively developed under tall-grass savannah regrowth with abundant Borassus palms on the gentle slopes of the broad upland areas of the Association.

The upper part of the profile is excessively well drained, but drainage is impeded by the clay layer and a temporary shallow waterable develops at the base of the profile during the rainy seasons. The soils are droughty during dry spells, especially where deep. Deep root-penetration by trees is impeded by the seasonal waterlogging of the lower layers.

Both hand and mechanical cultivation are easy on Doyum soils. For the latter, it would be necessary to clear large numerous of Borassus palms and a number of compact termite-mounds. The topsoils contain very little organic matter and the nutrient supply of the whole soil is very low. The profile is neutral to slightly acid in reaction almost throughout. Large amounts of organic matter as well as mineral fertilizers would require to be used for more intensive crop production.

Doyum soils, especially where relatively shallow, are prone to invasion by spear grass (*Imperata*). Following with a cover crop such as pigeon pea giving dense shade would be required to control this weed.

Mamfe series comprises red ironstone-concretionary clays with a loamy thicket topsoil. These soils occur as outliers from Oyarifa-Mamfe Complex to the west, but are of limited occurrence on certain uplands in the present complex. A full description of these soils is given above under Mamfe-Fete Complex (Tract 1) and Oyarifa-Mamfe Complex (Tract 2).

Agawtaw series, within the present area, comprises soils showing the following profile features: at the surface, up to 6 inches of grey-brown, silty or fine-sandy loam; below this, to approximately 18 inches, dark grey-brown or dark brown, slightly mottled, very compact, fine-sandy clay cracking into 6-sided blocks on drying; below this for several feet, pale grey or pale yellow-grey, hard or plastic, fine-sandy clay containing lime concretions at the base overlying weathered Dahomeyan acidic schists where seen. These soils are extensively developed on very gentle, externally well-drained slopes below Doyum soils. A full description and discussion of this series is given below under Agawtaw Consociation (Tract 10).

It is probable that if seasonally ill-drained sites occur, heavy clays of Tachem and perhaps Bumbi series may be found developed amongst Agawtaw soils. These series are fully described below under, respectively, Tachem Consociation (Tract 14) and Akuse Consociation (Tract 10).

Eastern Area

In the eastern half of the Accra Plains, Doyum-Agawtaw Association occurs within a triangular-shaped area broadening northwards from north of Dawa (mile $42\frac{1}{2}$, Accra-Lagos road) to the edge of the Volta floodplain. The boundaries of the association are indefinite since one of the two major component series, Agawtaw, is common both to this unit and to the surrounding Agawtaw Consociation. The boundaries have been drawn so as to include the major occurrences of Doyum soils, the major upland soils of the association. The mapping unit covers an area of approximately 37 square miles (23,680 acres).*

Besides small differences in the profile features of the major soils which will be described below, the eastern area differs from that in the west by the presence of frequent small rock outcrops and occasional small rocky hills. The parent rocks are more variable in composition, too, consisting of coarse and fine-grained granites and injection gneisses rich in biotite and with large crystals of feldspar. The soils occur under savannah vegetation, but the upland areas are not characterized, as they are in the west, by the occurrence of Borassus palms. There are minor occurrences of four soils not recorded in the western area, viz.—*Koni, Kenya, Lota and Hwapa series.*

The soils of the eastern association are described below in the following order:—

1. *Doyum series*
2. *Koni series*
3. *Kenya series*
4. *Lota series*
5. *Agawtaw series*
6. *Hwapa series*

Doyum series, in the eastern area, comprises fairly deep pale brown sands with a firmer, loamy or clayey, lower horizon overlying slightly to moderately-weathered rock. The soils are extensively developed on broad uplands under savannah vegetation.

The soils in the east differ from their equivalent in the west in the following respects: the sandy upper half of the profile is typically less than 3 feet in thickness (v.2–5 feet in the west); the texture is more variable between profiles, ranging from medium sand to fine gravel; the subsoil colour varies between pale grey-brown and very pale yellow (almost white), but has never the pink hue frequently seen in the west; the lower part of the profile is usually thicker (more than 12 inches), and often consists of a compact gritty loam rather than clay; this is usually only slightly mottled, and the occurrence of ironpan is rare; the weathered rock is typically loamy rather than clayey, and is only slightly to moderately weathered; and rock outcrops occur occasionally throughout the soils' extent.*

A typical profile has the following features: at the surface, 6 inches or so of brownish grey, slightly humous, medium or coarse sand, underlain by 18 inches or so of pale grey-brown or pale yellow-brown, medium or coarse sand; this is followed by 2 feet or so of pale yellow-brown, faintly mottled orange, hard, porous, gritty loam (occasionally clay) containing a thin layer of ironstained quartz gravel and stones at the base overlying the pale-coloured, slightly-ironstained, loamy, weathered granite or gneiss.

As in the west, the soils absorb rainfall freely but drainage is impeded in the subsoil. Perched water-tables do not seem to develop. The soils daily quickly become parched after the end of the rainy seasons. They have similar cultivation characteristics to the soils in the west, except for the presence of occasional rock outcrops. Only locally, as on a ridge to the north of Lota, are these liable to be sufficiently frequent to interfere with mechanized agriculture. Spear grass (*Imperata*) is again a troublesome weed in moister areas.

The nutrient status of these soils is on the same very low level as that recorded for those in the west; phosphorus appears to be particularly deficient. The sandy layer is slightly acid in reaction but the lower layers become slightly to moderately alkaline and may be affected slightly by soluble sodium salts.

Koni series consists of dull red or reddish-brown, compact, gritty clays with a shallow layer of quartz gravel at the base overlying mottled, moderately-weathered granite or gneiss at a depth of several feet. The soils occur only patchily on upper slopes amongst soils of Doyum series, more particularly in the extreme north and south of the eastern association.

*On the Ho-Keta Plains, the corresponding tract has subsequently been mapped as Ziwai-Pejeglo Association.

Drainage appears to be good both externally and internally. Under natural conditions, much of the rainfall is probably lost by surface run-off and moisture retained at depth may not be readily available to plants during the dry season. The soils are little used for hand-cultivation at present, presumably on account of their compactness. The grittiness of the clays might cause serious abrasion of mechanized tillage implements if these were ever introduced. Cultivation measures designed to improve the structure of the soils—subsoiling, ridging and the incorporation of organic matter—would be necessary to encourage deeper root-development.

The soils appear to be better provided with mineral bases (calcium, magnesium, potash) than most red savannah soils, especially in the lower horizons. They are poorly provided with organic matter and phosphorus, however. To a depth of about 30 inches, the profile is slightly acid to neutral in reaction but it gradually becomes slightly alkaline below this depth.

Kenya series includes yellow-brown, very compact, gritty clays, slightly mottled at a moderate depth and with a shallow gravel horizon at the base of the profile overlying moderately-weathered granite or gneiss. They may occur in small isolated patches on upper slopes amongst Doyum soils, or more widely on slightly lower sites, sometimes in association with Koni series. They are not extensive in area.

The moisture relationships of these soils are not well understood. Their colour indicates impeded internal drainage; but field investigations during the main dry season have shown them to be very dry throughout, and they appear to lose much of the rainfall they receive by surface run-off. They are little used for hand-cultivation; and their compact, gritty nature may lead to excessive abrasion of mechanical tillage implements should these be introduced. Root-development is likely to be impeded by the tight nature of the soil.

These soils are not expected to differ greatly from Koni soils in nutrient status. They are slightly acid in reaction in the upper part of the profile but become less acid or even slightly alkaline below about 30 inches.

Lota series is of very minor importance. It consists of grey-brown or yellow-grey gritty loams, or perhaps sometimes gritty clays, developed amongst stones and boulders of weathering granite or gneiss; they may become orange-brown below the topmost 6 inches. They have been only slightly humus-stained where observed. The soils occur very locally amongst some of the rock outcrops amongst Doyum soils. They are of insufficient agricultural importance to warrant further discussion.

Agawtaw series in the eastern area is more variable than in the western area. Besides the grey-brown soils with a fine-sandy topsoil overlying a compact clay subsoil becoming calcareous with depth, there also occur, nearer the heart of the complex, soils with similar profile features, but pale brown in colour, with coarser sand and occurring over weathered granite or coarse-grained gneiss instead of the more usual schist. Near the middle of the complex, these soils occur only on lower slopes; but towards the boundaries they gradually occupy more and more of the slopes until they merge into Agawtaw Consociation in which they may occupy all slopes from summits to depressions.

A more complete description and discussion of this important series is given below under Agawtaw Consociation (Tract 10).

Hawpa series has limited and occasional development along valley bottoms in the peripheral parts of the complex, and consists of dark to mid-grey sandy clays, loamy for a few inches at the surface, but very hard and blocky below this for about two feet, before becoming cloddy, rather plastic and slightly calcareous in the lower part of the profile; locally, however, hard porous, sandy loam is reached at depth. A fuller description of this series is given below under Agawtaw Consociation (Tract 10).

VEGETATION

The small patches of Mamfe soils in the west occur under thicket, and there is a discontinuous and narrow development of fringing thicket or woodland along some valley bottoms in the eastern area. With these exceptions, the soils of both areas occur under savannah vegetation.

In the west, Doyum soils support tall-grass savannah-regrowth amongst very frequent Borassus palms. The lower-slope Agawtaw soils occur under short grasses with widely-scattered clumps of thicket, usually associated with old termite-mounds. Colonies of medium grasses occur on less well-drained sites.

In the east, Doyum soils occur under savannah-regrowth, but this consists of colonies of tall, medium and short grasses in different localities; there are frequent savannah trees and shrubs but few or no Borassus palms. Agawtaw soils carry short grassland with widely-scattered clumps of thicket or small trees. The whole of this vegetation (in both areas) is liable to annual, and sometimes also seasonal, burning.

PRESENT LAND-USE

The upland soils support land-rotation cultivation. Fallow vegetation is thicket in the limited areas of Mamfe soils in the west, but elsewhere it is savannah-regrowth. Crops in both areas appear to be produced mainly for subsistence rather than for sale.

In the west, only a small proportion of the area is under cultivation, with groundnuts, cassava and vegetables (peppers, garden eggs, tomatoes) the usual crops produced, although maize is grown to some extent on Doyum soils between Dodowa and Aiyikuma, and probably occupies Mamfe soils when these are farmed. Clearings are usually of only an acre or so in extent Crops may be planted at the beginning of either of the two rainy seasons, and are planted on the flat at the usual spacing of approximately 3 x 3 feet. There is a very small oil palm plantation in shallow Doyum soils at a short distance along the Aiyikuma-Doyum road.

In the east, there are larger areas under cultivation, both on Doyum and Koni soils; Kenya soils may be cultivated in places, too, but this has not been recorded. Cassava (red-skinned variety), groundnuts and Bambara beans are the major crops produced. Okro and vegetables are also grown, and maize is produced locally in the north, probably only on Koni soils. Crops appear to be grown in both rainy seasons. Single-cropping appears to be the general practice. Clearings are usually of only a fraction of an acre. Except in the south and south-west, crops are sometimes grown on small, slightly-raised beds approximately 3 x 10 to 5 x 20 feet in extent: on these, crops are planted at the usual spacing, approximately 3 x 3 feet. This is more particularly the case towards the downslope limit of Doyum soils where advantage may be taken of the better moisture relationships existing there.

There are no yields data for any of the crops, but the general appearance of the crops suggests that yields are likely to be low. Yields must frequently be depressed by drought. Rosette disease of groundnuts has been observed in the eastern area.

The lowland soils, and in the eastern area, some of the upland soils, too, are used as grazing-land for the large herds of cattle kept in neighbouring villages. They are rarely farmed.

RECOMMENDATIONS REGARDING LAND-USE

No spectacular increase in productivity can be expected from Doyum soils. Production of the present subsistence crops—especially maize and groundnuts in the west and groundnuts and okro in the east—could undoubtedly be increased, however, by the use of improved crop varieties, the application of mineral fertilizers—nitrogen, phosphorus and potash all seem to be deficient—and especially the provision of more adequate amounts of organic matter.

In the latter respect, kraal manure or compost would be very useful, but they are unlikely to be available in adequate amounts and the required organic matter will have to be provided by way of vegetative fallows. The present coarse, open, grassland fallow cover provides little organic matter and planted cover crops need to be used. Pigeon pea is probably the most useful cover crop that could be grown at present, and would additionally be useful in controlling spear-grass. Alternatively, a mixture of *Andropogon gayanus* (or Guinea grass) with centrosema or other legumes could be sown and left down for two or more years as a ley either for direct grazing or for cutting and storage as fodder.

Trial plots of sisal, ginger, guava and cashew might be investigated, as well as of coconuts on the deepest soils in the west. Vegetables, if well manured, might be grown where seepage zones occur towards the lower slopes in the west. Sorghum and millet would suit the droughty soil conditions if varieties suitable for the Plains could be bred. Finger millet might also be introduced. Crops should be grown on contour strips and the aim should be to protect as much of the soil surface as possible with a cover provided by the growing crop of a mulch.

High crop yields are not to be expected from Doyum soils. It would doubtfully be economic to irrigate such soils; if this were practicable, overhead sprinkler methods would be most suitable. It might then be worthwhile attempting to produce high-quality tobacco, using fertilizers to achieve the required nutrient supply to the crop. It is probable that the soils will ultimately be used mainly for stock-rearing, however.

In the west, a minor industry might be based on the provision of fire—and termite-resistant poles from the large natural stands of Borassus palms.

The remaining upland soils in the east are too patchy in occurrence for systematic development. Lota series is unsuitable for agriculture, but Koni and Kenya series provide good agricultural soils. They are rather too compact for satisfactory hand-cultivation and would benefit from mechanical tillage. Subsoiling, ridging and the turning in of organic matter would provide a better agricultural tilth. Protective measures would be needed against erosion. Cassava, peppers and other minor vegetables are the only crops that can safely be recommended at present, but sorghum, millet and finger millet would be expected to yield satisfactorily if suitable varieties can be discovered for use on the Plains. These soils would benefit from irrigation, but are unlikely to be developed with this aid because of their limited extent and patchy mode of occurrence.

Agawtaw and Hwapa soils are an almost completely unknown quantity so far as cultivation is concerned. They appear potentially suitable for mechanized cultivation and irrigation, but require a considerable amount of investigation before development by this means can be considered practicable. It would seem necessary to attempt breaking up the hardpan layer by subsoiling to increase rooting depth and to improve internal drainage further by throwing the soil up in cambered beds with deep intervening drains to assist in flushing out soluble salts from the lower part of the profile. The soils need more organic matter, and nitrogenous and phosphatic fertilizers will need to be added for satisfactory crop production. Contour field layouts need to be adopted. With suitable management, they would be expected to be suitable for a wide range of irrigated crops, but this requires to be determined on a suitable experimental station.

Without irrigation, it is not considered very likely that these soils will be suitable for improved dryland farming because of the erratic rainfall they receive. Investigations are needed, however, to determine whether contour furrowing or strip cultivation might be effective in making better use of this rainfall and so allow the production of such crops as sorghum, millet, finger millet and pulses. Valley bottoms might be capable of producing fodder crops if, by the periodic construction of low bunds, water could be held on the soil for a longer period than at present. Similar techniques are more fully discussed under Simpa-Agawtaw Complex below.

Until they can be developed by irrigation, therefore, it seems likely that Agawtaw soils in this complex will remain utilizable only as rough-grazing land. Improvements which might be effected in this respect will be discussed more fully in Part III of the Report.

Unsurfaced roads are quite practical on Agawtaw soils if their use is strictly limited to dry periods. Their serviceability can be improved by the provision of side-drains and culverts. The loose sand of Doyum series makes such roads less practical on these soils, more particularly in the western tract, and wet-season use is impractical.

Doyum soils present difficulties for the construction of major roads. Roads built over such sandy soils—witness the Accra-Senchi road between Dodowa and Agomeda which for part of this stretch is built over Doyum soils—tend quickly to collapse into deep transverse swells and hollows. This collapse is probably not so much attributable to the fact that the road is built over sand but to the fact that the lower layers of this sand are waterlogged in the rainy season and become subject to flow under pressure in this condition. One solution here would be to realign the road a mile or so to the west on the more suitable upland soils of Oyarifa-Mamfe Complex. Where roads must be built over Doyum soils, however, it would seem essential to provide side-drains penetrating through the basal gravel layer; around the down-slope edge of the soils, where the seepage zone approaches the surface, cross-drains or culverts under the road may be required in addition. In any case, a thick foundation layer would seem to be desirable to insulate the road-surface from the unstable sand below. This problem is brobably less acute over Doyum soils in the east where the subsoil is rather firmer and perched water-tables seem to develop less frequently.

Over Agawtaw soils, the compact layer at the top of the subsoil should preferably be left intact. If this can be kept dry by an adequately-sealed road-surface (and perhaps berm as well) and the provision of deep side-drains and ample culverts, it will provide a substantial foundation to the road in itself. This is less practical where Agawtaw soils occupy bottom sites, and here broadbase causeways will need to be provided.

The problem of road-building in this tract is aggravated by the paucity of supplies of suitable materials for foundations and surfacing. In the west, small deposits exist in the patches of Mamfe soils. More substantial deposits exist in the neighbouring Oyarifa-Mamfe Complex, mainly south of Dodowa and north and east of Agomeda. Rock for foundations could be quarried at the foot of the Akwapim Range. In the east, crushed rock is available from a quarry in a small granite outcrop some 6 miles north of Sege on the Aveime road, and there are other outcrops suitable for use in this tract. There is a great shortage of 'laterite' gravel, the nearest deposit to the tract that is known occurring on the watershed ridge immediately north of the Sege Fuelwood plantation, some three miles north of **Sege,** and this is probably of small extent.

TRACT 8

General

This tract extends in a narrow belt to the east of the Accra-Senchi road from near Somanya in the north to near Agomeda, where it swings to the east of Doyum-Agawtaw Complex as far south as Se (Kodiabe); it then widens rapidly southwards until along the Accra-Lagos road between Labadi and Dawhwenya it is approximately 20 miles in width.

The major part of the tract is occupied by *Simpa-Agawtaw Complex.* Smaller disconnected areas in the south are occupied by *Nyigbenya*, *Akuse* and *Ashaiman Consociations.* Enclaves of Korle, Toje, and Tachem Consociations and of Oyibi-Muni Association have been excluded from the tract and are discussed separately. With the latter associations excluded, the tract covers an area of approximately 190 square miles (121,000 acres).

Simpa-Agawtaw Complex consists predominantly of pale-coloured sands overlying gravelly clay on the uplands and grey-brown, impervious clays on the lowlands. In the south, the highest upland areas are frequently capped by red ironstone-concretionary clays which, where sufficiently extensive, have been mapped separately as Nyigbenya Consociation. Between Nungua Veterinary Farm and Ashaiman, there are several small areas of black and brown calcareous clays. Where sufficiently extensive these have been mapped separately as Akuse and Ashaiman consociations respectively. A further small area of black clays has been mapped to the east of Agomeda. Other, smaller, occurrences are known to occur to the north of Tema, near Doyum and near Somanya within Simpa-Agawtaw Complex. Brown, calcareous clays of Dome series* occur within the small area of Akuse Consociation to the east of Agomeda.

The mean annual rainfall increases from less than 30 inches near the coast to slightly over 40 inches in the extreme north. The southern half of the tract is exposed to fresh sea-breeze throughout much of the year. The relief is gently undulating at between 0–250 feet above sea-level. There are no permanent streams: valleys do not always possess continuous stream channels, in fact. Dahomeyan acidic schists and gneisses underlie most of the area, but basic igneous rocks underlie the areas covered by the black and brown clays. Rock outcrops are very rarely encountered. Stream channels are usually bordered by a narrow fringe of woodland or thicket, but the remainder of the tract occurs under savannah vegetation.

SOILS

Almost all the soils of Nyigbenya, Akuse and Ashaiman Consociations are also found in Simpa-Agawtaw Complex. It will eliminate unnecessary repetition of soil series description, therefore, if these are given for the tract as a whole. First, however, the disposition of the soil series within the mapping units will be described.

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*Now *Agomeda series*, see footnote p. 135.

Simpa-Agawtaw Complex

This complex covers approximately 178 square miles (c.114,000 acres). A minor outlier has been mapped along the Accra-Senchi road in the south. The major component soils are developed over a variety of Dahomeyan acidic schists and gneisses on gently-undulating relief under savannah vegetation but there are minor areas underlain by intrusive granite and pyroxenite, basic gneisses, Togo quartzite schists and Tertiary sediments.

The major upland soils, of *Simpa series*, consist of pale-coloured sand overlying gravelly sandy loam to sandy clay. They cover approximately two-thirds of the area. The major lowland soils, of *Agawtaw series*, consist of grey-brown, compact, calcareous clays. The topographical relationship between the two soils is not simple: Agawtaw series may occupy the whole of the topography locally, and Simpa soils may also occur patchily amongst Agawtaw series on middle slopes. In some areas in the south they are intermixed on such a local scale, individual expanses of each soil apparently occupying only a few square yards, that it would be impossible even with detailed mapping to map the two soils seperately.

The highest parts of the undulations in the southern part of the complex frequently carry red concretionary clays of *Nyigbenya series*: (whether similar occurrences of *Mamfe* soils occur (under thicket) in the north has not been established).

In the south, there are a few, small, upper-slope occurrence of deep, red, non-concretionary loams of *Toje series*. These are surrounded by *Agbozome* soils, developed in materials similar to those in which Simpa soils have developed, but in which the pale-coloured, sandy upper layer is thicker than 5 feet. These soils, together with a deep subseries of Simpa series, are widely developed in the area near and to the south of the Accra-Lagos road.

Small patches of black clays of *Akuse series*, in addition to the larger areas mapped separately, occur locally to the north of Tema, to the west of Doyum and to the east of Somanya. Similar small patches of brown calcareous clays of *Ashaiman series*, in addition to the area mapped near Ashaiman, occur locally in the vicinity of Nungua Veterinary Farm. Both soils may occur on any topographical site.

Soils of *Doyum*, *Korle*, *Minya*, *Koni* and *Kenya series* occur very locally on upland sites, mainly in the south. Dark grey, compact, sandy clays of *Hwapa series* occur sporadically along valley bottoms.

Nyigbenya Consociation

This consociation, covering a total area of approximately 7 square miles (c.4,500 acres), includes those areas of *Nyigbenya* soils which are sufficiently extensive to have made mapping practicable on the scale employed. Their occurrence almost coincides with the 250-foot contour on the summits of the long spurs which project from Nyigbenya-Hacho Complex towards the coast in the southern half of the tract. Some of the occurrences appear to coincide with outliers of Togo quartzite schist which locally gives rise to red, brashy light clays of *Korle series*. Small areas of deep red loams of *Toje series* occur amidst Nyigbenya series in some occurrences.

Akuse Consociation

Black calcareous clays of *Akuse series* have been mapped in two widely-separated localities. East of Agomeda, rather shallow (c.30 inches) black clays occur on the undulations together with minor areas of brownish-grey calcareous clays of *Dome* series, both soils apparently developed from unidentified basic rocks; non-calcareous black clays of *Bumbi series* occupy the depressions. On, and in the neighbourhood of, Nungua Veterinary Farm, deep black clays are developed on all topographical sites over pyroxenite and pyroxene gneiss; *Bumbi* soils occur in nearby depressions. The black clays here are displaced locally by brown calcareous clays of *Ashaiman series*, and frequently interrupted by small patches of brown, ironstone-concretionary clays of *Nungua series*. The areas mapped cover approximately 6 square miles (3,840 acres).

Ashaiman Consociation

This soil association covers an area of approximately half a square mile (320 acres) a short distance to the west of Ashaiman cross-roads. It consists of minor upland areas of *Osudoku* soils developed amongst bouldery outcrops of pyroxenite; and brown, calcareous clays of *Ashaiman series* developed over this rock, or pyroxene gneiss, on surrounding gentle slopes.* There is a limited occurrence of a red concretionary soil similar to *Nyigbenya series*, but not occurring on the uplands as do the true Nyigbenya soils in this tract.

The soils of these mapping units are described below in the following order:—

1. *Nyigbenya series*
2. *Simpa series*
3. *Doyum series*
4. *Agawtaw series*
5. *Hwapa series*
6. *Minya series*
7. *Korle series*
8. *Toje series*
9. *Agbozome series*
10. *Koni series*
11. *Kenya series*
12. *Akuse series*
13. *Bumbi series*
14. *Osudoku series*
15. *Ashaiman series*
16. *Nungua series*
17. *Dome series*

Nyigbenya series comprises red ironstone-concretionary clays occurring mainly on the higher summits but also in a small patch on lower ground on the western border of Ashaiman consociation. The concretionary subsoil has often hardened into ironpan around the edges of the summit soils. The soils are conspicuous by the presence of red termite-mounds. Near the Accra-Lagos road they have been widely quarried for road material.

A full description of these soils is given above under Nyigbenya-Hacho Complex (Tract 3).

Simpa series comprises important soils with a grey-brown to pale yellow-brown sandy surface layer which may vary in thickness within a few yards from almost nothing to more than 3 feet, overlying a variable thickness of grey or brown, often mottled orange, sandy loam to sandy clay containing very abundant quartz gravel or stones above weathered Dahomeyan acidic gneiss or schist. These soils occur extensively on gentle upper and middle slopes throughout Simpa-Agawtaw Complex.

Where the sandy layer exceeds 30 inches in thickness over large areas, as happens on some uplands near and to the south of the Accra-Lagos road in the Tema area, the soils have been recognized as *Santeo subseries*. Where in this area this layer exceeds feet, the soils have been included within Agbozome series (described below).

Transitional variants sometimes occur bordering Nyigbenya soils in which the colour is brown to orange-brown, and towards Agawtaw series when compact clay is reached before the gravel horizon and the lower horizons become less acidic in reaction.

The gravel layer is locally found to be iron-cemented. Such soils are too local in occurrence to be mapped separately.

Simpa soils absorb water readily except during very heavy rainfall and may become waterlogged in the lower horizons following prolonged heavy rainfall. Moisture appears to be retained satisfactorily at depth during normal dry seasons, but the sandy upper layer quickly becomes parched. The soils are little cultivated at present, but large areas could be mechanically cultivated where there is no danger of encountering the gravel layer near the surface. On exposure, the soils seem liable to 'pack'; anti-erosion measures would therefore be required if extensive areas were to be farmed. It would seem necessary, too, to relieve the waterlogging of the lower horizons, and so allow deeper root-penetration into the more valuable clay layers and weathered rock, by providing some form of drainage system; whether tile drainage would be effective, or whether a network of open surface drains would be necessary requires to be investigated.

The sandy upper layer contains very little organic matter and is almost barren of nutrients. It is usually neutral to slightly acid in reaction. The clayey lower layer is moderately acid, but appears to retain satisfactory amounts of mineral nutrients. The whole soil, however, is markedly deficient in phosphorus. This element, together with nitrogen, would need to be added in fertilizers for satisfactory crop production, and the organic matter status would need to be improved.

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*Marble has also been seen underlying a small area of these soils in this area.

Doyum series occurs only locally in this tract on upland sites, to the south-east of the indefinite boundary of the present complex with Doyum-Agawtaw Complex. These soils consist of 2–5 feet of pale brown coarse sand overlying a shallow, mottled, gravelly clay layer which rests on mottled, highly-weathered granite. A full description of the series is given above under Doyum-Agawtaw Complex (Tract 7).

Agawtaw series is the major lowland series of the tract but it also extends onto upper slopes in some areas in the south. Briefly, the soils consist of a grey-brown to pale brown, porous, fine to medium sandy loam topsoil overlying a darker-coloured, very compact, clay upper subsoil which impedes internal drainage, and a more plastic clay lower subsoil containing lime nodules. The underlying acidic gneiss or schist is only moderately weathered, and contains lime nodules in the joints and bedding planes.*

A shallow gravelly clay horizon usually separates the soil from the weathered rock. In soils transitional between Agawtaw and Simpa series, this gravel layer increases in thickness at the expense of the calcareous subsoil. Where such soils are sufficiently extensive, as appears to be the case locally north of Ashaiman cross-roads, they are recognized as *Zenu subseries.*

In the west of the tract, in valleys draining from Papao or Krabo soils, the soils of Agawtaw series tend to be pale grey and more silty.

A fuller description of Agawtaw series is given below under *Agawtaw Consociation* (Tract 10).

Hwapa series occurs only occasionally along valley bottoms amongst Agawtaw soils. The soils are dark to mid-grey in colour and consist of sandy loam for a few inches at the surface overlying very hard, blocky, sandy clay below this for about 2 feet, when the clay becomes more plastic, although still sandy, and contains small amounts of lime concretions. The series is more fully described under Agawtaw Consociation (Tract 10) below.

Minya series consists of soils with similar topsoils to those of Agawtaw series, but the subsoil consists of grey or brown, often mottled, plastic clay full of small ironstone concretions and gravel. The underlying acidic schist of gneiss is usually highly-weathered but not ironstained. Lime concretions may locally occur in the lower part of the profile.

These soils occur very patchily amongst Agawtaw series, usually where these occur on upper slopes. They show signs of impeded internal drainage but appear to be droughty in the dry seasons. No hand-cultivation has been observed, and it would be advisable to avoid patches of these soils in mechanical cultivation so far as possible because of the risk of excessive abrasion of tillage implements. The soils accumulate only very small amounts of organic matter in the droughty topsoil, and the nutrient status of the soils is rather low. They are slightly acid near the surface but become slightly to moderately alkaline with depth.

Because of their limited importance, the soils will not be considered in further detail.

Korle series consists of shallow red light clays developed in brashy Togo quartzite schist and occurs very locally amongst Nyigbenya series on some upland sites. These soils are fully described above under Oyarifa-Mamfe Complex (Tract 2). In the present tract they occur under savannah vegetation.

Toje series is found very locally on the summits of undulations, sometimes amongst Nyigbenya soils, but also independently in the neighbourhood and to the south of the Accra-Lagos road near Ashaiman. In profile the soils consist of more than 30 inches of friable red loam becoming more clayey with depth; this may overlie red ironstone-concretionary clay or directly overlie weathered acidic gneiss or Togo quartzite schist.

A detailed description of the series is given above under Nyigbenya-Hacho Complex (Tract 3).

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*Soils on the piedmont slopes surrounding Togo quartzite schist ridges in Korle Consociation (Tract 5) near Dawhwenya were provisionally included with Simpa-Agawtaw Complex at the time of the survey. Subsequent detailed surveys in the area have indicated that the soils need to be separated from Agawtaw series at the series level.

The most extensive soils, of *Hanya series*, are dark brown to reddish brown in colour, sandy light clay or clay in the topsoil and sandy clay below, the subsoil forming a prismatic hardpan; lower layers are slightly calcareous and affected by moderate amounts of soluble salts. The underlying rock is usually basic gneiss, and has weathered to considerable depths into a mottled plastic clay.

The soils of *Dawhwenya series* resemble Hanya soils in colour and texture of the fine earth but contain many quartzite stones in the subsoil and lower layers. They are more acid in reaction near the surface and only neutral to slightly alkaline in the deeper layers. They do not appear to contain lime concretions and are likely to be less affected by salts.

Agbozome series, within this tract, consists of soils with a deep layer of very pale grey or pale brown sand which may be underlain at depths greater than 5 feet by gravelly clay resting on weathered acidic gneiss. Where they occur elsewhere in the region these soils are associated with lower slopes undulations developed in the Tertiary sands; but in the present arca, they occur on upper slopes, sometimes surrounding small areas of red Toje soils, but also occurring independently. Their occurrence is limited to the part of the tract near and to the south of the Accra-Lagos road.

These soils are very free-draining, and although they may temporarily possess a shallow perched water-table above the clay layer during the rainy seasons, they become droughty during the dry seasons. There is nothing to interfere with tillage, either manual or mechanical, although small rock outcrops were encountered near their down-slope limit on a hill-top north-west of Ashaiman. They permit free root-development, but seem liable to pack at the surface when left bare.

The nutrient status is very low. They accumulate only very small amounts of organic matter in the topsoil and have little power to retain nutrients.

Koni series comprises deep, reddish brown to orange-brown, compact, gritty clays overlying weathered acidic gneiss. In this tract, Koni soils are found very locally developed on middle slopes amongst Simpa and Agbozome soils in the extreme South of the tract. They differ from Koni soils in the eastern area of Doyum-Agawtaw Association in containing a prominent layer of stones and gravel a foot or more thick in the lower part of the clay layer. This is too deep to interfere with normal cultivation.

A fuller description of Koni series is given above under Doyum-Agawtaw Association, (Tract 7).

Kenya Series is developed in similar parent materials to Koni series, but the soils are well drained. They consist of brown to yellow-brown, cornpact gritty clays overlying a layer of gravelly clay at a moderate depth and then weathered acidic gneiss. They occur only patchily on middle and lower slopes in the extreme south of the tract.

A full description of the series is given above under Doyum-Agawtaw Association, eastern area (Tract 7).

Akuse series includes very dark grey, heavy, plastic clays which become calcareous at a moderate depth. Within the present tract, they are developed over a variety of basic igneous rocks and on all topographical sites. The largest area mapped includes a number of irregular-shaped occurrences on and around the Nungua Veterinary Farm where the soils are extensively cultivated by machinery. Here the soils are deep and appear to overlie highly-weathered pyroxene gneiss or pyroxenite. In the occurrence to the east of Agomeda the soils are usually only 2–3 feet deep and overlie an unidentified basic rock. Smaller, unmapped, occurrences associated with other basic rocks occur to the north-east of Tema, west of Doyum and east of Somanya.

With the exception that in this tract they overlie a number of different rocks and appear to have a rather higher clay content, the soils do not appear to differ significantly from those developed over the main Black Clays belt (Tract 9). A full description of the series is given below where this tract is treated.

Bumbi series includes black, heavy, plastic clays, slightly acid in reaction in the upper part of the profile and only becoming alkaline below a depth of 30 inches. They are developed locally in depressions in association with Akuse soils. A full description of the series is given below under Akuse Consociation (Tract 9).

Osudoku series covers only a very minor area within Ashaiman Consociation in the present tract, and will be found more fully discussed below under Osudoku Consociation within Tract 9. The soils occur on upper slopes and consist of crumbly loam or light clay, black for a few inches at the surface but dark brown to brown below, developed over or amongst ironstained, spherical boulders of pyroxenite.

Ashaiman series comprises dark brown to slightly reddish brown, cloddy, plastic clays 1–3 feet deep containing small amounts of lime concretions in the lower part of the profile and developed on gentle upper, middle and lower slopes over pyroxenite or pyroxene gneiss. The major occurrence, a short distance to the west of Ashaiman cross-roads, has been mapped separately; patches of similar soils on Nungua Veterinary Farm have been included within Akuse Consociation.

Under natural conditions, the soils are subject to surface run-off during heavy rainfall and tend to become droughty during dry spells. If opened up by cultivation, their moisture relationships should improve considerably.

Ashaiman soils are appreciably more friable near the surface than the black clays, but they are not hand-cultivated at present. On Nungua Veterinary Farm they are mechanically cultivated, although with the light equipment used, this can only be performed within a narrow range of moisture conditions: when wet, they are too heavy and plastic; when dry, they are too hard and compact. They would develop a better tilth if cultivated on high ridges or cambered beds. These should be arranged slightly off the contour to facilitate drainage during heavy rainfall.

In their natural state, the soils are well provided with lime but have low contents of organic matter, nitrogen and phosphorus. The latter element would need to be added for the intensive crop production to which they are suited. Except where lime concretions occur in the surface layer, topsoils are generally slightly acid in reaction but lower layers are slightly to moderately alkaline and may contain small amounts of soluble salts.

Nungua series comprises soils with a dark brown to grey-brown, friable, sandy heavy loam to light clay topsoil overlying a few feet of brown and grey mottled plastic clay containing abundant, ochreous, ironstone concretions and quartz stones and gravel. Weathered rock, if encountered, is likely to be pyroxenite. Lime concretions may be encountered in the lower subsoil locally.

These soils occur in small patches amongst Ashaiman soils on Nungua Veterinary Farm where they stand out as gravelly patches on the cultivated fields. Their moisture relationships are imperfectly understood, but they appear to absorb water more readily and to dry out more rapidly than Ashaiman soils, apparently becoming waterlogged for a time following heavy rainfall.

Topsoils are usually neutral to slightly acid but lower layers vary in reaction from slightly acid to moderately alkaline. Lime and potash appear to be plentifully provided, but there is little organic matter and nitrogen and phosphorus contents are low.

Dome series has only been recorded over a limited area within Akuse Consociation near Agomeda where the soils occur amongst Akuse soils on the slopes of a gentle undulation towards the north of the area mapped. They differ slightly in colour from the major occurrence of the soils in Danfa-Dome Complex and here consist of about 30 inches of brownish-grey to pale olive, plastic clay with a few lime concretions and a thin layer of quartz and ironstone gravel in the lower part of the profile overlying an unidentified weathered basic rock.*

A full description of the series is given above under Danfa-Dome Complex (Tract 4).

VEGETATION

With the exception of narrow fringes of thicket or woodland along the discontinuous stream channels, the tract is everywhere covered with savannah vegetation. This consists predominantly of short grassland with widely-scattered clumps of thicket or small trees. The woody vegetation is usually associated with old termite-mounds. The candelabra-like tree, *Elaeophorbia drupifera*, is particularly conspicuous on the latter over the southern half of the tract.

The deeper sands of Simpa (Santeo) and Agbozome series sometimes carry medium and tall savannah regrowth, but large areas of these soils to the south of the Accra-Lagos road are covered with a dense, low, thorn scrub of *Dichrostachys glomerata.* The upland areas of Nyigbenya soils are conspicuous because of the development of wind-aligned clumps of thicket amongst the grassland vegetation, variously short and tall from place to place. Akuse, Bumbi, Dome and Ashaiman soils support medium grassland which has frequent scattered shrubs and trees in the north, but is almost treeless in the south.

PRESENT LAND-USE

The minor amounts of cultivation in this tract are practically confined to the deeper upland soils of Nyigbenya series in particular, and Toje, Simpa (Santeo) and Agbozome series to a lesser extent. Cassava and small vegetables are the usual crops attempted, except near the coast where gourds and okro are grown. These crops are conspicuously impoverished in appearance, but crop yields are not known.

On the Nungua Veterinary Farm, over 200 acres of Akuse, Ashaiman and Nungua soils are

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* Possibly marble. These soils have subsequently been separated from Dome series and recognized as *Agomeda series*.

under permanent cultivation. *Fodder grasses and legumes are produced with the aid of farmyard manure. Yields periodically suffer because of prolonged droughts and attack from army worms.

Southwards from the Okwe stream, the major form of land-use is cattle-grazing. This part of the tract provides the major grazing area for the approximately 17,000 herd of cattle kept (1951 Census) in the western half of the Accra Plains. None-the-less, the short grasses provide little bulk and probably have a low nutritional value. Conditions become precarious during the long dry season until the first showers stimulate a new flush of growth. Large areas are burned seasonally to encourage fresh growth. Water-holes along the discontinuous stream channels and along road-sides retain water very well, but as the main dry season proceeds more and more of these dry out and cattle have longer distances to walk daily to find both pasture and water.

RECOMMENDATIONS REGARDING LAND-USE

The development of the full potentialities of this tract depends on the provision of irrigation facilities. Agawtaw, Hwapa, Akuse, Bumbi, Ashaiman, Toje, Koni, Kenya and Dome soils would all appear potentially suitable for development by this means, and some areas of Simpa soils might be suitable, too. Little is known at present, however, concerning the techniques of cultivating the heavy clays amongst these soils, and their development could only be undertaken after suitable preliminary investigations had been carried out. The areal extent of Simpa and Agawtaw soils is such that it is recommended that an experimental station of some 200 acres extent be set up at an early date on which their irrigational, cultural, manurial and cropping requirements can be thoroughly investigated along similar lines to those recommended for the Black Clays on the Kpong Irrigation Research Station. It is suggested that this be located along the proposed Kpong-Tema water pipe-line, somewhere between the Dodowa-Prampram and Accra-Lagos roads, so that irrigation water might be available before the building of the Volta dam.**

Heavy equipment would be required to handle the heavy soils and artificial manures to maintain their fertility under continuous cropping. They might be expected to produce a complete range of irrigated crops—amongst them rice, sugarcane and cotton—but this can only be determined by investigation. There will, however, be a need to produce large amounts of fodder to support the equally-important development of large-scale stock-rearing over these areas which is recommended. Large-scale management would be essential for the development of these soils.

It might be possible to grow fodder-crops along valley-bottoms by making better use of the present surface run-off. This might be effected by constructing low bounds across the line of drainage at intervals along the bottoms. These would require reinforced overflow channels to prevent wash-outs occurring during exceptional rainfall. Heavy equipment would be required to handle the soils of Agawtaw, Hwapa and Bumbi series involved. This form of cultivation could probably only be carried out in conjuction with large-scale stock-rearing.

Without the aid of irrigation, the possibilities of increasing crop-production in this tract appear to be small. The restricted areas of red loams are usually too exposed to be of much value for agriculture. If they are to be developed, attention must be paid to mixed cropping and the provision of adequate fallows along the lines indicated for similar soils in Tract 3. Dry-farming techniques (with suitable provision for the maintenance of ground-cover) on Agawtaw and Simpa soils require to be investigated on the experimental station recommended. Sorghum, millet, finger millet, bambara beans, suitable pulses and cucurbitaceous plants appear to be the only food-crops possibly suitable in the south. Sisal and perhaps ginger might be tried on Simpa and Agbozome soils. North of the Okwe stream it should be possible to grow maize and groundnuts in the first rainy season, perhaps followed by cassava or by a second season crop of sorghum or millet.

Except on Simpa soils with gravel at a shallow depth, it would be desirable to improve internal drainage on Simpa-Agawtaw soils by growing the crops on cambered beds or high ridges. These would need careful grading to ensure safe disposal or run-off during heavy rainfall. The soils would benefit from the addition of kraal manure which should be readily available throughout most of the tract.

*A similar acreage is now cultivated on the adjoining farm of the University College Faculty of Agriculture. Comprehensive experimental work relating to crop and animal husbandry commenced on Akuse, Ashaiman, Simpa and Agawtaw soils in 1954.

**This need is now largely being met by the University College Agricultural Research Station at Nungua.

Green manures might also be used to maintain an adequate content of organic matter. Trash left on the ground from previous crops could provide a valuable protective mulch. Fertility would need supplementing by the liberal use of mineral fertilizers, especially those providing phosphorus and nitrogen.

The heavy equipment needed for the clay soils, the necessity for the large-scale use of artificial fertilizers and the large areas which would require to be commanded for economical working all demand that if this form of development were proved practicable it should be organized and managed on a large-scale basis.

Regardless of the results of such investigations, the greater extent of the tract is likely for long to be utilized for rough-grazing. Improvements in the quality of the pasturage is required, although this will undoubtedly be costly to achieve. The application of nitrogen and phosphorus, in which all the soils are markedly deficient, might be the most economic method. Water-holes need to be excavated at intervals along the valleys for use both by man and stock.

Whether irrigation were to be practised or not, it would be desirable in the south to reduce transpiration losses due to exposure to the sea-breeze by planting wind-breaks of suitable trees near the coast and at intervals inland.

Nyigbenya soils provide a ready source of road-gravel in this tract. Additional supplies are available from Nyigbenya and Mamfe soils in the neighbouring tracts to the west. Virtually the only rock available for foundation material within the tract is that already quarried north of Ashaiman, but ample supplies of Togo quartzite schist are available in Korle Consociation along parts of the eastern boundary of the tract. Simpa soils themselves could provide suitable road gravel in many places where the gravel layer is thick, but the clay matrix in the lower layers is too highly plastic and its use should be avoided.

Conditions in respect of road-construction are broadly similar to those discussed for Doyum-Agawtaw Association (Tract 7), and the recommendations given there may be referred to. Simpa soils present much the same problem as Doyum soils and appear to need drainage to effect a solution. This will be difficult to effect in areas in the south where Simpa and Agawtaw soils are intermixed on a very small scale because of the widely-fluctuating depth of the seepage zone.

The plastic clays of Ashaiman, Akuse and Dome series should be avoided where possible. Where they cannot be avoided, techniques similar to those discussed for the Black Clays in Tract 9 should be used.

TRACT 9

General

This tract extends in a broad belt down the centre of the Accra Plains from the edge of the Volta floodplain in the north almost as far as Tema in the south. By far the greater part of this belt—the Black Clays belt—is occupied by *Akuse Consociation*. Smaller disconnected areas in the north and centre are occupied by *Kloyo* and *Osudoku* Consociations. Enclaves of Nyigbenya-Agawtaw Complex and of Lupu and Tachem Consociations have been excluded and are discussed separately below under Tracts 12 and 13 respectively. With these exceptions, the tract as mapped covers an area of approximately 280 square miles (c. 180,000 acres).

Mean annual rainfall increases from less than 30 inches near the coast to around 45 inches in the extreme north. Data for Akuse in the north show an average annual rainfall of 43.75 inches with a variability co-efficient of 21 per cent and an average of 85 rainfall days per year. Temperatures are higher and humidities lower than in the south, but the latter area is exposed daily to a fresh sea breeze which has a strong drying effect.

The greater part of the tract occurs under savannah vegetation. The topography is for the most part very gently undulating at less than 300 feet above sea-level, with slopes rarely exceeding 5 per cent and usually of 2 per cent or less; but in the centre and north, isolated rocky hills (inselbergs) rise abruptly from the plains to as high as 1,400 feet in the case of Ningo Hill. Drainage is mainly by sheetflood over the entire ground-surface, and valley bottoms are characteristically streamless. However, the Okwe stream in the north-west and the Dechidaw stream in the south-west, both draining from the Akwapim Range, have a semi-perennial flow.

Almost the whole of the tract is underlain by Dahomeyan garnetiferous hornblende gneiss, a metamorphosed basic rock, which also forms the outcrops on the large rocky hills. There are local intrusions of pyroxenite, the major occurrence forming a long, discontinuous line of low hills to the east of Krobo Hill in the north of the belt.

SOILS

Since the soils of Kloyo and Osudoku consociations also occur within Akuse Consociation, it will eliminate unnecessary repetition of soil series descriptions if these are given for the tract as a whole. Before this is done, however, the disposition of the soils within the mapping units will be described.

Akuse Consociation

This mapping unit covers an area of approximately 270 square miles (c.173,000 acres). By far the greater proportion of this area is covered by black calcareous clays of *Akuse series* developed over garnetiferous hornblende gneiss on all topographical sites of the gently-undulating relief. There are relatively small occurrences of associated slightly—and non-calcareous slopewash and alluvial clays of *Bumbi* and *Lupu series* along valley bottoms, but the greater extent of the latter series has been mapped separately under Lupu Consociation. The consociation includes a multitude of relatively minor soils developed in different parts of the tract, usually in the vicinity of the rocky hills.

Kloyo Consociation

This consociation includes soils developed on the steep slopes of, and in the internal valleys of, the isolated rocky hills in the centre and north of the tract. The several detached occurrences altogether cover approximately 11 square miles (c.7,000 acres).

The major soils are shallow, dark-coloured, loams to clays of *Kloyo series* developed over and amongst numerous rock outcrops of garnetiferous hornblende gneiss on the steep flanks of the hills. There are minor occurrences of similar shallow soils of *Osudoku series* over small pyroxenite intrusions. Deep, dark-coloured, alluvial sandy clays of *Yongwa series* are found locally in the deep valleys, more particularly in the central valley of the Shai Hills. The soils developed at the foot of these hills have been included in Akuse Consociation.

Osudoku Consociation

This mapping unit, occupying approximately 1 square mile (640 acres), covers a discontinuous line of low pyroxenite hills to the east of Krobo Hill. *Osudoku series*, consisting of shallow, dark-coloured, loams or clays developed over or amongst boulders of weathering pyroxenite, covers the entire area.

The soils of these mapping units are described below in the following order:—

1. *Akuse series*
2. *Bumbi series*
3. *Lupu series*
4. *Tepanya series*
5. *Kloyo series*
6. *Muete series*
7. *Shai series*
8. *Tetedwa series*
9. *Yongwa series*
10. *Nyigbenya series*
11. *Bundase series*
12. *Osudoku series*
13. *Ashaiman series*

Akuse series comprises black or dark grey heavy clays with lime concretions occurring mainly in the lower part of the profile. In the normal soils, bedrock is not reached within 30 inches of the surface but usually occurs at 3–4 feet. It is usually rather loamy and only moderately weathered. The soils are highly plastic when wet but become hard and compact when dry and then crack vertically from the surface. Most profiles have small to moderate amounts of small, black, brittle, manganese concretions and small, hard, black or orange, shiny, iron concretions scattered throughout them. Small rock outcrops are frequently encountered in the north of the belt and locally between the Shai Hills and Dawhwenya in the south, but elsewhere they are very rare.

The soils are far from uniform throughout the belt. Two major subseries have been recognized. These and some of the more important variants are described below.

Soils of *Prampram sub-series* resemble the normal soils in profile characteristics, but weathered bedrock is reached within 12–30 inches of the surface. They are patchy in occurrence and are found most frequently on slightly steeper slopes—2–4 per cent—in the northern part of the tract, particularly near and to the north of the Somanya-Akuse road. Small rock outcrops are frequent.

Soils of *Jawpanya subseries* differ from the normal soils in becoming olive-brown to yellow-brown below a depth of 1–2 feet. They frequently contain large amounts of small, black manganese concretions and soft ironstone concretions. They are developed on low-lying sites in a broad belt near the western boundary of the tract in the vicinity of Doyum.*

Several variants occur in other places. In the vicinity of the Kpong Irrigation Research Station, soils often contain a thin layer of quartz pebbles at the base of the profile. To the south and east of Ningo Hill, some profiles contain appreciable amounts of quartz grit. In the south, the ground-surface is often littered with small amounts of lime concretions and larger amounts of ironstone gravel, some of which has become incorporated in the upper part of the soil profile. Over old settlement sites throughout the tract, abundant pottery fragments and stone artifacts occur on the ground-surface and in the soils to a depth of 18 inches or so. Locally throughout the tract there are small-scale variations in colour, in the texture or consistency of the surface horizon, in the size of the structural units between the vertical cracks and in the content of lime and/or ironstone concretions. Very detailed surveys would be required to map these differences separately.

Under natural conditions, the soils quickly absorb water during rainfall until the cracks close up. Thereafter during heavy rainfall, they are impervious and shed water by surface run-off. The surface relief generally ensures fairly rapid external drainage, but internal drainage is impeded. On drying, wide vertical cracks develop. The soils dry out deeply during prolonged dry spells and become droughty. The soils of Jawpanya subseries appear to remain waterlogged or very moist for longer periods than the normal soils.

These soils are only cultivated to a very minor degree at present, chiefly in the north. The clays are too hard and cloddy when dry and too heavy and plastic when moist for hand cultivation. It will require to be determined on the Kpong Irrigation Research Station how best they can be handled by machinery. There is likely to be a very limited range of soil-moisture conditions between which cultivation operations can be easily performed. When thoroughly wet, as during rainfall, the soils do not support wheeled vehicles and it will be essential to use crawler tractors.

The initial preparation of the land for cultivation should not be unduly difficult, provided that suitable heavy mechanical equipment is available. There are generally few trees to clear, but 'bush-ploughs' will be required to deal with the wide-spreading, lateral surface roots of these and the more frequent shrubs. Termite-mounds are infrequent, but such as occur are very compact and will require to be demolished. Rock outcrops, and soils in which there is a danger of meeting hard rock within cultivation depth, will require to be mapped before any area can be developed. These obstacles are rare in the south and centre, but are frequent near and to the north of the Somanya-Akuse road and around the rock hills generally.

After the initial breaking in of the land, there should be no further physical difficulties to overcome. van der Merwe in describing the South African Black Clays reports that some of them "remain 'raw'" and unproductive for at least 3 years before a normal crop is produced" (14); and the Black Clays cultivated on the Nungua Veterinary Farm were reputedly unproductive in their first year. After a few years' cultivation, however, they develop a good tilth and become self-mulching in the cultivated layer. Inter-row tillage should therefore be relatively simple for dry-land crops.

In the case of soils used for flood irrigation, however, there will be little opportunity to dry out and crack into clods and van der Merwe says of irrigated Black Clays in South Africa which remain perennially moist that they appear to deteriorate in structure (15). It may be desirable to alternate dry-land crops with paddy crops to maintain a satisfactory tilth under these conditions.

The surface drainage of the soils is unlikely to be difficult since they generally occur on gently-undulating topography. The most level land is likely to be used for flood irrigation; and soils on slopes will usually be developed by furrow irrigation which will at the same time provide drainage. At the same time, the field channels must be adequate to remove the large quantities of surface run-off accumulating during rainstorms. Uncultivated land must be provided with interceptor drains where necessary to direct sheetflood away from cultivated land. All channels and furrows will need to be designed so that they do not develop into gullies. These, again, are matters which require investigation on the Kpong Irrigation Research Station.

*These soils are more widely developed on the Ho–Keta plains and have now been differentiated as a separate series.

Close attention must be paid to the improvement of internal drainage, a matter which requires early investigation on the Kpong Station. Unless all new land is to be broken in during the main dry season, it will be advisable to put in the drainage system before ploughing commences. Heavy rainfall on undrained ploughed land is liable to prevent further tillage operations on the soil until the following dry season, resulting in the loss of a whole cropping season. It will probably be necessary to grow crops on cambered beds 20–30 feet broad separated by drainage channels 1–2 feet deep running on a graded slope. Rain falling on the soil will then drain laterally through the cultivated layer into the adjoining channels and prevent waterlogging. Treated in such a manner, the soils are likely to moulder down into a desirable, stable, crumb structure. By this means, too, the level of harmful salts, present in some areas at least, might be controlled.

The soils have a satisfactory lime-status but are rather poorly provided with nitrogen, potash and especially available phosphorus. These elements will need to be provided if the high yields the soils are capable of are to be obtained. Minor element deficiencies may become apparent where large quantities of lime are brought to the surface during land preparation and would need to be corrected by the application of appropriate sprays or fertilizers.

Bumbi series comprises black clays transitional between Akuse soils on the uplands and Lupu soils in the major depressions. They are recognized separately because these soils cover significant areas along minor valley-bottoms and along the lower-slope margins of major depressions. They differ from Akuse soils in being slightly acid in reaction to at least 30 inches, although lime concretions usually begin to occur at between this depth and 60 inches. They are generally heavier in consistency at the surface than Akuse soils.

The upper part of the profile consists of very dark grey to very dark brown, heavy clay, plastic and impervious when moist, but hard and cloddy when dry. Wide vertical cracks develop in the dry soil, and the ground-surface is markedly tussocky. Below approximately 30 inches, the colour gradually changes to mid-grey or olive; the cloddy structural units often have shiny surfaces and are faintly stained orange. Lime concretions, usually large, hard and dense, become visible at 30–60 inches and may be segregated in 'nests' at the junction of structural faces. Small, hard ironstone concretions may occur scattered throughout the profile. Soft, black, manganese concretions frequently occur throughout the profile, but are more conspicuous in the lower horizons. Bedrock is rarely encountered within 6 feet of the ground-surface.

These soils are highly impervious. They remain waterlogged for a longer time after rainfall than Akuse soils, but not for the prolonged periods during which Lupu soils are affected. They fairly quickly dry out after the end of the rainy seasons. They remain perennially moist below a depth of approximately 30 inches (and higher in the centre of clods), but this moisture may not be readily available to plants.

The soils are heavier and more plastic than Akuse soils, but their cultivation characteristics are not likely to differ significantly from those discussed for that series. Development is likely to be by means of flood irrigation. Appreciable amounts of soluble salts occur in the lower layers of some soils, but there should be no danger of salt accumulation at the surface if the soils are properly handled.

The soils slightly to moderately acid in reaction in the upper part of the profile, but become alkaline below about 30 inches. They have a moderate organic matter content, deeply distributed down the profile, but are poorly provided with potash and particularly phosphorus. Large amounts of mineral fertilizers will need to be added for the intensive crop production to which these soils appear suited.

Lupu series comprises heavy, black, non-calcareous clays developed in seasonally-waterlogged or flooded depressions in the Black Clays tract. These soils resemble Bumbi soils, but are even heavier and are more strongly leached to greater depths. The major occurrences are found along valleys draining towards the Volta floodplain and along the Jawpa-Dechidaw streams, where they have been mapped separately. The soils are more fully discussed below under Lupu Consociation (Tract 13).

Tepanya series comprises soils in which a shallow layer of black to dark brown sandy loam to sandy clay overlies grey to yellow-brown plastic clay containing abundant ironstone concretions. Some profiles contain patches of lime in the subsoil. The underlying rock, weathered to varying degrees, does not usually occur within 30 inches of the surface. These soils occur in small patches throughout Akuse Consociation, usually on upper slopes, but are more extensively developed in a long belt running parallel with, and approximately one mile to the west of, the Shai Hills.

In a small patch of the soils east of Agomeda, a red clay, hardening on exposure, was encountered below the black clay. On a more detailed survey, this variant would require to be recognized as a distinct series, but because of its small importance it has been included here for convenience.

Except where the black clay layer is deep, these soils absorb water more readily than Akuse soils. Drainage appears to be impeded internally, and the concretionary horizon often remains perennially moist. Where the concretions occur near the ground-surface, the soils become droughty in the upper layers.

The soils in themselves have little agricultural value but have to be taken into account because of their patchy occurrence amongst the more valuable Akuse soils. They are generally less compact than the latter and the concretions brought to the surface during cultivation might further lighten the consistency of the topsoils. They are sufficiently impervious to make irrigation practicable, but difficulties might be expected because these soils would dry out at a different rate from the adjoining Akuse soils, and crops grown would tend to be irregular in growth and yield. The concretions, too, might cause excessive abrasion of tillage implements.

Under natural conditions, the soils are low in nitrogen, potash and phosphorus, and these nutrients would need to be added as fertilizers under continuous cultivation. They are usually slightly acid to neutral in reaction in the upper layers but become moderately alkaline towards the base of the concretionary later.

Kloyo series comprises shallow, dark-coloured, soils found amongst frequent rock outcrops on the steep slopes of rocky hills of garnetiferous hornblende gneiss. Similar soils occurring on more gentle slopes on the plains have been recognized as *Krobo subseries.*

The profile consists mainly of hard, often bouldery, rock with relatively small amounts of soil properly squeezed between the outcrops and in the joints. At the top there is up to a foot of black to dark brown, humous, crumbly and porous loam to light clay containing abundant garnet, hornblende and feldspare sand and, occasionally, small pieces of weathered rock. This may directly overlie fresh rock; but often, dark brown plastic clay or reddish-brown, friable light clay continues for some way down joints.

The soils recognized as *Krobo subseries* are similar in profile form, although often rather more clayey, but occur on more gentle slopes (c.5 per cent) amongst scattered rock outcrops on the Plains. They occur in small patches very occasionally throughout the northern half of the Black Clays belt and in the area between the Shai Hills and Dawhwenya.

Kloyo soils are very well drained externally and moderately well drained internally. Under savannah conditions, they become droughty in the dry season, but under forest on Krobo Hill they appear less so.

The soils on Krobo Hill appear to have been cultivated in former times, but the soils generally occur on slopes too steep to be considered suitable for agriculture today. Soils of Krobo subseries are cultivated to a minor extent and, because of their patchy occurrence amongst Akuse soils, may have to be taken into account in future development. They are more free-draining, and because of their shallowness are less suitable for irrigation and mechanized agriculture. Investigations designed to discover suitable methods of cultivating areas including small patches of these soils should be carried out on the Kpong Irrigation Research Station.

The total amount of soil available for plants to utilize is, of course, smaller than in Akuse series, but this is relatively better supplied with nitrogen, potash and phosphorus. Large amounts of the latter element occur on former settlement sites.

Muete series includes shallow, dark-coloured, sandy clays found in a belt of variable width surrounding the foot of the rocky hills. In profile, the soils consist of up to 18 inches of very dark brown to very dark grey, sandy heavy loam to sandy clay, cracking from the surface when dry. The underlying lirock, garnetiferous hornblende gneiss, is often hard and little weathered, and small linear rock outcrops are common. Profiles may locally contain lime concretions, erratic stones and pottery fragments eroded from remnants of soils with such accumulations upslope. The soils are more porous than Akuse soils, but become very hard when dry.

The soils are subject to surface run-off, but absorb more moisture than Akuse soils. Drainage is slightly impeded internally, but the soils are too shallow and too exposed to retain moisture adequately through the main dry season.

Small amounts of cultivation occur on these soils in the north of the region. Because of the occurrence of hard rock outcrops and their shallow nature they are little suited to mechanized or irrigation agriculture. If developed extensively they would require anti-erosion measures since they occur on slopes of around 5 per cent and already show signs of slight gullying.

Nitrogen, potash and phosphorus are likely to be deficient except near old settlement sites and would have to be added by way of fertilizers if the soils were developed. The profile is generally slightly acid in reaction down to the weathered rock where it becomes alkaline.

Shai series comprises the eroded remnants of former calcareous soils covering parts of the basic gneisses, but confined now to strongly-gullied fragments at the western foot of the Shai Hills and Krobo Hill. They consist, where least eroded, of 2–3 feet of dark brown, crumbly (which often form a continuous layer on the ground-surface), overlying a variable depth of recognizable garnetiferous hornblende gneiss weathered to a reddish-brown to yellow-brown, iron—and manganese-stained, heavy, sandy clay with occasional flecks of lime. Bands of hard, unweathered rock pass through the profile locally and may form small linear outcrops.

The known occurrences of the soils probably amount to no more than an acre or two, and they can accordingly have no possible agricultural value. They will not be discussed further here, therefore.*

Tetedwa series has only been identified on the gentle slopes below the western flanks of the Shai Hills, but it may be expected to occur in similar sites near other rocky hills. The soils consist of up to 3 feet of dark-coloured, porous, sandy clay with thin alluvial layers of lime and ironstone concretions, often pottery fragments, too, underlain by several different layers of plastic, calcareous clay.

The surface layer, 1–3 feet thick, consists of dark brown to very dark grey-brown, porous, sandy clay with thin alluvial bands of yellow-stained, lime concretions, spherical ironstone concretions and, often, pottery fragments; this layer becomes very hard when dry. Below this layer, in soils transitional up-slope to Muete series, hard, little-weathered bedrock (garnetiferous hornblende gneiss) may be reached directly. Typically, however, there are up to three layers of heavy, plastic clay, each layer from 2–4 feet thick and varying in colour from dark grey to pale grey or yellow-grey, some layers containing lime concretions throughout, others only in a narrow horizon at their base.

These soils absorb water more readily than Akuse soils, but still lose a considerable amount by surface run-off. Drainage is impeded in the lower layers, which remain perennially moist. The surface layer dries out thoroughly during the dry seasons; moisture in lower layers is probably not readily available to plants.

The soils are uncultivated at present, but would offer no obstacles to mechanical cultivation, although abrasion of tillage implements in the sandy clay at the surface might be excessive. Except where shallow, they are considered suitable for irrigation.

Nitrogen, potash and particularly phosphorus contents are low. Fertilizers would need to be used for intensive crop production. Locally, unusually large accumulations of phosphorus may occur where there has been former settlement on the site. Lime-status is satisfactory.

Yongwa series is developed in deep alluvial deposits consisting of alternating clay and sand layers which occur in the upper parts of valleys leading from the larger rocky hills.

The surface horizon, 6 inches or so thick, consists of black, humus, very friable, sandy loam to light clay. Below this occur many alternating layers, from a few inches to a few feet thick, of grey plastic clay, dark brown sandy clay and reddish brown loose sand (predominantly garnet). There may very occasionally be alluvial layers of lime concretions or small boulders of rock. Bedrock is only encountered at great depth.

Drainage is normally good, and flooding only seems to occur after exceptionally heavy rainfall. Moisture retention depends on the relative proportions of clay and sand layers, but from the appearance of the natural vegetation it seems likely to be satisfactory. The soils have an excellent natural tilth, suitable both for hand and mechanical cultivation. Except where sandy layers predominate, they would be suitable for irrigation, too.

*Since the close of the survey, the greater expanse of these soils at the foot of the Shai Hills has been removed during the excavation of the quarry in the adjoining hill.

These soils have very favourable nutrient relationships. They have a high content of organic matter, and are well supplied with nitrogen, phosphorus, lime and potash. Since the greater part of these appear to be concentrated in the humus, fertilizers would require to be added for continuous cropping.

Unfortunately for purposes of development, these soils occur only in narrow alluvial strips along a few valley-bottoms and could only be considered for development if adjoining soils were developed, too.

Nyigbenya series comprises red ironstone-concretionary clays with shallow loamy topsoils. Within the present tract, their occurrence is restricted to a few upland areas in the south-east where they are often rather gritty. An occurrence at the southern foot of Bundase Hill contains broken ironpan at a shallow depth. These soils are fully treated above under Nyigbenya-Hacho Complex (Tract 3.)

Bundase series comprises reddish-brown clays developed in ironstained, decomposed (but recognizable) garnetiferous hornblende gneiss. The soils occur rarely on summits of undulations throughout the tract, but in aggregate only amount to a few acres' extent.

The surface horizon consists of about 4 inches of dark brown or dull reddish-brown, crumbly, light clay to clay containing fresh pyroxene crystals and occasionally quartz grit and a few scattered ironstone concretions. Below this, there is 2–3 feet of clayey, highly-weathered rock, dark brown to dark reddish-brown at the top but gradually becoming orange-brown and then yellow-grey in the less highly-weathered zone below. The clay is plastic when moist, but hard and cloddy near the surface and friable below when dry.

These soils are well drained externally and internally, and appear to absorb rainfall fairly readily. They remain moist in the lower layers where deep, but are droughty where shallow in the southern part of the tract. Little cultivation has been observed, and the soils are usually of insufficient extent to have any agricultural value. Hard rock outcrops in some occurrences would render them unsuitable for mechanical cultivation.

They contain little organic matter and are likely to be relatively deficient in all the major nutrients, although well supplied with lime.

Osudoku series includes soils with a shallow, dark grey-brown to black, friable loam or clay topsoil overlying dark brown or brown loam amongst weathering, ironstained boulders of pyroxenite. These soils occupy the steep, bouldery slopes of the discontinuous line of pyroxenite hills extending from east of Krobo Hill in the north to south-west of the Shai Hills in the south. Minor occurrences occur in other places where smaller intrusions of pyroxenite have permeated the garnetiferous hornblende gneiss. The bedrock in these areas is brashy rather than bouldery and there may be a few inches of brown, cracking light clay or clay between the humous topsoil and the weathering rock.

Because of their general occurrence on steep slopes amongst abundant rock outcrops, these soils are unlikely to have any agricultural value, and will not be described more fully. They are very well drained, although not apparently excessively droughty, and are likely to be well-provided with calcium, magnesium and perhaps phosphorus but not other major plant nutrients.

Ashaiman series comprises dark brown to slightly reddish brown, heavy plastic clays of moderate depth containing small amounts of lime concretions in the lower part of the profile and overlying weathering pyroxenite or pyroxene gneiss. They are very patchy in occurrence within this tract, and are usually associated with the minor than the major occurrences of Osudoku soils. Their most extensive occurrence is to the north-east of Ningo Hill where they contain more sand than in the type locality and, in eroded phases, are sometimes calcareous to the surface.

A full description of the soils is given above under Ashaiman Consociation (Tract 8).

VEGETATION

The greater part of the tract occurs under savannah. In the south there are almost no trees, and vegetation consists predominantly of open medium grassland in which *Vetiveria fulvibarbis* is markedly dominant. *Dichrostachys glomerata*, a low acacia-like shrub which is difficult to eradicate once established, appears to be invading this part of the Black Clays belt. Baobab trees and occasional patches of thicket to the south and south-east of the Shai Hills are associated with former settlement sites. Woody vegetation increases in frequency northwards, although the majority of this remains low and stunted. *Vetiveria* remains a common grass, but is mixed with a number of other medium and tall species. Borassus palms occur fairly frequently in the central parts of the tract and are abundant along the minor valley immediately south-west of Krobo Hill.

Forest or thicket fringe the Okwe and lower Dechidaw streams, and occur along some of the streamless valley-bottoms in the north. Elsewhere, valley-bottoms carry close stands of tall *Andropogon* grasses amongst which occur frequent low trees, mainly *Mitragyna inermis.*

The flanks of the rocky hills usually carry medium and tall grassland, with patches of thicket or dry forest in some cases, but the northern and eastern flanks of Krobo Hill carry secondary forest transitional to high forest. Dense coastal thicket occurs at the western foot of Ningo Hill; and well-developed savannah trees surround Osudoku and other villages in this vicinity.

PRESENT LAND-USE

The Black Clays belt is very little utilized at present, but in occurrence of extensive former settlement sites with stone-age cultivation tools in various parts suggests that its soils have been more widely used in the past, although perhaps, even so, probably only by refugees after local inter-tribal wars. Cultivation today is confined mainly to small amounts of subsistence cropping of cassava, okro, maize and small vegetables in the very north of the belt. Yongwa soils are utilized to a small extent to the east of Krobo Hill, and more intensively around Ningo Hill; and Akuse (normal and Prampram subseries); Kloyo (Krobo), Tepanya, Muete and Ashaiman soils are used to a very small extent in the Somanya-Kpong-Akuse triangle and north-east of Ningo Hill.

Methods of production are similar to those in general use for subsistence crops on light-textured red soils near the Akwapim Range to the west, and no attempt is made to improve the structure of heavy Akuse soils by planting crops on mounds, ridges or elevated beds. (It may be noted, however, that old termite-mounds, on these as well as other soils throughout the region, are often selected for cultivation). There are no yields data, but crops generally are of a poor stature and anaemic appearance. Whether the latter is attributable to nitrogen deficiency, to mineral deficiencies induced by the presence of too much lime or to poor soil-moisture relationships and impeded root-development remains to be established.

Although the adjoining savannah-covered soils to the east and the west are extensively grazed, the grassland over the Black Clays belt remains almost untouched. Whether this is due to the absence of water-holes, the predominance of *Vetiveria fulvibarbis*—a grass which cattle appear not to relish—or to some other factor requires to be investigated.

RECOMMENDATIONS REGARDING LAND-USE

The Black Clays of this tract are considered highly suitable for development by mechanized irrigation farming. Similar soils in South Africa are known to be cultivated successfully by this technique, and similar soils in India are still productive after several thousand years of continuous cultivation. It is considered that if irrigation from the Volta dam becomes available, this tract could ultimately, although not necessarily immediately, become the most highly productive in the region and in the country. It is imperative, therefore, that it be developed by the most efficient means practicable.

There exist considerable difficulties in the way of bringing the Black Clays into production, however. There is no inherited local tradition of irrigation, the cultivation of heavy clays nor the maintenance of soil fertility under continuous cropping. Moreover these soils are too heavy for hand-cultivation but will demand the use of heavy machinery; and tillage is likely to be difficult except over a limited range of moisture contents since the soils are too heavy and plastic for this when moist and are very hard and compact when dry. Under the continuous cropping which will be necessary if irrigation is to be economic, and which, in any case, needs to be practised for the full development of the soils' potentialities, the large-scale employment of artificial fertilizers will be essential since the incorporation of large amounts of organic matter—even if it were possible to provide this in sufficient quantity to maintain economic crop-production—would not seem to be desirable on these heavy clays.

Since there is no local experience of irrigation or cultivation on such soils, investigations designed to work out techniques for use on the different soils and slopes which occur and to discover which crops might suitably be grown are required and will be carried out on the Kpong Irrigation Reasarch

Station: recommendations for the course these might follow have been given in the Kpong Pilot Area Report (16). Flood irrigation of rice and perhaps jute and fodder crops would be possible, particularly along valley bottoms; furrow irrigation might be practised on the uplands to produce such crops as sugarcane, cotton, tobacco, cereals, pulses and fodder crops. Land unsuitable either because of shallow soils, rock outcrops or the fact that it is beyond the reach of irrigation, should be used as rough-grazing which, after suitable investigations, it might be possible to improve by such means as re-seeding with more suitable grasses, legumes and herbs, irrigation, surface-tillage or manuring (especially with phosphates). Stock-rearing, and perhaps, ultimately, dairy-farming, would need to be closely integrated with crop production for the most efficient utilization of the soils of this tract.

The impermeability of the soils will demand careful drainage-control measures. Cultivated plot must be protected by interceptor drains from surface run-off from surrounding land, especially in the neighbourhood of the rocky hills. Large drainage channels, perhaps with small dams and weirs, will be required along valley bottoms to control the discharge of streams entering from outside the irrigated areas and to cope with drainage from the cultivated areas themselves. On the latter, drainage ditches or, under flood-irrigation, outlets between paddies, must be ample to deal with storm conditions, especially if the latter arise suddenly at a time when irrigation water is being applied, and must be aligned or protected so that there is no danger of their developing into gullies and inducing soil erosion.

Except under flood-irrigation, cultivation should achieve a great deal in opening up the structure of these soils and thereby reduce water losses by surface run-off. 'Pressure' implements such as mouldboard ploughs should not be used, especially when the soils are wet. Fields should be laid out in a system of cambered beds with deep drains between each bed. Ridges on the beds should be as high as is practicable for the crop being grown. In this way, internal drainage will be improved and the soil will develop and maintain a stable crumb structure giving better aeration and permitting better root development.

When extension from the research station becomes practical, development should proceed not by means of piece-meal *ad hoc* schemes utilizing arbitrarily-determined areas, but systematically, drainage-basin by drainage-basin, within each of which control of both natural and irrigation water can be effected at all times without jeopardizing development in down-stream areas at a later date. Rational land-use demands that all the land should be utilized to its full potentiality. Development should not be concerned solely, therefore, with the extension of irrigation agriculture, but should be planned to bring into use all the soils of a drainage-unit at the same time. In the case of the Black Clays, this largely means utilizing non-irrigable areas for rough-grazing, settlement and the supply of fuelwood.

Before any extensions are made, detailed topographical and soil maps should be prepared to serve as a basis for planning. This will be particularly important in the northern half of the tract where the deeper soils suitable for irrigation farming are frequently broken by patches of shallower soils or rock outcrops. The areas most suitable for large-scale irrigation farming lie in the centre and south of the tract.

If large-scale irrigation from the Volta dam were not to be available, projects such as those recommended by the Rice Mission (17) would need to be reconsidered. These involved the construction of earth dams across valleys over the Black Clays belt itself to provide irrigation for small projects down-valley. Because of the gentle relief, there are few places where this might be practicable, both because of the length of the earthwork required and the shallowness of the reservoir impounded with consequent excessive evaporation losses. The Rice Mission favoured investigations in the Apasokope area east of Krobo Hill in the north of the belt. If such a scheme was considered practicable, crops and methods found suitable at Kpong could be introduced.*

Such projects could only have a limited applicability. Valley bottoms over the remainder of the belt, however, might be utilized for cultivation by making more effective use of flood water. This might be achieved by erecting low bunds at intervals across the smaller valley bottoms, but such control might not be necessary over the broader depressions leading to the Volta floodplain. Where bunds were constructed, outlets from one level to the next would need reinforcing to avoid the danger of wash-outs

*A site for such a scheme was selected and investigated in the Dechidaw valley near Dawhwenya in 1959. See Evans and Swinson (1959). Construction works began in April, 1960.

during heavy rainfall. The development of these valley bottoms would be particularly useful for fodder-production to supply dry-season feed to stock. It would need to be carried out by large-scale mechanical methods.

Yongwa soils would make excellent soils for vegetable production if they could be protected from flooding. Where not developable in this way, they might be planted to fruit trees: mango, orange, pawpaw, guava, custard apple, sweet and sour sops would be worth trial.

The large areas unaffected by such local valley-bottom schemes would need to be developed for rough-grazing. Investigations are required to discover why the Black Clay. are so little grazed at present: whether it is due to the poor quality of the grazing because of the predominance of *Vetiveria fulvibarbis;* the lack of waterholes; the tussocky surface of the soils; or some other factor. Water-holes for man and stock might need to be bitumen-lined because, from observations in road-side borrow-pits, it appears that the underlying weathered rock is pervious.

Investigations are required on the Kpong Irrigation Research Station to discover whether it might be possible to produce crops on the black clays without the aid of irrigation. Heavy machinery would need to be used for initial development, but lighter equipment might be used subsequently so long as the soils were kept well drained.

Measures which might be effective in making better use of the rainfall would include contour-furrowing or strip-cultivation and the cultivation of such drought-resistant crops as dwarf sorghums, millet and finger millet. In the extreme north, it might be possible to grow sugarcane; and maize and okro might be grown in the first rainy season. The soils would benefit from occasional periods under deep-rooting leguminous crops. These might simply be cover crops such as pigeon pea, or might have a secondary value as fodder, pasture or use in the human diet. The rainfall in the southern half of the belt is probably both too low and too unreliable to make dry farming possible.

The rocky hills can have no useful form of land-use, except to provide building-stone. Settlement is not recommended at the immediate foot of these hills because of the danger of blocks of rock occasionally rolling down the slopes. The baboons and monkeys, and perhaps hyaenas, too, which inhabit some of the hills will need to be exterminated to prevent their depredations on crops and stock.

Road-construction is particularly difficult over the Black Clays because of the manner in which these soils shrink and crack on drying and swell—causing heaving—on wetting. Unsurfaced roads are not practical, unless their use can be rigidly restricted to dry periods: the soils are highly plastic when moist and would not support wheeled vehicles in this condition or would become so deeply rutted along the wheel tracts as to be unusable later when dry. For roads not carrying heavy traffic, it is desirable to dig out the soil to a depth of a foot or more and replace it with a layer of coarse stones covered with a non-plastic surface layer. Ample drains, preferably at least 2–3 feet deep, should be provided along both sides of the road.

For major roads, experience in other countries where Black Clays occur indicates that it is necessary to remove the clay completely down to bedrock, or at least down to 3 feet, and replace it with inert material. Deep drains along both sides of the road are again essential. Because of the high percentage run-off experienced over the Black Clays, large culverts are required to take drainage water under roads. Where possible, roads should be aligned along sumits of spurs to take advantage of better drainage.

There is a great shortage of road-building materials in this tract. There is ample rock available in the inselbergs for quarrying and crushing for foundation material, but the rock is very hard and the cost of working it may be expected to be high. Togo quartzite schist is available in a number of places near the western boundary of the tract. There are no suitable supplies of 'laterite' gravel within the tract. The gravel in Tepanya soils could only be used if separated from its plastic clay matrix. The nearest supplies of suitable material are in Nyigbenya Consociation in Tract 8 and, in the north, in Oyarifa-Mamfe Complex (Tract 2). Supplies for the eastern half of the tract are confined to very minor, and quite inadequate, deposits in Nyigbenya series occurring within Nyigbenya-Agawtaw Complex. (Tract 12).

Agawtaw Consociation

General

This consociation occurs immediately to the east of the Black Clays belt and consists predominantly of *Agawtaw* soils—grey-brown, impervious clays, calcareous at depth—developed on very gentle, savannah-covered relief over Dahomeyan acidic gneisses and schists. These soils extend into Doyum-Agawtaw Association in the centre, into Toje-Agawtaw Association in the south and into Nyigbenya-Agawtaw Complex in the south-west of the tract, where they occur, however, in association with other major soils. As mapped, the consociation covers approximately 130 square miles (c.83,000 acres).

Mean annual rainfall over the tract increases from 30 inches or less in the south to 35–40 inches in the north, but totals vary considerably from year to year. There are no permanent streams; stream channels are, in fact, often discontinuous. Drainage from the upland areas is entirely by surface run-off, and water flows along valley-bottoms only for a few hours immediately after storms. The discontinuous stream channels provide water-holes which often retain supplies throughout the dry seasons.

SOILS

Besides Agawtaw series, the mapping unit includes relatively minor occurrences of a number of other soils. These are described, after Agawtaw series, in the following order:—

1. *Agawtaw series*
2. *Minya series*
3. *Lota series*
4. *Doyum series*
5. *Simpa series*
6. *Hawpa series*
7. *Dawsi series*
8. *Bumbi series*
9. *Tachem series*

Agawtaw series consists of grey-brown soils, loamy for 6–12 inches at the surface then abruptly changing to an impervious clay which contains lime concretions below a depth of about 2 feet. The uppermost 9–12 inches of the subsoil is very compact and cracks vertically into 6-sided blocks when dry. This layer is referred to below as the hardpan. The base of the profile usually occurs at 3–4 feet and is marked by a thin line of small ironstone concretions and quartz gravel overlying weathered gneiss or schist which often contains large lime concretions. The soils generally occupy the whole of the very gentle topography from summits to bottoms.

The soils vary from place to place in colour and texture. The silty and fine-sandy soils are more extensive and are usually pale grey or pale grey-brown above and below the hardpan. The medium-sandy soils, more common in the south, are usually pale-brown near the surface and pale brown to yellow-brown below the hardpan. Eroded phases, in which the hardpan occurs at or within an inch or two of the surface, occur locally on the uplands.

The loamy topsoils are capable of absorbing water to a certain extent, but the subsoil is highly impervious, and under natural conditions a considerable amount of rain-water is lost by surface run-off. The topsoils rapidly become droughty during the dry seasons. Moisture retained in lower horizons appears not to be available to plants; in fact, the lower part of the profile often appears to be permanently dry.

The cultivation characteristics of these soils are completely unknown locally at present. Soils with hardpan subsoils elsewhere in the world are recognized as difficult agricultural soils and rarely support a high level of crop production. If they are to be developed locally, it would seem essential to break up the hardpan layer by deep knifing; this would require the use of heavy tractors. A system of field drains might be necessary, too, to improve internal drainage and encourage the leaching of sodium from the hardpan layer; otherwise, the hardpan might be expected to re-form and the value of subsoil tillage, an expensive operation, be lost. Soils such as these are highly susceptible to erosion when cleared and care will need to be taken with field layouts and furrow alignment; the use of cambered beds suggests itself for investigation in this respect. Numerous, very compact, old termite-mounds, often carrying a clump of trees, would require to be cleared initially.

The present nutrient status of the soils is low. They contain very little organic matter and nitrogen and especially phosphorus contents are very low. The potash content is moderate, and calcium and magnesium are plentifully supplied in the lower horizons. The topsoil and hardpan layers are usually slightly acid in reaction, but lower layers are moderately alkaline and contain appreciable amounts of salt.

Phosphatic and nitrogenous fertilizers will be required for successful crop production. They would be expected to improve pasture production, too. The soils would benefit from the addition of organic matter; kraal manure is available in large amounts in this tract and should be made use of.

Under irrigation, deep drains would require to be provided to control the level of salts in the profile. Properly handled, there need be no risk of these soils becoming salinized to the surface under any form of land-use.

Minya series includes soils with similar grey-brown, loamy topsoils to those of Agawtaw series but with a subsoil consisting of a variable thickness of grey or brown, often mottled, plastic clay containing very abundant small, spherical, ironstone concretions. The underlying acidic gneiss on schist is usually highly weathered but not ironstained. Lime concretions are occasionally found in the lower layers or in the weathered rock. These soils occur patchily amongst Agawtaw soils, usually on upper slopes, but are of very minor importance.

A slightly fuller description of this series is given above under Simpa-Agawtaw Complex (Tract 8).

Lota series comprises grey-brown to yellow-grey gritty loams, or perhaps sometimes clay, developed among stones and boulders of weathering granite or gneiss on, or at the foot of, the very rare rock outcrops which may possibly occur in this tract. They are of insufficient importance to warrant further discussion.

Doyum series, in the present tract, comprises soils with 2–3 feet of pale brown to pale yellow-brown, medium to coarse sand overlying 1–2 feet of similar-coloured, but weakly mottled, compact, sandy loam to sandy clay including a thin layer of gravel at the base resting on slightly to moderately-weathered granite or coarse-grained gneiss. The major areas of these soils have been mapped, and fully described, within the eastern area of Doyum-Agawtaw Association (Tract 7). The occurrences within the present tract are confined to a few small outliers on summits of undulations to the west of this association.

Simpa series consists of soils with a variable, but usually shallow, layer of pale brown or pale grey-brown, medium or fine sand overlying 1–2 feet of ironstained quartz stones and gravel in a matrix of brown or grey-brown, often mottled, sandy loam to clay and then weathered acidic soils, mainly in the extreme south-west of the tract, but are of small importance in this tract.

A full description of the series is given above under Simpa-Agawtaw Complex (Tract 6).

Hwapa series comprises soils with a few inches of dark grey, sandy topsoil overlying a dark grey, very compact, sandy clay subsoil cracking vertically into large 6-sided blocks; at 1–2 feet, this grades into several feet of mid-grey, cloddy, plastic, sandy clay containing small amounts of lime concretions and sometimes lenses of sand. The soils occur in narrow, discontinuous strips along valley bottoms in association with Agawtaw soils, from which they differ in their darker colour, the greater size of the structural units in the compact subsoil and, usually, in their greater total depth.

Rainfall is supplemented by surface run-off from adjoining Agawtaw soils, and flooding or water-logging may occur for a few hours after heavy rainfall. Internal drainage is impeded by the hardpan layer. Water-holes retain water well, although the soils themselves do not possess a water-table and dry out rather deeply during dry periods.

The soils are uncultivated at present, and their development by mechanized irrigation agriculture must depend on the development of the adjoining Agawtaw soils because of their patchy mode of occurrence. The cultivation problems to be faced are likely to be similar to those needing investigation in Agawtaw series. Sodium salts occur in the lower layers and their level will need to be controlled by ensuring adequate drainage. Termite-mounds in these soils are of exceptional volume, and the soils frequently carry a fringe of woodland along stream channels: these would require clearing if the soils are developed.

Hwapa soils contain little organic matter, nitrogen and phosphorus. The potash status may be satisfactory. The topsoil and hardpan layers are slightly to moderately acid in reaction but lower layers are usually moderately alkaline. For successful crop production it would be essential to add phosphatic and nitrogenous fertilizers, and it would be desirable to build up the organic matter status of the soils. Phosphatic and nitrogenous fertilizers might be expected to improve pasture production.

Dawsi series locally displaces Hwapa series along valley bottoms, but appears to be of very small importance. The soils consist of a few inches of grey-brown, slightly humous, very compact clay (sometimes pulverized to a powder by cattle-trampling) overlying pale grey, very compact clay with frequent manganese concretions; below a depth of approximately 5 feet, the clay contains increasing amounts of white feldspar grit and is faintly ironstained; highly-weathered acidic gneiss eventually becomes recognizable at depths greater than 8 feet. Small, spherical iron stone concretions and quartz gravel are frequently found scattered over the ground-surface but none occurs in the profile. Lime concretions have not been recorded, but they might be expected to occur locally.

These soils are highly impervious, and, although they may be flooded during and immediately after rainfall, they appear to absorb little water and have been seen to be dry throughout during the main dry season. No cultivation is found at present. They are suitable for development by mechanized irrigation farming if flooding can be controlled, but they are of insufficient extent to be developed without the simultaneous development of adjoining Agawtaw soils. Internal drainage would need to be improved so as to encourage the development of a more suitable structure for root-development. Cambered beds would be useful in this respect. Drainage is necessary to control the level of salts which appear to be present in appreciable amounts in the lower layers.

The soils contain only low amounts of organic matter under present conditions and appear to be deficient in nitrogen and phosphorus. These would need to be added if the soils were cropped. Potash may be present in plentiful amounts. The profile is neutral to slightly alkaline in reaction throughout.

Bumbi series has only been found developed within this tract in a small, poorly-drained, lowland area along the Sege valley approximately two miles north of the Accra-Lagos road at Mile Post 47. Here the soils consist of black, cloddy, plastic clay gradually becoming olive-brown with depth, and cracking widely from the surface into large tussocky blocks when dry. Lime concretions occur below a depth of about 30 inches.

A detailed description of this series is given above under Akuse Consociation (Tract 9).

Tachem series appears only to be locally developed within this tract along part of the Sege valley near and to the south of the occurrence of Bumbi soils noted immediately above. The soils consist of 6 inches or so of black, humous, plastic clay overlying a foot or so of brown plastic clay and then a great depth of grey, strongly mottled red, plastic clay. They crack widely from the surface when dry. A thin layer of lime concretions was seen in the lower part of one profile, but the soils are normally moderately acid throughout.

These soils are more fully discussed below under Tachem Consociation (Tract 13).

VEGETATION

The characteristic vegetation over this tract is open short-grassland with widely scattered clumps of thicket or trees, often associated with old termite-mounds. The discontinuous stream channels are fringed with thicket or low woodland. Medium and tall grassland occurs over some of the lighter-textured upland soils in the south-west and along some streamless valley bottoms. Settlements are protected from grass fires by a low thicket of evergreen vegetation, and cactus or sisal fences are used to surround cattle kraals and cultivated land.

PRESENT LAND-USE

The small areas of lighter-textured upland soils in the south-west are under land-rotation cultivation with savannah regrowth. Farms are small and widely scattered, and serve only for subsistence cropping. Cassava (red-skinned variety) is the main crop planted, but groundnuts (and/or Bambara beans), okro and vegetables are occasionally seen, all grown on the flat in pure stands. The quality of the crops appears low.

Old cattle kraals around some herding settlements on Agawtaw series are under semi-permanent cultivation. Crops may apparently be grown continuously for up to 8–10 years before yields become so low (or weed infestation so bad?) that the plot has to be abandoned. It may then be used as a kraal again for 3–4 years before being cropped once more. Cassava, groundnuts, Bambara beans, tomatoes and maize are the usual crops grown, but small amounts of sorghum have also been recorded. There are no yields data, but crops seen have appeared poor.

The major form of land-use over the tract is cattle-grazing. Agawtaw soils provide the major grazing soils in the region, although the grazing is only satisfactory by present local standards. Water-holes appear usually to retain water satisfactorily through normal dry seasons; but the grasses become parched and woody at such times and can be of little nutritional value to the stock. Burning is practised seasonally to stimulate fresh growth. Some areas around herding settlements and water-holes appear to have become over-grazed.

RECOMMENDATIONS REGARDING LAND-USE

The soils of Agawtaw series provide even more of a problem for agricultural development than the Black Clays. In this case it is due to the presence of the clay hardpan in the subsoil which impedes drainage and root-development. The soils occur extensively on very gentle topography, however, and if suitable methods of cultivating the soils can be worked out, they would appear well suited to development by mechanized irrigation agriculture. The investigations which are required before any development can proceed could suitably be carried out on the research station recommended for similar soils in Tract 8.

If irrigation from the Volta dam becomes available, and investigations show that the soils can economically be cultivated, they would require to be developed by large-scale methods. The crops suitable and methods required can only be determined by experiment. Close control of drainage will be required, and a close system of field drains may be needed to encourage improved internal drainage and the leaching of sodium from the upper subsoil and salts from lower layers.

If irrigation from the Volta dam is not available, it is unlikely that small-scale dams could generally be provided because of the gently configuration of the valleys. Control of flood-water along valley bottoms, however, might make fodder-production possible, but the areas available are generally less extensive than over the Black Clays. Investigations are required to discover whether dry-land farming of the soils would be practicable on the upland sites, but the possibility that this might be successful is not accounted very great.

No matter whether irrigation becomes practicable or not, cattle herding is for long likely to remain the major form of land-use over this tract. The major improvement required is in methods of husbandry. Investigations are required to discover methods of improving the present rough-grazing and how best artificial pastures might be provided. The small areas of lighter soils within the tract could only be developed for rough-grazing.

TRACT 11

General

This tract has been mapped to include the major occurrences of Toje soils—deep, red, non-concretionary loams developed in the Tertiary sediments. Where possible, as along the coast between Nungua and Kpone, and to the north of Songaw lagoon, these soils have been mapped separately as *Toje Consociation*. Elsewhere, between Prampram and Toje (Mile 62½, Accra-Lagos road), these soils occur more or less patchily on uplands amongst Agawtaw soils—grey-brown soils with a sandy topsoil overlying compact, impervious clay developed over Dahomeyan acidic gneisses and schist—which cover remainder of the topography: *Toje-Agawtaw Association* has been mapped here. A minor upland area of red ironstone concretionary clays has been mapped separately as *Nyigbenya Consociation*. The tract as mapped covers an area of approximately 125 square miles (80,000 acres).

The tract occupies gently-undulating, savannah covered topography at 0-250 feet, with Tertiary sediments generally forming the upland areas and acidic gneisses and schists underlying the middle and lower slopes. The mean annual rainfall is around 30 inches throughout and is everywhere unreliable in occurrence, especially in the second rainy season.

SOILS

Since the various soils developed in the Tertiary sediments are common to both the major associations, it will avoid repetition if soil series descriptions are given for the tract as a whole after the disposition of the series within the mapping units has been explained.

Toje Consociation

This consociation covers approximately 16 square miles in the largest occurrence near the junction of the Accra-Lagos and Accra-Ada roads, and there are numerous detached occurrences to the west as far as Nungua. As mapped, the whole consociation occupies approximately 30 square miles (c.19,000 acres).

The greater part of the consociation consists of deep, red, non-concretionary loams of *Toje series;* but locally, around the edges of these soils, there are yellow loams of *Koloidaw series* and very pale grey to white sands of *Agbozome series,* the latter only on lower slopes on the sea-ward side of the unit in the east. One or two narrow depressions in the main area of Tertiary deposits are underlain by what appear to be old lagoon clays in which grey-brown, plastic, calcareous clays of *Alajo series* have developed.

Toje-Agawtaw Association

This association consists of red *Toje* soils and, to a lesser extent, yellow *Koloidaw* soils developed over Tertiary deposits on the uplands; and grey-brown, impervious clays of *Agawtaw series,* together with minor occurrences of *Minya, Koni, Kenya* and Hawpa soils, developed over acidic gneisses, schists and intrusive granites on the middle and lower slopes. In the coastal areas in the vicinity of Prampram and Old Nungo, pale-coloured sands of a subseries of *Agbozome series* are developed in what appear to be marine-terrace deposits. This association covers approximately 95 square miles (60,800 acres).

Nyigbenya Consociation

This consociation covers an area of less than one square mile on the summit of a ridge near mile 44½ on the Accra-Lagos road and consists of a number of detached occurrences of red, concretionary clays of *Nyigbenya series.*

The soils of these mapping units are described below in the following order:—

1. *Toje series*
2. *Koloidaw series*
3. *Agbozome series*
4. *Nyigbenya series*
6. *Minya series*
7. *Koni series*
8. *Kenya series*
9. *Hwapa series*
10. *Alajo series*

Toje series comprises deep, very well-drained, red, friable, sandy loams to sandy clays developed in the Tertiary deposits. This soil covers almost the whole of the areas mapped as Toje Consociation as well as the upland areas in Toje-Agawtaw Association.

Toje soils absorb moisture freely except when left bare. Under the prevailing climatic conditions they tend to be droughty in the topsoil but lower layers have a good moisture storage capacity.

These soils are widely favoured for cultivation at present because they are easy to handle. Mechanical cultivation would be easy, too, although numerous termite-mounds would require to be dispersed before this technique could be introduced. Without ample amounts of organic matter in the soils, the topsoils soon lose their tilth during cultivation. Compact layers similar to 'plough pans' have been seen developed in the lower topsoils of some heavily cultivated soils. The turning in of frequent cover crops or the addition of farmyard manure will be essential if intensified crop production is to be maintained.

The nutrient status is very low, except on old settlement sites. Almost the whole nutrient supply is contained in organic matter, only small amounts of which accumulate under the present fallow vegetation. Nitrogen, potash and phosphorus are all likely to be deficient. Small amounts of lime, probably associated with old termite-mounds, occur in small profiles, but the soils are normally near-neutral in reaction in the topsoil becoming moderately acid below.

Koloidaw series includes pale orange-brown to brownish yellow, sandy loams, becoming more clayey and often rather mottled with depth, and sometimes overlying weathered gneiss within 6 feet of the ground-surface. The soils are found on two different topographical sites: on occasional upper slopes within Toje-Agawtaw Association they are developed in shallow Tertiary deposits and may contain a gravel and concretion layer at a depth of 4-5 feet overlying thoroughly-weathered gneiss; on lower slopes in the main area of Tertiary deposits they are deeper and may become more compact and clayey in the lower horizons. Seepage ironpan was encountered at depth in one lower-slope profile.

The soils are free-draining in the upper horizons, but drainage is slightly impeded in the lower horizons of both upland and lowland soils. The topsoils become droughty during dry periods; they appear to be more droughty than in Toje soils. In the lower-slope soils at least, there is probably satisfactory retention of moisture in lower layers through normal dry periods. The handling characteristics of these soils differ little from those discussed for Toje soils. Their nutrient status appears to be similarly low, but may be slightly better where weathering rock occurs within root-range. They are generally near-neutral in reaction near the surface becoming slightly to moderately acid with depth.

Agbozome series, where normally developed, consists of 6 feet or more of loose, medium-grained sand the colour of which changes from mid-grey or grey-brown at the surface to pale grey to white below a depth of 2 feet; lower layers may be firmer and slightly clayey, with weak orange and black stains. These soils occur in a narrow belt along the lower-slopes of the more easterly occurrences of the Tertiary deposits where these border the flats to the north of Songaw lagoon and to the west of the lower Volta.

In soils recognized as *Goi subseries*, the sand is pale yellow-brown in colour and is underlain at 30–60 inches by yellow, or yellow-brown, sandy clay which is usually faintly stained orange but may be more strongly mottled orange and black locally. At the base of this horizon, a shallow layer of pebbles may be found overlying highly-weathered acidic gneiss. Within the present tract, these soils are developed along a narrow level strip behind the coast in the Prampram-Ningo areas.

The normal soils are excessively well drained and droughty throughout. The soils of Goi subseries appear to contain a seasonal water-table in, and immediately above, the clay layer; this may be slightly saline. These soils are easily hand-cultivated and permit great proliferation of roots, but they are too droughty to support annual crops satisfactorily.

Their nutrient status is amongst the lowest in the region. They contain exceptionally low amounts of organic matter and have a very low capacity to hold nutrients. Nitrogen, potash and phosphorus contents are very low. The normal soils are generally slightly to moderately acid in reaction throughout, but soils of Goi subseries become slightly to moderately alkaline in the clay layer.

Nyigbenya series occupies the whole of the small upland area mapped as Nyigbenya Consociation. The soils consist of a shallow, reddish brown, loamy topsoil overlying several feet of red, ironstone-concretionary clay before ironstained, thoroughly weathered acidic gneiss is reached. The concretionary layer has become cemented to form ironpan in some places, especially around the edges of the occurences where bouldery outcrops frequently occur.

A full description of the series is given above under Nyigbenya-Hacho Complex (Tract 3).

Agawtaw series consists of grey-brown or pale brown soils with a sandy topsoil overlying a compact sandy clay subsoil which contains lime concretions below a depth of about 2 feet. They are developed extensively on middle and lower slopes within Toje-Agawtaw Association over acidic gneisses and schists. The soils are externally well-drained, but suffer from impeded internal drainage above the compact subsoil. They are continuous in extent with Agawtaw soils in the neighbouring Agawtaw Consociation (Tract 10) under which heading a full description of the series will be found.

Minya series consists of soils with a thin, grey-brown, loamy topsoil underlain by a variable thickness of grey or brown, often mottled, plastic clay containing very abundant, small, ironstone concretions. The underlying acidic gneiss or schist is usually highly weathered but not ironstained. Lime concretions are occasionally found in the lower layers or in the weathered rock. These soils occur very patchily amongst Agawtaw soils, usually near their upper-slope limit.

A slightly fuller description of this minor series is given above under Simpa-Agawtaw Complex (Tract 8).

Koni series comprises reddish-brown, compact, gritty clays overlying little-weathered, but not iron-stained, granite at depths of 5 feet or more. These soils have only been recorded within the present tract on the summit of a low ridge immediately to the north-east of Dawa. (The higher parts of this ridge to the north are covered with Toje soils. Koni soils differ visibly from these in being gritty, micaceous, more clayey and more compact.

A full description of the series is given above under Doyum-Agawtaw Association, eastern area (Tract 7). *Hwapa series* comprises dark grey, very compact, sandy clays which have a thin topsoil and become slightly calcareous at depth. They occur discontinuously along drainage grooves and valley bottoms in Toje-Agawtaw Association: (Agawtaw soils frequently occupy the whole of the valley bottom as well as the slopes).

A full description of this minor series is given above under Agawtaw Consociation (Tract 10).

Alajo series includes grey-brown, weakly mottled orange, heavy, plastic clays containing lime concretions at a moderate depth. Within the present tract, they occur as valley-bottom soils in the few narrow depressions penetrating the main area of Toje soils in the east. They differ from the soils occurring in the west of the region in that they may be more or less sandy in their topsoils due to slopewash from the adjoining Toje-Koloidaw soils; and in the lower courses of the valleys draining southwards they may be underlain by sand at 4–6 feet.

A full description of the series is given above under Alajo Consociation (Tract 4).

VEGETATION

The whole of the tract occurs under savannah. On the lighter-textured, upland soils this consists of medium and tall grassland regrowth. This includes scattered bushes in the west, but in the main of Toje soils in the east and over Nyigbenya Consociation there are closely-spaced linear clumps of coastal thicket aligned north-west to south-west. Mango trees are very common on all the upland soils.

Over the heavier lowland soils, there is short grassland with widely-scattered clumps of thicket or small trees, usually on old termite-mounds. Fringing thicket or woodland occur in narrow strips along the discontinuous stream channels. Medium swamp-grassland covers some areas of Alajo soils.

PRESENT LAND-USE

Where the Tertiary deposits form a discontinuous line of hills immediately behind the coast between Nungua and Ningo, they are used mainly as settlement sites by fishing communities. These villages are surrounded by plots of impoverished cassava, vegetables and gourds on the exposed and exhausted soils.

Further east, the light-textured soils are everywhere under land-rotation cultivation with savannah and wind-aligned thicket regrowth. Farming is particularly intensive on Toje soils in the neighbourhood of Tamatuku junction and fallow periods are brief. Cassava (red-skinned) is the major crop grown, but there are minor amounts of maize, vegetables, okro and groundnuts (or Bambara beans). Crops are mainly planted in the first, and more reliable, rainy season, but small amounts are planted at the beginning of the second rains, too. They are usually grown on the flat at the usual spacing of approximately 3 x 3 feet; but occasionally, usually towards the lower slopes, crops have been seen planted on slightly-raised beds, approximately 20 x 6 feet in size, running roughly along the contour. In cattle-grazing areas, cultivable land is usually surrounded by a live fence of cactus or sisal.

There are no yields data, but from the general appearance of the crops their yields would appear to be low. Cassava, in particular, appears to suffer greatly from exposure to the constant sea-breeze, and during the dry seasons its foliage is reduced to a few, small, yellowed leaves at the top of a short spindly stem. The maize seen has been of stunted appearance.

The lowland areas of Toje-Agawtaw Association, and, to a lesser extent, some of the upland areas, too, are used as grazing-land in a similar manner to that described for the adjoining Agawtaw Consociation (Tract 10).

RECOMMENDATION REGARDING LAND-USE

This tract lies remote from the Volta dam site and is consequently not likely to be included within development schemes requiring irrigation water from this source for a considerable period. Toje and, to a lesser extent, Koloidaw soils would respond very well to irrigation, however, and it might at some future date become economic to provide irrigation to the main areas of these soils north of Songaw lagoon either from the proposed main irrigation canal or by pumping water direct from the Volta or its creeks immediately to the north and east of the area. Suitable sites for small dams from which these soils might be irrigated do not appear to exist in or near the tract. Any water obtained from boreholes in the Tertiary sediments would likely be too saline for use in irrigation.

Because of their free-draining nature, consumption of irrigation water on Toje and Koloidaw soils would be high. Overhead irrigation might be more suitable than furrow irrigation. Crops that might be grown include maize, pulses of various kinds, tomatoes and other vegetables. Trials might be made with cotton, tobacco,* pineapples, citrus, pawpaw and various fodder crops.

Without the aid of irrigation, the aim of improving agriculture on Toje and Koloidaw soils must be to build up their fertility and to cultivate drought-tolerant crops. The selection by plant-breeders of varieties of sorghum and millet suitable for the Accra Plains environment would be of particular benefit to farmers on these soils. Finger millet might also be tried. Cassava, Bambara beans, cucurbits and certain pulses are also suitable. Mangoes, cashew and guava are suitable fruit trees.

In cultivating these soils, whether with the aid of irrigation or not, it will be essential to increase their organic matter content. Kraal manure is readily available locally and should be used to its full extent. Frequent fallows under deep-rooting cover crops such as pigeon pea will be desirable where kraal manure is not used. Alternatively, grass-legume leys might be planted for grazing or fodder production if mixed farming develops and would also serve to build up the soil organic matter. For maximum crop production, mineral fertilizers will also need to be used: nitrogen and phosphorus appear to be the major deficiencies, but potash may need to be added for certain crops.

In both hand and mechanical cultivation, contour field layouts should be adopted. The aim should be to protect the soil surface as far as possible against direct exposure to sun, wind and rain. In hand cultivation, this is best done by planting a mixture of crops, one of which should be procumbent or scrambling: Bambara beans, various other legumes and cucurbits are suitable for this purpose. In mechanical cultivation, much could be applied, particularly along the furrows, or trash-farming methods adopted.

Toje-Koloidaw soils would be very suitable for development under mixed farming. These soils, it may be noted, could easily be ploughed by bullocks. Planted grass-legume leys, as indicated above, would help restore soil fertility after cropping. Pasture and fodder plants suited to the conditions need to be investigated:† it may be noted that guinea grass, a valuable fodder grass, is common in the regrowth vegetation on these soils. Manure from the animals could be put back into the cultivated soils. The livestock might include sheep, goats and pigs, as well as cattle. Additional rough-grazing for the grazing animals would be available on the adjoining Agawtaw, Alajo, Ada and Songaw soils (some of which occur in adjacent tracts).

It might be possible to provide water-holes for these stock on the adjoining clay bottom soils amongst and to the north of the Tertiary sediments, but water in excavations south of the Accra-Ada road might be expected to be too saline for use. Over the main occurrence of Toje soils it will ultimately be necessary to provide a pumped water supply from the Volta or one of its creeks.

Agbozome soils might be suitable for intensive vegetable production if irrigation facilities were provided for the adjoining Toje-Koloidaw soils. They would need heavy manuring for this purpose; some of this manure should be in the form of organic matter. Without irrigation, these soils are only suitable for low-level subsistence cropping with cassava, Bambara beans, cucurbits and tiger nuts. Mango trees appear to grow satisfactorily on these soils but would not be suitable on those of Goi subseries. Coconut palms may grow satisfactorily for a number of years on these soils, but losses are liable to occur in years of exceptional drought. They would benefit from mulching.

Nyigbenya soils in this tract have little value except to provide well-drained settlement sites and a source of road gravel in an area deficient in such materials.

The lowland clays of Agawtaw, Hwapa and Alajo series would need to be developed by similar methods to those outlined for Tract 10. More water-holes need to be provided in these valley bottoms to supply man and stock.

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*Tobacco should not be grown within a distance of about five miles inland from the coast because of the risk to chlorides in salt spray blown inland on the sea-breeze affecting the curing quality of the leaf.

†These investigations could conveniently be carried out at Ohawu Agricultural Station on the Ho-Keta Plains where the soils are similar but the climate slightly more humid.

It would be desirable in this tract to reduce the desiccating effect of the daily sea-breeze on plants by planting wind-breaks at intervals inland from the coast. This would be particularly desirable in any areas developed by means of irrigation. Near the coast, it might be necessary to plant hedges round individual fields. Further inland, it might be possible to include fruit trees—such as mango, akee apple (*Blighia sapida*), cashew and guava—in the wind-breaks. There is a shortage of fuelwood in this tract, and the possibility of planting and utilizing fuelwood plantations in such a way that they also serve as wind-breaks needs to be examined. *Cassia* and *nim* would suit the conditions.

Road-construction in this tract is handicapped by the general shortage of foundation and surfacing material. The only source of 'laterite' gravel are in Nyigbenya Consociation at Mile 44½ on the Accra-Lagos road; equivalent material is obtainable from quarries in the Tertiary basal pebble-bed near mile 62 on this road, and it might be possible to trace this deposit further west along the northern edge of the Tertiary sediments. The nearest source of rock for foundations is in Doyum-Agawtaw Association (Tract 7), some 6 miles north of Sege (mile 47½, Accra-Lagos road).

Toje soils are quite suitable for the building of unsurfaced roads. Such roads are slippery when wet, however, and from deep ruts under these conditions. Their use should be restricted during and for a few hours following heavy rainfall, therefore. Alignment along summits, provisions of side-drains, cambering the road-surface and frequent grading should minimize the length of time roads need to be closed. Koloidaw and Agbozome soils are less suitable, often becoming loose and incoherent to a depth of a foot or more when dry. Agawtaw soils provide a firm surface when dry, but are sticky when wet.

For major roads, Toje soils again provide no special problems. Koloidaw and Agbozome soils again provide difficulties, however, and should be avoided where possible. Where this cannot be done it may be necessary to excavate the loose sandy surface layer to a depth of 18 inches or more and replace it with inert red earth: subsoils of Toje soils might be suitable for this purpose if properly compacted and kept well-drained.

Recommendations in respect of road-construction over Agawtaw soils have been given for these soils in Tract 10 and should be referred to if required. Alajo soils should be treated in the same manner as Agawtaw soils occurring in depressions.

TRACT 12

Nyigbenya-Agawtaw Complex:

General

The boundary between the basic and acidic Dahomeyan rocks in the south-east of the Black Clays belt appears to be diffuse. Although on a more detailed survey it might be practicable to delineate the boundary more accurately, this has not been possible on the scale of the present survey and the soils developed within this zone have been mapped as a complex. In all, the three areas so mapped cover approximately 20 square miles (12,800 acres).

The tract covers gently-undulating relief drained by surface run-off to valley-bottoms which are usually streamless. The summits of the major undulations carry red, ironstone concretionary clays of *Nyigbenya series*, and the upper parts of lower undulations sometimes carry black or grey-brown, ironstone-concretionary clays of *Tepanya* and *Minya series* respectively. Over the greater part of the tract, grey-brown, impervious clays of Agawtaw are developed, together with small areas of pale-coloured sandy and gravelly soils of *Simpa series*. Black calcareous clays of *Akuse series* appear to be confined to valley-bottoms on the north-western flanks of the two larger units of the complex: they have been mapped separately to the south.

The mean annual rainfall is around 30 inches, but is characteristically variable and unreliable. Almost the whole of the area occurs under savannah vegetations, but there are patches of thicket locally on the higher summits.

SIOLS

The component soils of this complex have all been described above under other associations. They will only be briefly treated below, therefore, and in the following order:—

1. *Nyigbenya series.*
2. *Tepanya series*
3. *Minya series*
4. *Agawtaw series*
5. *Simpa series*
6. *Akuse series*

Nyigbenya series comprises red sandy (or gritty) clays containing very abundant, spherical, iron, stone concretions and variable amounts of quartz gravel overlain by a shallow, loamy or sandy topsoil of a reddish hue and underlain, sometimes at great depth, by weathered, but not ironstained-acidic Dahomeyan schist where seen. These soils, occurring on summits, have usually been used for settlement in former times and the topsoils are often more or less considerably disturbed by the addition of red clay from old houses, by stones, pottery fragments and molluse shells.

A full description of the series is given above under Nyigbenya-Hacho Complex (Tract 3).

Tepanya series comprises soils with a variable, but usually shallow, thickness of black, plastic clay overlying several feet of grey, often mottled brown, heavy, plastic clay containing very abundant spherical ironstone concretions; the profile is normally underlain by weathered garnetiferous hornblende gneiss. Within the present complex, these soils occur patchily on upland sites amongst Akuse soils, and at the surface are often sandy and contain shells and pottery fragments, indicating that they have formerly been settled. Patches of lime sometimes occur in the lower layers.

This series is more fully treated under Akuse Consociation (Tract 9) above.

Minya series is the equivalent of Tepanya series, but is developed patchily amongst Agawtaw soils. The soils contain a similar ironstone-concretionary layer and are sometimes calcareous at depth, too, but are overlain by a shallow, grey-brown, sandy loam topsoil and underlain by weathered acidic gneiss or schist. These soils, too, have usually been disturbed by former settlement.

A slightly fuller description of the series is given above under Simpa-Agawtaw Complex (Tract 8).

Agawtaw series is the most extensive series of the complex, developed over the gentle middle and lower slopes mainly to the south and south-east of the summits in the two major units where Nyigbenya soils occur. The soils consist of a few inches of grey-brown or pale grey-brown, firm, porous sandy loam at the surface, overlying a foot or so of dark grey-brown or dark brown, slightly mottled, very compact, sandy clay cracking into 6-sided blocks when dry and grading into pale grey-brown clay containing lime concretions before weathered rock is reached.

Within this complex, the soils over some areas are rather shallower than the normal soils of the series, and rather hard quartz schist, overlain by a thin layer of quartz gravel, may be reached at 2–3 feet. Such soils do not always contain visible lime, but they usually become alkaline in reaction either at the base of the profile or in the weathered rock.

A full description of the series is given above under Agawtaw Consociation (Tract 10).

Simpa series consists of soils with a variable, but usually shallow, thickness of pale brown or pale grey-brown sand overlying a layer of grey or brown sandy loam to clay containing abundant, ironstained quartz stones and gravel before little-weathered acidic gneiss or schist is reached, usually at a depth of 2–3 feet in the present area. These soils occur patchily amongst Agawtaw series, but appear to cover only a small area within this tract.

A full description of the series is given above under Simpa-Agawtaw Complex (Tract 8).

Akuse series within the present complex, occurs mainly in drainage-grooves leading northwards or north-westwards of the summit soils of Nyigbenya series in the two major units mapped. The soils consist of black, compact, plastic clay becoming dark to mid-grey and calcareous below a depth of 18–24 inches, and overlying garnetiferous hornblende gneiss at a depth greater than 30 inches. They crack widely from the surface when dry, giving a tussocky ground-surface difficult to walk or drive over. Spherical ironstone concretions, and sometimes lime concretions, occur scattered over the ground-surface.

A full account of the series is given above under Akuse Consociation (Tract 9).

VEGETATION

Where the upland soils have been disturbed by settlement, or their concretionary layer is near the surface, they frequently carry a scanty cover of short grasses and sedges; but locally, patches of evergreen thicket occur, probably remnants of a former fire-barrier around the dwellings, and Baobab trees are common, too. Elsewhere, these soils, together with Agawtaw soils, generally carry short grasses with widely-scattered thicket or tree clumps. Akuse soils carry medium grasses, especially *Vetiveria fulvibargis*, with few, scattered trees and bushes.

PRESENT LAND-USE

A minor amount of cassava is grown on upland soils to the south of the Accra-Lagos road, but no cultivation has been observed to the north, and the greater part of the tract is used as grazing-land in a similar manner to that described for Agawtaw Consociation (Tract 10).

RECOMMENDATIONS REGARDING LAND–USE

Akuse and Agawtaw soils in this complex would require to be developed by similar means to those described for the major areas of these soils in the adjoining Akuse and Agawtaw Consociations respectively (Tracts 9 and 10).

Nyigbenya soils here are of limited extent and can only be used for poor rough-grazing or as settlement sites (with suitable provision for water supplies) if the surrounding soils are developed.

Nyigbenya soils provide a readily-accessible source of road-gravel in a part of the region very deficient in such materials. They are, however, rather less suitable for road construction than similar deposits in the west of the region since the clay matrix is more plastic, particularly towards the base of the profile.

Recommendations given for Tract 10 should be referred to for information on Agawtaw soils in respect of road-building. Akuse soils should be avoided if at all possible; where they have to be crossed, recommendations given for these soils in Tract 9 should be taken into consideration.

TRACT 13

GENERAL

The three soil associations grouped within this tract are all found along valley-bottoms liable to seasonal flooding by water draining from the Black Clays and/or Agawtaw soils. *Lupu Consociation* is found predominantly along the edge of the Volta flood plain, but also in narrow strips along the lower Dechidaw and its Jawpa tributary. *Tachem Consociation* occupies the Okwe valley, the upper Jawpa and Chipa valley bottoms (west of Doyum) and the upper Dechidaw valley to the west of the Black Clays belt, as well as the lower Hwapa valley to the east of this belt. *Okwe-Tachem Complex* occupies a broad depression between the lower Okwe stream and Korle-Okwe Complex in the north of the region. As mapped, these associations cover almost 30 square miles (c. 19,000 acres).

Mean annual rainfall over these areas varies from around 30 inches in the south to 40–45 inches in the north. This is supplemented by run-off received from adjoining clay areas. Where stream channels exist, fringing forest or thicket are found; elsewhere, the broad depressions are covered with swamp-grassland.

SOILS

Since certain soils are common to more than one of the associations, repetition of soil descriptions will be avoided if the series are described together for the whole tract. First, however, their disposition within each association will be explained.

Lupu Consociation

This consociation, covering approximately 16 square miles (c.11,500 acres) in its several detached occurrences, consists predominantly of black, heavy, plastic, non-calcareous clays of *Lupu series* developed in seasonally-flooded alluvium derived from the adjoining Black Clays. Between the upland

Black Clays of Akuse series on the undulations and the depression soils of Lupu series there is a narrow belt of transitional soils of *Bumbi series*, similar to Lupu series in the upper horizons but becoming calcareous at 30–60 inches.

In the north, the boundary between these soils and those of *Tefle series* developed in Volta alluvium is indefinite, so that occurrences of grey, mottled, heavy clays of the latter series may be expected locally to lie within the consociation as mapped: they will not be discussed below, but are described under Tract 14.

Tachem Consociation

This consociation is developed over seasonally-flooded clay alluvium derived predominantly from the Dahomeyan acidic gneiss areas. It covers approximately 10 square miles (6,400 acres). The dominant soils are those of *Tachem series* which consist of heavy, plastic clay, black near the surface, with Lupu Consociation in all occurrences are indefinite.

Okwe-Tachem Complex

This association occupies approximately 2 square miles (1,280 acres) in a seasonally poorly-drained area near and to the west of the lower Okwe, stream, but the boundaries with Korle-Okwe Complex and with Tachem Consociation are indefinite. All the soils are developed in heavy clay alluvium. They are all patchy in occurrence, but *Okwe series* appears to predominate. These soils consist of brown clay which is calcareous at a moderate depth. *Tachem* soils are black at the surface becoming brown to a depth of 18–24 inches and then grey, strongly mottled red. *Akawle series* includes very minor river-bank soils, grey-brown to brown in colour and rather light-textured near the surface. Bumbi and Lupu soils, as described in Lupu Consociation above, also occur in minor amounts.

The soils of these associations are described below in the following order:—

1. *Lupu series*
2. *Tachem series*
3. *Okwe series*
4. *Bumbi series*
5. *Akawle series*

Lupu series comprises black to dark grey, very heavy, plastic clays developed under swamp-grassland in seasonally-flooded depressions adjoining the Black Clays areas. The ground-surface is tussocky and the soils crack widely to great depths when dry. At depths greater than 5 feet, 'nests' of lime concretions have occasionally been observed. Grey, yellow and orange mottled sand or sandy clay underlies Lupu soils in the Dechidaw valley near Dawhwenya, usually at depths greater than 6 feet.

The soils are flooded for periods of a few days at a time during the rainy seasons, but the northerly occurrences may be flooded for several weeks during the second rainy season when drainage water from the Black Clays belt is impounded by the high level of the Volta at this time of the year. During the dry seasons the soils dry out deeply.

Small amounts of chewing cane are grown near the Volta floodplain, but the soils are generally too heavy for hand-cultivation. If flooding could be controlled they would be excellent soils for mechanized irrigation agriculture, especially for flood-irrigation. For furrow-irrigation, it would be desirable to plant crops on ridges or beds to improve the internal drainage and structure of the soils. Problems in handling the soils will be similar to those requiring investigation on upland Black Clays on Kpong Irrigation Research Station. Heavier equipment is likely to be needed, however, because of the heavier nature of the soils and even greater attention will need to be paid to drainage because of the depression sites they occupy and the fact that appreciable amounts of sodium salts occur below the topsoil in the natural soils.

Under present conditions, moderate amounts of organic matter accumulate in the topsoil which is then moderately well provided with nitrogen and phosphorus. The soils are low in potash throughout and are very acid in reaction below the topsoil. Under continuous cultivation, nitrogen and phosphorus are likely to be the major nutrient requirements. Initial treatment with lime and gypsum may be needed to correct the acidity and displace some of the harmful sodium from the soils.

Tachem series includes soils which differ from Lupu soils in that, below the black humous horizon, they become brown for a foot or two and then become strongly mottled grey and red in the lower part of the profile. Quartz gravel or pebbles sometimes occur in the clay at the base of the profile, but rarely appear within 6 feet of the surface. These soils occur in seasonally waterlogged or flooded depressions under swamp-grassland, and appear to have developed in clay alluvium derived predominantly from the adjoining acidic gneiss soils.

Tachem soils remain more or less waterlogged throughout normal rainy seasons, but appear only to be flooded for a few days after exceptionally heavy rainfall. During the dry seasons, they crack deeply and become droughty. Permanent water-tables do not exist in these soils.

The agricultural potentialities of Tachem soils are similar to those of Lupu series described immediately above although in the west at least, the depressions in which they occur are much narrower than those in which Lupu soils are developed and they are rather less heavy to work in the topsoil. Heavy crawler equipment will none-the-less be required for tillage. Harmful salts only occur at depth and no difficulties should arise from salinization under normal irrigation practice.

Under natural conditions, the soils accumulate moderate amounts of organic matter and, initially at least, are likely to be fairly well provided with available nutrients. Under continuous cropping, however, it would be necessary to add nitrogen and phosphorus. These soils are moderately to very acid in reaction throughout, and liming might be required for some crops. Exceptionally, alluvially-derived lime concretions are found locally in the soils near the Kpong Irrigation Research Station.

Okwe series contains seasonally-waterlogged, dull brown, or yellow-brown weakly mottled orange, silty, plastic clays with black, humous topsoils—sometimes loamy and porous—and with a calcareous horizon below about 30 inches. A layer of quartz pebbles underlies the profile: where it occurs within 30 inches of the surface—as happens frequently, but locally—the soils are recognized as *Okwenya series*.

These soils occur locally along the lower Okwe floodplain and in the broad depression to the west where they merge into Korle-Okwe Complex. A full description of the series is given above within the latter complex (Tract 6).

Bumbi series is locally developed in a lower-slope transitional position between Akuse soils on the uplands and Lupu soils in the depressions, but also occurs locally amongst Tachem and Okwe soils. In profile, the soils consist of heavy, plastic, cracking clay, black at the surface but grading down through dark-grey to mid-grey (locally brownish-grey) and becoming faintly mottled at depth. They are acid in reaction to at least 30 inches but become alkaline between this depth and 60 inches with the development of 'nests' of lime concretions.

A full description of the series is given above under Akuse Consociation (Tract 9).

Akawle series is a very minor series only recognized locally along the Banks of the River Okwe. In profile, the soils consist of a few inches of dark grey-brown, humous, fine-sandy or silty loam overlying dark brown, porous, sandy light clay which becomes heavier and more compact with depth. Lime concretions may occur at depth overlying the weathered rock.

These soils occur under fringing forest and are liable to be flooded temporarily after heavy rainfall within the catchment of the Okwe. After these periodic inundations, they are seen to be covered with a fresh deposit of pale-coloured, fine-sandy or silty alluvium which is quickly incorporated into the humous topsoil by ants and earthworms.

The soils are of insufficient areal extent to warrant further description.

VEGETATION

These seasonally-inundated soils all carry swamp vegetation of some kind. In the north, floodplains characteristically occur under dense stands of tall grasses of a swamp variety of *Andropogon gayanus*, but there are patches of medium and short swamp grasses here and there. Fringing forest or thicket occur along stream channels where these exist, and along the lower Okwe this is occasionally cleared for cultivation. Otherwise, frequent small trees of *Mitragyna inermis* occur amongst the swamp-grassland.

In the south, medium grasses of *Schizachyrium* and *Vetiveria* species predominate together with scattered *Mitragyna* trees. Fringing woodland or thicket occur along stream channels.

PRESENT LAND-USE

This tract is very little utilized at present. Minor amounts of sugarcane, grown for chewing, have been seen on Lupu soils to the east of Akuse in the north. For this crop, grass is cleared from a small plot, and as the floods recede (October-November), setts are pushed into the moist soil. Cane is reaped before next year's floods (September-October), and a ratoon crop may be taken the following year.

Subsistence cropping of maize, cassava and okro has been noted on Okwe soils. Crops are grown in single stands in both rainy seasons. Thicket fallows between successive periods of cultivation appear to exceed 10 years; but savannah regrowth is invading some of the areas on the margins of the savannah.

Elsewhere, in the south, cattle may graze the grassland to a small extent, but apparently only incidentally to their passage through this vegetation to water-holes along the valley bottoms.

RECOMMENDATIONS REGARDING LAND-USE

The soils in depressions adjoining the Volta floodplain could be developed in a similar manner regardless of whether the Volta dam provided irrigation or not. In the latter case, crops might be grown by planting as the floods receded; or, preferably, two-way pumps might be installed along the Volta levee to control flooding during the rainy seasons and to pump water back on to the land from the river during the dry seasons. This latter method will be more fully discussed in Part III of the Report.

With irrigation or flood-control, it might be possible to grow rice, sugarcane, cotton, pulses, fodder-crops and perhaps some of the traditional local food-crops. These soils are too heavy for development by independent peasant-farmers, and would need the use of heavy machinery, artificial fertilizers and large-scale management. Methods of cultivation to be investigated on the Kpong Irrigation Research Station would be broadly applicable to these soils, although fertilizer requirements would need to be investigated separately.

In the absence of a major irrigation scheme, it would seem desirable to emphasize the production of fodder-crops to supply the adjoining stock-rearing areas with dry-season feed. Fodder-production could be the main aim in developing the remaining areas of these soils, too. This might be effected in the larger depressions in the north without flood-control measures; but in the narrower depressions, or in areas less frequently inundated, it might be advantageous to erect low bunds (with protected spillways) across the line of drainage to retain some of the occasional sheet-flood water on the land.

In the Dechidaw valley 2 miles north of Dawhwenya, the Consultants at one time considered constructing an earth dam to supply water to Tema. Such a structure would be equally useful in supplying irrigation water to a small irrigation project on the Black Clays, including Lupu soils, in the neighbourhood.*

These soils should be avoided so far as possible in road-construction. Where roads must cross them, they should do so at their narrowest points. Unsurfaced roads can be used when the soils are dry, although initial grading would be required to reduce the tussocky surface of Lupu soils.

For all-weather roads, it will be essential to build causeways. These must be built of inert material brought in from other tracts: Togo quartzite schist in Tracts 5 and 6 is the most convenient source in the north and west. Causeways should be broad-based and as high as is practical. Bridges and large culverts will be required to accommodate the large amounts of flood-water liable to flow down some of the valleys these soils occupy.

Alternatively, the possibility that for comparatively little extra expense, such causeways might also be made to serve as dams needs to be considered. If this were required, the causeway would need to be more carefully keyed into the underlying alluvium and spillways would need to be provided instead of bridges. Such causeway-dams could be particularly useful in the Dechidaw-Jawpa and Okwe valleys.

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*Construction work began in April, 1960, on a dam site a mile or so downstream of the Consultant's site. This will retain water for consumption by local livestock and for the irrigation, ultimately, of some 600 acres of Lupu and Akuse soils in the neighbouring Ohudaw valley.

SUB-REGION III (VOLTA FLOODPLAIN)

TRACT 14

General

THIS TRACT includes those areas of Volta alluvium subject to flooding (if flooded at all) only by fresh (i.e. non-saline) water. It increases in width from barely a hundred yards in the Volta gorge in the north to more than 2 miles in the centre and south-east. Excluding the major lagoons, it covers an area of approximately 113 square miles (72,300 acres).

The floodplain tract comprises two associations. *Amo-Tefle Association* covers the greater part of the area and consists of more or less poorly-drained, pale-coloured, sandy, silty and clay soils developed in recent or contemporary Volta alluvium. Relatively small, detached areas towards the outer edge of the alluvial tract and standing up to 40 feet higher than the floodplain soils include red and yellow, silty clay terrace soils mapped as *Aveime-Zipa Association.*

Mean annual rainfall over the tract increases from around 30 inches in the south-east to 45 inches in the north (Ada 32 inches; Akuse 44 inches). Over Amo-Tefle Association, this is supplemented by floodwater from the Volta during September-November, although the extent of the floods varies considerably from year to year. Swamp-grassland covers most of the area, but patches of forest and thicket occur in places. There is extensive settlement along the river bank and the soils are heavily farmed in some localities.

SOILS

Amo-Tefle Association

This association covers an area of approximately 95 square miles (60,800 acres). It comprises three major soils.* *Chichiwere series* includes yellowish soils developed in well-drained, sandy alluvium along the high river bank and, in the south, on abandoned levees. *Amo series* comprises grey mottled brown or red, silty clays occurring behind the river bank but subject to only occasional flooding; these soils cover the greater part of the association. *Tefle series* occupies the lowest-lying areas subject to seasonal flooding, sometimes prolonged, and comprises grey heavy clays.

Because of the indefinite boundary between this association and Lupu Consociation (Tract 13) alongside the Black Clays belt, the area mapped within the present association may include small areas of black, heavy clays of *Lupu series.* It may similarly include small areas of red and yellow silty clays of *Aveime* and *Zipa series* which escaped the traverse-line grid; these soils will be found discussed below under Aveime-Zipa Association.

The soils of the association are described below in the following order:—

1. *Chichiwere series*
2. *Amo series*
3. *Tefle series*
4. *Lupu series*

*Chichiwere series*** occurs in a strip 20–30 yards wide along the high banks of the Volta and alongside some of the cut-off channels. In their natural state, the soils consist of a great depth of pale brown or yellow loose sand overlain by a dark grey-brown, humous, forest topsoil. Thin layers of grey silty clay sometimes occur at depth and pebble beds are sometimes met at as little as 30 inches especially downstream of Battaw. The upper layers are frequently contaminated to a great depth by clay from old house-walls and by charcoal, organic matter and oyster shells since the river banks have been settled for centuries.

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*Subsequent investigations have shown the need to separate these soils still further; *Chichiwere* and *Amo series* now include those soils developed in alluvium no longer subject to regular flooding; *Mepe* and *Siko series* are developed to recent sandy or silty alluvium still subject to regular flooding.

On the Ho-Keta Plains, it has been found possible to subdivide Amo series still further: the series named is restricted to soils with silty clay texture and very acid reaction from the surface: soils with rather looser, more loamy topsoils, often yellower in colour, and neutral to only moderately acid in reaction in the topsoil although very acid below, have been recognized as *Hake series.* The latter soils occupy a transitional position between true Amo soils and Chichiwere soils.

**Similar soils occurring under grassland on river-banks and sandbanks liable to seasonal flooding have been separated as *Mepe series.* They are not of great extent. They differ visibly from Chichiwere soils in that the sand is looser and less humous-stained. They are liable to be covered with fresh deposits of sand after each flood.

These soils, except on old settlement sites, are free-draining and would appear to be droughty for shallow-rooting annual crops. It is doubtful whether they are ever flooded today, but along the lower stretches of the river water may rise high in the profile when the Volta is at flood-level. Where clay from old settlements has built up the profile, moisture relationships are slightly improved, although on contemporary settlement sites the clay is compact and water is lost by surface run-off.

The soils are easily hand-tilled and, if cleared of their present woody vegetation, could readily be mechanically cultivated. They are unlikely to be developed for this purpose on their own account, however, because of their limited areal extent.

The undisturbed soils contain low nutrient reserves below the humous topsoil. On old settlement sites a very high nutrient status may occur, although perhaps patchily.

*Amo series** includes grey, mottled, silty clays which have an overall yellow-brown appearance near the surface and give rise to yellow-brown termite-mounds. They occupy almost level land between the high river bank on one side and the bottom-lands on the other.

The uppermost 6 inches or so of the profile consist of dark grey to dark brown, humous, porous, very fine sandy or silty loam to light clay. This horizon is paler in colour, and rather loose and powdery near the surface where exposed on cultivated land. It grades down through a brown transitional layer into grey, strongly mottled yellow and orange (locally, bright red, also), very fine sandy or silty clay. This may normally be expected to continue to great depths, but towards the southern extremity of the tract, loose sand and peddles have been encountered at a depth of as little as three feet.

Variations in texture and consistency occur, since on the one side the soils grade into the sandy soils of Chichiwere series and on the other into the heavier clay soils of Tefle series. Near the Black Clays tract, too, as on the Kpong Irrigation Research Station, they are locally made heavier and more plastic by the admixture of a certain amount of Black Clays alluvium. Human settlement has disturbed the soils locally.

The soils are liable to flooding by the Volta during September to November, although the extent and duration of the inundation varies from year to year: it seems probable, in fact, that the higher parts may no longer be subject to regular flooding.† During the dry seasons they dry out deeply, and they are fairly well drained, except on lower-lying sites, during the main rainy season when the Volta is at a low level. These soils are widely used for cultivation at present, and would be suitable for mechanized irrigation agriculture, too. They may puddle at the surface when exposed for long periods, and occasional rotations with cover crops which could be ploughed in would probably be required to keep the soils in good heart if continuous arable cropping were to be practised. Appreciable amounts of sodium salts apparently occur in the lower layers of some profiles and an efficient drainage system would be required to control their level in the profile.

The soils appear to be moderately well supplied with nutrients under natural conditions but nitrogen and phosphorus fertilizers would almost certainly need to be added for intensive cultivation. It would be desirable to ensure the maintenance of a good level or organic matter in these silty soils to assist in maintaining a satisfactory tilth. The higher-lying soils are near-neutral in reaction in the topsoil but become moderately to very acid below. Towards the boundary with Tefle series, especially in the south-east, the soils tend to become more acid at the surface and may become extremely acid if kept well drained. Lime would require to be added to correct this acidity.

Tefle series contains grey, mottled, heavy clays developed in bottom-lands flooded or waterlogged for long periods following the Volta floods—and during the rainy seasons, too, in some places—and remaining more or less moist throughout the greater part of the year.

The uppermost foot or so of the profile consists of dark grey-brown, heavy clay, cracking vertically when dry. Where this horizon remains moist throughout the year, incompletely-decomposed, rather ironstained, organic matter accumulates in a mid-grey, clay. Below this, there is a great depth of mid-grey, heavy clay, more or less strongly mottled with red and orange where drying out takes place, but blue-grey with black stains where water-logged throughout the year.

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*Those soils developed in silty clays which are liable to seasonal flooding, when fresh deposits of silt may be left at the surface, have later been recognized as *Siko series*. These soils are usually looser, greyer in colour and less brightly mottled than typical Amo soils.

†The higher, non-flooded soils would not be included within *Hake series*.

These soils are almost perennially ill-drained. Where drying-out occurs, they become hard and cloddy, and, except for flood-irrigated crops, internal drainage would require to be improved so as to develop a better tilth. They are little used for cultivation, but if flooding could be controlled, would be well suited to mechanized irrigation farming, especially for swamp rice production. Methods of cultivation worked out for Lupu soils are likely to be applicable in large part to these soils. Drainage would be required to control the level of sodium salts in the profile.

Large amounts of organic matter accumulate in these soils under present conditions and contain the greater part of the available nutrient supply. The body of the soil is highly acid. Nitrogen and phosphorus would need adding for continuous cropping, and it would be desirable to reduce the acidity by adding lime.

Lupu series comprises very dark grey, little-mottled, heavy, plastic, cracking clays developed in seasonally-flooded alluvium derived from the Black Clays belt. Within the present tract, such soils are likely to be found locally near streams draining across the Volta floodplain from the Black Clays and near the indefinite boundary drawn between Lupu Consociation and Amo-Tefle Association.

A full description of Lupu series is given above under Lupu Consociation (Tract 13).

Aveime-Zipa Association

This association occupies a number of detached areas towards the outer edge of the Volta floodplain downstream of Lupu lagoon where there occur remnants of a river terrace, probably originally 30–40 feet above the present floodplain, but now often eroded to less than 20 feet above this level. The boundaries indicated owe a considerable amount of their detail to use made of the aerial photographs. As mapped, the association covers approximately 18 square miles (c.11,500 acres).

Aveime and *Zipa* series are the only soils present. The former, occupying the higher, better, drained sites, consists of red silty clays; the latter, more extensive, and covering the lower-lying-probably more-eroded, sites, consists of yellow-brown silty clays, rather heavier than in Aveime series. Both soils locally contain lime concretions at a moderate depth.

These soils are discussed below in the following order:

1. *Aveime series*
2. *Zipa series*

Aveime series consists of brick-red, well-drained, porous, silty or fine-sandy clays, locally containing lime concretions at a moderate depth. They are developed on the higher parts of river-terrace remnants along the outer edge of the lower Volta floodplain.

The surface foot or so has usually been disturbed by cultivation and is humous-stained to varying degrees. Where recently disturbed, there is brown to orange-brown, porous and friable, fine sandy loam to light clay. (Under thicket, this horizon would be expected to be dark grey-brown to a depth of 6 inches, grading into brown or orange-brown to a depth of 12 inches). This layer grades downwards into brick-red, rather firm, porous light clay to clay, cracking slightly in the profile when exposed and becoming friable. Below approximately 5 feet, the clay tends to become mottled red and yellow. Lime concretions have frequently been recorded below a depth of 30 inches, but appear to be localized in occurrence and may probably be associated with old termite-mounds*.

These soils readily absorb water except when left bare. They retain moderate amounts of moisture at depth, but the upper part of the profile becomes droughty during prolonged dry periods.

Ease of tillage and freedom of root-development make these soils highly favoured for farming at present since they occur in areas where ill-drained or heavy clays predominate. They would be suitable for mechanized irrigation agriculture, too. Termite-mounds are numerous and would require to be cleared before there could be large-scale cultivation.

Under present conditions, these soils accumulate little organic matter and have little nutrient holding capacity in the topsoil. Nitrogen and phosphorus contents are both low, and need supplementing for increased crop production. There are moderate amounts of potash, more particularly in the deeper layers. Lime occurs rather locally, so that some profiles (probably representing the greater

*Aveime and Toje series are apt to be confused on superficial examination. Aveime soils are distinguished by their occurrence along the Volta floodplain (and in the old delta), their higher silt and clay content in the uppermost 12–18 inches of the profile (where Toje soils are more sandy and their tendency to become mottled with depth).

extent of the soils) are moderately to very acid in reaction throughout, whereas others are slightly acid near the surface but become alkaline below.

Zipa series comprises yellow-brown, silty or fine-sandy clays, locally containing lime concretions at a moderate depth. The soils occur on very gentle middle and lower slopes of terrace-remnants where Aveime soils occupy the upper slopes, but may cover the whole of more eroded remnants.

The surface layer has usually been disturbed by cultivation, and to a depth of approximately a foot consists of greyish-brown, porous or loose, silty fine sand or loam. (Where undisturbed, the uppermost 3–4 inches would be expected to be dark grey-brown and humous). This layer grades downwards into yellow-brown, silty or fine sandy clay which is rather friable and porous at first but becomes heavier than in the adjoining Aveime soils at a moderate depth. The upper part of the subsoil may show a tendency towards hardpan formation when dry. Below approximately 30 inches, the soils become more or less mottled grey, yellow and orange, and occasional soft, black, manganese concretions occur. Lime concretions are more commonly found than in Aveime soils, but none-the-less, appear to be local in development and are probably associated with old termite-mounds.

Rainfall is readily absorbed, except on bare soils and appears to be satisfactorily retained in the sub-soils, although the topsoils become droughty during dry periods. Hand-cultivation is widely practised, and the soils would appear to be suitable for development by mechanized irrigation farming. Termite-mounds are very frequent, and very compact when down-graded, and would require to be cleared for mechanized farming. Anti-erosion measure might be required locally where moderate slopes leading down to creeks occur.

Little organic matter accumulates in the topsoils at present, and the soils contain little nitrogen and phosphorus. These would need to be added for more intensive crop production. Lime occurs in many profiles, but probably only patchily. The soils correspondingly vary in reaction from moderately acid throughout in some cases to slightly acid near the surface and alkaline below in others.

Appreciable amounts of sodium salts occur in the lower layers of some profiles. Under irrigation, adequate drainage would need to be provided to prevent these salts from being brought to the surface.

VEGETATION

The greater part of Amo-Tefle Association is covered with tall swamp-grassland with *Andropogon gayanus var. genuinus* predominating. Small trees of *Mitragyna inermis* are very common. Thicket occurs in patches irregularly throughout the tract, usually on Amo soils. Chichiwere soils along the river bank characteristically carry high fringing forest, but this has been cleared by settlement or cultivation in many areas and replaced by thicket with oil palms.

The greater extent of Aveime-Zipa Association occurs under tall grass savannah regrowth with scattered shrubs and trees. The latter are usually of savannah species, but forest trees such as the silk cotton occur locally. Patches of coastal thicket occur in some localities, more especially in the south-east.

PRESENT LAND-USE

With the exception of the bottom-lands, the whole of the area is under land-rotation cultivation, sometimes with tall grass, sometimes with thicket, fallows. Cultivation is locally intensive, and it appears possible that some Amo soils are under almost continuous cultivation*. There are large expanses of savannah regrowth, however, and local patches of high thicket, which suggests that fallow periods away from the immediate vicinity of settlements are long, perhaps exceeding 10 years.

Subsistence farming is the general rule, and cassava is by far the most common crop planted, but maize is grown as a cash-crop in the north and groundnuts are important near Mepe. Elsewhere, minor amounts of vegetables, okro, sweet potatoes and Bambara beans are grown. Short-term crops may be planted in March-April to benefit from the main rainy season, or, on Amo soils, in November-December as the floods recede. Cassava appears mainly to be planted in the second rainy season. Crops are usually grown in single stands on the flat at the usual irregular spacing of approximately 3 x 3 feet; but small raised beds, roughly 10 x 3 feet in extent, have been observed in use locally along the lower Volta, more particularly for the cultivation of sweet potatoes. Mixed cropping of maize, groundnuts and cassava seems to be more common on Aveime soils.

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*This is particularly the case with Siko soils.

Small amounts of sugarcane are grown locally on bottom soils. Grass is cleared, and the setts pushed into the soil in November-January as the floods recede and whilst the clayis still soft. Cane—for chewing— is harvested in September-October before the floods made the sites inaccessible. A ratoon crop may be taken the following year, but competition from regrowth of swamp grasses becomes increasingly severe, and second ratoon crops do not appear to be taken.

There are no yields data, but from the general appearance of the crops, production would not be expected to be high. The droughtiness of the normal Amo and Aveime soils over which most of the cultivation is practised, is probably the limiting factor. Spear grass (*Imperata*) is a troublesome weed-grass on Amo soils.*

Small oil-palm plantations have occasionally been recorded on Amo and Chichiwere soils. A small cocoa farm exists, too, on settlement-enriched Chichiwere soils to the east of Akuse. These soils would not normally be considered good for cocoa, but none-the-less, the health of the trees here appears good and yields moderate.

RECOMMENDATIONS REGARDING LAND-USE

Irrigation of some parts of this tract should be possible whether the Volta Dam provides irrigation water or not. In the latter case, two-way pumps would need to be installed at the mouths of creeks leading into the river to control the depth of flood-water draining down valleys from the Black Clays and Agawtaw Consociation during the rainy seasons, and to pump water back along high-level canals to provide irrigation during the dry seasons. It will be recommended in Part III of the Report that a trial scheme of this sort, following up a topographical and hydrological survey, should be set up at an early date along the lower courses of the Dawhwe and Lumen streams between Akuse and Asuchuale. If this were successful, other schemes would be possible along the central stretch of the floodplain.* *

With irrigation it should be possible to grow a wide range of irrigated crops, but particularly swamp rice and sugarcane. Fodder production might also be important to supply the adjoining stock-rearing areas. Independent peasant farming might be possible on the higher Amo and Aveime soils; but large-scale management of the heavier bottom clays would be required, using heavy machinery.

Without such measures, more use might be made of Amo soils by mixed-cropping of maize (or suitable sorghums or millets if available) with a leguminous ground-cover crop, and by promoting woody fallows or the planting of pigeon pea to replace the grass which is widespread at present. The latter, too, would be more effective in controlling spear grass which is rampant on these soils. The heavier bottom clays might be made use of for rice as well as for chewing-cane.

On Amo, Chichiwere, Aveime and Zipa soils it is desirable to build up the content of organic matter. Kraal manure or compost (from household refuse and crop residues) should be added where it can be obtained. Failing this source of supply, cover crops should be grown at frequent intervals in the rotation. The soil surface should be protected as much as possible against direct sunshine and rainfall by the foliage of the crop itself supplemented by mulch where possible; under mechanized agriculture, trash-farming methods might be used.

There is a need to provide more roads to and within this tract to speed development. Roads would best be aligned along Chichiwere soils along the high river bank, but substantial bridges or small ferries will be needed to cross creeks where these occur. Suitable foundations for bridges will

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*Crop yields appear to be better on Siko soils, probably not so much due to the addition of fertile silt during flooding but to the fact that moisture is available in the subsoil throughout the growing period or, where it is not, is supplemented by hand watering. Tomatoes, okro, green corn, sweetpo tatoes and other vegetables, besides cassava, are the major crops. Cassava mosaic appears more serious than is seen elsewhere. The major weed grass is a wild sorghum which when cut down makes a good mulch, a fact the local farmers appear to appreciate. The value of these small areas of seasonally flooded soils is reflected in the small size of individual farms. These are only of some 20 x 20 yards extent on the Siko peninsula near Aveime.

* *A survey of the Lower Volta Floodplain commenced under the auspices of the United Nations Special Fund in April, 1960, to assess the potentialitics for large-scale agricultural development in the tract making use of irrigation and drainage. In Phase I, a general soils, hydrological and agricultural survey is being made of the whole tract at the end of which it is expected that an area suitable for development will be selected. Phase II, which is scheduled to be completed by April, 1963, will entail making a design study for the development of the selected area.

be difficult to provide along most of the floodplain, and it might be more suitable to use pontoon-type bridges which can be raised and lowered with fluctuations in flood-level.

Amo-type clays are very slippery when wet and very dusty when dry when used in road-making, quickly wearing into ruts and pot-holes when wet and quickly corrugating when dry. Because of the dearth of rock and 'laterite' gravel within ready access of most of the tract, however, these clays will probably have to be used widely for secondary roads. Conditions can be improved by providing adequate side-drains and culverts and keeping the road-surface regularly graded.

Major roads would need to be built up on causeways, especially over the lower-lying Tefle soils. The nearest sources of fill are the Kpong-Senchi area in the west and mile 62 on the Accra-Lagos road in the south-east. Rock for quarrying and crushing for foundation material is available near the outer edge of the tract in a number of places in the central stretches: e.g. Ningo Hill and its outlines south of Asuchuale; and a number of small granite outcrops occurring near the central N.E.-S.W. axis of Doyum-Agawtaw Association (Tract 7, eastern area).

The better-drained ridges provided by Aveime-Zipa soils should be used for roads where possible. Unsurfaced roads can be taken over Aveime soils satisfactorily but the surface layer of Zipa soils is apt to pulverize and become incoherent. For better roads, this layer in Zipa soils would better be excavated down to the clay substratum and replaced by fill from Aveime soils. (The latter material, it may be noted, is rather plastic and less suitable as fill than true red earths of Nyigbenya and Toje series). Side-drains in Zipa soils should penetrate to a depth of 2–3 feet to effect proper drainage in the rainy seasons.

SUB-REGION IV (VOLTA DELTA AND COASTAL FLATS)

TRACT 15

General

This tract embraces a large area of low-lying land to the west, north and north-east of Songaw lagoon and appears to represent part of a delta formed by the Volta when sea-level was slightly higher than at present. It includes one major and three minor soil associations, viz:—

(*a*) *Aveime-Ada Association;*
(*b*) *Ada Consociation;*
(*c*) *Aveime-Zipa Association;*
(*d*) *Agbozome (Goi) Consociation;*

The soils of Aveime-Ada Association extend into an extensive area (mapped as Ada-Oyibi Association) along the lower Volta but in the latter case they have been mapped separately and excluded from the present tract because of their association with saline soils. Within the boundaries indicated, the tract occupies an approximate area of 45 square miles (28,800 acres).

The topography occurs entirely under savannah vegetation and consists of extensive, almost-level flats, probably representing former lagoons, from which rise occasional slight ridges which appear to represent former river banks (levees) and sand banks. Heavy clays of *Ada* and *Songaw series* occur over the flats; lighter, porous clays of *Aveime* and *Zipa* soils occur, as along the Volta floodplain, on the slightly higher, terrace-remnants, but to the south-west of Songaw lagoon the slight elevations carry sandy soils of *Agbozome series* (*Goi subseries*).

Drainage over this area is almost entirely by surface run-off over the heavy clays on the flats. The flow is towards Kaja and Angaw lagoons in the north, but, over the greater part of the area, it is towards Songaw lagoon. Drainage, however, is very slow, and these soils often lie waterlogged during the rainy seasons.

Mean annual rainfall is around 30–35 inches, but is very variable from year to year and the second rainy season is particularly unreliable. The low rainfall is made even less effective by the exposure of the tract to the constant daily sea-breeze.

As indicated above, the tract consists predominantly of an association of Aveime-Zipa soils on the uplands and Ada or Songaw soils over the flats, but with Agbozome (Goi) soils covering low upland areas to the south-west of Songaw lagoon. Where possible, these soils have been mapped separately as, respectively, Ada and Agbozome (Goi) Consociations and Aveime-Zipa Association; but over the greater part of the tract this has not been found practicable, and this area has been mapped as Aveime-Ada Association. Since, therefore, the tract consists almost entirely of Aveime-Ada Association, the soil series descriptions below will be given, not for each association in turn, but together for the whole tract. They are treated in the following order:—

1. *Aveime series*
2. *Zipa series*
3. *Agbozome series* (*Goi sub-series*)
4. *Ada series*
5. *Songaw series*
6. *Oyibi series*

Aveime series comprises well-drained, brick-red, porous, silty or fine-sandy clays, rather loamy at the surface and locally calcareous at a moderate depth (probably only over old termite-mounds). The soils occupy the higher parts of gentle undulations (which often rise on more than 5–10 feet above the adjoining flats) but they are not of great extent. They can be distinguished from the soils of Toje series developed in the nearby Tertiary deposits by their more clayey texture, the occurrence of mottling at a depth of 5–6 feet, and by the comparatively low-level sites—generally surrounded by alluvial soils—on which they occur.

A full description of this series is given above under Aveime-Zipa Association (Tract 4).

Zipa series contains yellow-brown, silty or fine-sandy clays, rather loamy at the surface but becoming rather compact and cloddy in the subsoil. Below about 30 inches they usually become mottled—sometimes strikingly so, with large black and orange patches—and often, although only patchily, contain lime concretions. These soils may occur on middle and lower slopes of gentle undulations below Aveime soils, but more frequently within the present tract they cover the whole of some of the low ridges. In this tract, salt contents in the lower layers are likely to be higher than they are further upstream.

The series is more fully described above under Aveime-Zipa Association (Tract 14).

Agbozome series (*Goi subseries*) comprises soils with a surface layer of pale yellow-brown loose sand underlain at 30–60 inches by yellow, or yellow-brown, sandy clay which is usually faintly iron-stained but may be more strongly mottled orange and black locally. These soils cover broad low ridges to the south-west of Songaw lagoon, where the major occurrences have been mapped as consociations.

These soils are more fully discussed above under Toje-Agawtaw Association (Tract 11). Within the present tract they differ slightly from the soils described there in that neither a gravel horizon nor bedrock seem likely to occur within 6 feet of the surface, that lime (probably from old termite-mounds) occurs locally in the clay layer, and that brackish water-tables develop in and slightly above the clay layer during the rainy seasons.

Ada series comprises extremely acid, very strongly mottled, heavy clays which occupy the greater part of the extensive, seasonally ill-drained flats in this tract. The surface horizon, from a few inches to a foot thick, consists of greyish brown, silty or fine-sandy loam to clay, firm and porous in the profile, but loose and powdery if disturbed when dry. Below this, there is strongly mottled grey and red, very compact clay, sometimes cracking into 6-sided columns for a foot or so at the top of the layer. Gypsum crystals usually occur in the profile below a depth of 18–36 inches, although they are not invariably seen. The clay usually extends down to at least 6 feet; but towards the extreme south of the tract, loose yellow sand may underlie the profile at 4–6 feet.

The soils are highly impervious and become waterlogged at the surface during the rainy seasons. During the dry seasons the surface layer becomes droughty, and moisture retained by the clay in lower layers is probably not readily available to plants. Brackish water may exist seasonally in the sand underlying the southern areas, and the whole profile contains substantial amounts of soluble salts.

There is little hand-cultivation of these soils at present. Their clay texture and occurrence on extensive, almost-level land suggest their development by means of mechanized irrigation farming, but this would first require that the soils be drained to leach the salts from the upper part of the profile. Very little clearing would be required to bring the soils under cultivation.

Organic matter and nitrogen contents are fairly low at present and phosphorus reserves are very low. Nitrogenous and phosphatic manures would be required for satisfactory crop production, and large amounts of lime would require to be applied to reduce their present extreme acidity.

Songaw series comprises heavy, cloddy clays, dark grey near the surface gradually becoming yellowish—to brownish— grey below 1–2 feet and containing both gypsum crystals and lime concretions in the lower part of the profile. The soils may be underlain by sand at as little as 3 feet in the extreme south, but more generally the clay exceeds 6 feet in thickness. These soils occur over extensive flats to the west of Songaw lagoon, but their relationship to Ada soils occurring nearby is not fully understood.

Waterlogging occurs during the rainy seasons, and there is a brackish water-table which appears to fluctuate in depth seasonally. From the impoverished appearance of the vegetation (short and medium grasses and sedges), this water might not be usable by or available to plants.

These soils are too heavy for cultivation by present methods, but they appear to be potentially suitable for mechanized irrigation farming because of their impervious nature and their occurrence over extensive level expanses. They would require the use of heavy implements. Deep drainage-channels would require to be provided to control the level of the brackish ground-water and to leach sodium salts from the upper part of the profile. There are almost no termite-mounds or trees to be cleared.

These soils differ greatly in reaction from those of Ada series since they are slightly acid near the surface and become moderately alkaline with depth. Under natural conditions, they have very low nitrogen and phosphorus contents and these nutrients would need to be added for intensive crop production.

Oyibi series contains soils rather variable in colour, but consisting predominantly of grey (dark to pale), heavy, compact clays containing variable amounts of sand and usually mottled orange and black immediately below the humous surface layer. Yellow loose sand or lighter, mottled, silty clay may be reached at depths below 30 inches. These soils may be expected to occur in small depression sites within the association which are occasionally flooded with slightly-saline water.

A full description of the series is given below under Ada-Oyibi Association (Tract 16).

VEGETATION

The entire tract occurs under savannah. On the uplands this consists of medium and tall-grassland with scattered bushes, often on termite-mounds. Thicket clumps occur towards the north; and wind-deformed thicket clumps occur on the coastward side of the larger occurrence of Agbozome (Goi) soils. On the long spur projecting towards Ada, stunted oil palms are so abundant as almost to constitute oil-palm thicket.

The flats occur predominantly under short grasses and sedges with widely-scattered thicket clumps, sometimes containing the wild date palm (*Phoenix reclinata*), but Songaw soils occur under medium grasses (*Vetiveria fulvibarbis*) without any woody vegetation.

PRESENT LAND-USE

The upland soils are everywhere under land-rotation cultivation with savannah regrowth fallows, although towards Ada large areas are under oil palms, either wild or planted, and are not now cultivated. Subsistence cropping of cassava is the rule, by methods similar to those used on the adjoining Toje soils. Cultivation is more frequent on Aveime and Agbozome (Goi) soils, and fallow periods on these soils are often very short, probably as little as two years in some cases. Crops are very impoverished in appearance, especially on exposed sites near the coast, and crop yields can only be poor. The oil palms are very stunted and appear to be unproductive. The better-drained upland soils are important in determining settlement sites and lines of communication.

Ada and Songaw soils are utilized as grazing-land, although to a lesser extent than Agawtaw soils to the north, probably due to the shortage of fresh water in the neighbourhood.

The 'upland' soils of Aveime, Zipa and Agbozome (Goi) series need to be developed by similar methods to those recommended for the adjoining Toje soils (Tract 11, q.v.). Agbozome (Goi) soils would not be suitable for irrigation, except perhaps overhead irrigation of a highly-specialized crop. Aveime and Zipa soils might receive attention if the surrounding lowland soils were developed by this means, and could produce such crops as maize, tomatoes and vegetables.

Without irrigation, mixed cropping of drought-resistant crops should be practised and adequate fallows ensured. Conditions are suitable for mixed farming. Mango, cashew and guava are suitable fruit trees for these soils. All these soils would benefit greatly from the addition of animal manure if this could be collected from kraals in the neighbourhood.

Ada and Songaw soils appear suitable for development by irrigation from the Volta, although perhaps only in the distant future. Hydrological investigations would first be required, however, to determine whether difficulties would arise because of the presence of the brackish water-table in Songaw series (and perhaps at a greater depth in Ada series, too), and, if so, whether drainage could be effected naturally or by pumping. These soils could only be handled by heavy machinery and development would need to be organized by large-scale methods. Swamp rice would be the most suitable crop to grow.

Without the major irrigation scheme, a limited scheme might be possible south-east of Huakpo by reinforcing the causeway at mile 55½ on the Accra-Lagos road to impound water in the narrow valley to the north. This scheme would also depend on the hydrological investigations indicated in the last paragraph showing that drainage would be possible to control the level of soluble salts in the irrigated soils.

Over the greater extent of the heavy soils, cultivation would be impracticable because of the low and unreliable rainfall, and these areas would continue to be used for rough-grazing. The economics of pasture-improvement by manuring with phosphates and lime need to be examined. Water-holes would require to be excavated; bitumen-lining would be needed to prevent contamination from the brackish ground-water.

Whether the area were to be irrigated or not, it would be desirable to plant shelter-belts along the coast or lagoon margins and at intervals inland to reduce transpiration losses in cultivated areas. In the more exposed areas suitable for cultivation, it might be necessary to plant hedges around fields. The trees and shrubs to be planted would need to be tolerant of brackish conditions.

Road-building in this tract is made difficult by the poor drainage of the most extensive soils and the shortage of foundation and surfacing materials. Unsurfaced roads are suitable for use in the dry season on Aveime, Songaw and Ada soils; Zipa and Agbozome (Goi) soils are less suitable because their surface layers tend to become incoherent when dry. Ada and Songaw soils become sticky and plastic when wet and roads over these soils would become impassable for long periods during the rainy season.

Major roads should be aligned along the better-drained Aveime soils so far as possible. Zipa and Agbozome (Goi) soils present difficulties because of the instability of the material in the upper part of the profile and the waterlogging of the lower horizons in the rainy seasons. Provision of an embankment for the road and deep side-drains may be needed on these soils as well as Ada soils. The latter soils are subject to surface run-off during heavy rainfall and frequent culverts will be needed in most areas.

The nearest source of fill is at mile 62 on the Accra-Lagos road. The nearest rock available is six miles north of Sege, mile 47½ on this road.

TRACT 16

General

This tract, covering approximately 90 square miles (57,600 acres), includes five mapping units associated with coastal sand-dunes and the saline lagoons along the coast and the lower Volta. These are:—

(a) *Ada-Oyibi Association,* occurring only around Songaw lagoon in the east;
(b) *Songaw Consociation,* occurring to the north of Sakumo lagoon alongside the lower Densu in the west;

(*c*) *Oyibi-Muni Association*, immediately surrounding all the saline lagoons;
(*d*) *Keta Consociation*, including those stretches of the coastal sand-dunes sufficiently extensive to be mapped separately; and
(*e*) *Keta-Oyibi Association*, including those stretches of the coast where a narrow sand-dune is backed by a discontinuous series of narrow lagoons or marshes, themselves too narrow to be mapped separately under Oyibi-Muni Association.

These associations receive a mean annual rainfall of around 30 inches. There are no data for evaporation losses, but these must be considerable since the soils occupy sites very much exposed to the daily sea-breeze.

SOILS

Soil series descriptions will be given for the tract as a whole since several of the soils occur in more than one of the associations; but first, their disposition in these associations will be described.

Ada-Oyibi Association

This association occupies approximately 40 square miles (25,600 acres)*, mainly to the east of Songaw lagoon, but also in a smaller expanse to the south-west of this lagoon. It comprises grey mottled red, extremely acid, heavy clays of *Ada series* covering extensive 'raised' flats, mainly in the north of the easterly occurrence; and grey, variably mottled, compact clays of *Oyibi series* occupying only the sides of creeks in the north-east, but, towards the south-east and in the west, occupying low-lying land liable to flooding by slightly- to moderately-saline water either during the rainy seasons or when the Volta is in flood. The association extends to the banks of the Volta in the extreme east. Local occurrences of mangrove swamp give rise to blue-grey muds of *Truku series*.

The 'upland' areas occur under short grassland; the lowlands occur under marsh-grassland or locally mangrove thicket.

Songaw Consociation

This mapping unit occupies approximately four square miles (2,560 acres) to the north of Sakumo lagoon in the extreme south-west of the region. It consists predominantly of grey, heavy, alkaline clays of *Songaw series* developed over extensive grass flats of slightly-elevated former lagoon clays. There are relatively small areas of *Oyibi* soils along a salt-water distributary of the Densu.

Oyibi-Muni Association

This association occurs around all saline lagoons along the coast and around Angaw lagoon which enters the lower Volta near Big Ada. These detached areas, the lagoons themselves excluded, together cover approximately 35 square miles (22,400 acres).

Oyibi soils occupy marshes and the sides of creeks liable to periodic flooding by slightly-to moderately-saline water. *Muni series*, usually the more extensive member of the association, covers the almost-bare salt flats periodically flooded by highly-saline water. Patches of mangrove swamp here and there give rise to blue-grey muds of *Truku series*.

Keta Consociation

This mapping unit, covering an approximate area of four square miles (2,560 acres), consists of those parts of the discontinuous coastal sand-dune which it has been possible to map separately. The largest occurrence is the narrow bar which contains Songaw lagoon and the broader extension of this which projects eastward into the Volta estuary. The only soils represented, of *Keta series*, consist of pale brown to pale yellow loose sand containing shells in the lower part of the profile. They are extensively used for settlement and characteristically occur under coconut palms.

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*Lagoons excluded.

Keta-Oyibi Association

To the west of Songaw lagoon, the coastal sand-dune carrying soils of *Keta series* is usually narrow and is often backed by a discontinuous series of narrow, saline or brackish lagoons insufficiently extensive for their associated soils of *Oyibi* and *Muni series* to be represented satisfactorily on the map-scale used. This part of the tract has been mapped as Keta-Oyibi Association. As delineated it covers approximately 9 square miles (5,760 acres). The soils and their associated vegetation have been briefly indicated above under Keta Consociation and Oyibi-Muni Association

The soils of these associations are described below in the following order:—

1. *Ada series*	4. *Muni series*
2. *Songaw series*	5. *Truku series*
3. *Oyibi series*	6. *Keta series*

Ada series comprises very strongly mottled pale grey and red compact clays which are extremely acid in reaction throughout and contain gypsum crystals in the lower layers. They occur over seasonally ill-drained (but not flooded), grass-covered flats, mainly in the northern part of Ada-Oyibi Association. A full description of the series is given above under Aveime-Ada Association (Tract 15).

Songaw series contain heavy, cloddy clays, dark grey near the surface, becoming yellowish to brownish grey at depth and containing both gypseous and calcareous layers in the lower part of the profile. A brackish water-table occurs at a moderate depth. Within the present tract they only occur to the north of Sakumo lagoon along the lower Densu where they occupy a fairly extensive raised lagoon flat. A more detailed description of this series is given above under Aveime-Ada Complex Association (Tract 15).

Oyibi series comprises grey, sometimes mottled orange or red, heavy clays found in low-lying areas liable to periodic flooding by slightly-to moderately-saline water. These soils support marsh grasses or sedges.

In some profiles there may be a few inches of grey-brown sand or sandy loam at the top; more generally, there is heavy clay from the ground-surface. This varies in colour from dark to pale grey and is mottled red and black and becomes very hard and blocky in horizons which dry out seasonally. Gypsum crystals occur locally. In perennially-waterlogged horizons, marine shells are abundant. Sand appears generally to underlie the profile, but usually below a depth of 30 inches. Buried mangrove peat or black humous layers are occasionally encountered.

These soils are poorly drained both internally and externally, and often contain brackish to saline water at a moderate depth. If flooding could be controlled they might be leached of their sodium and brought into production. They would at first be expected to be very intractable, sticky when moist and compact and hard when dry; but liberal treatment with lime or gypsum would improve their tilth.

On draining, they would become extremely acid in reaction and lime and complete fertilizers would require to be applied to bring them into production.

Muni series includes alluvial lagoon clays which are periodically flooded by highly saline water but are exposed for long periods as bare, or almost bare, salt flats around all the lagoon margins. The uppermost 2–3 inches of the profile consists of grey or yellow-grey, incoherent sand or sandy clay, encrusted with salt at the surface. This is underlain by alluvial layers of greyish clay and sand, often strongly mottled red, purple and black and containing abundant shells.

These soils are unlikely to be developed, at least for some considerable time, since this would involve the leaching out of their present high salt content and subsequently their protection from flooding by salt water.

Truku series consists of sticky, blue-grey alluvial clays with an inch or so of black liquid mud at the surface and shells throughout the profile. These soils developed in *Rhizophora* (still-root) mangrove swamps subject to tidal or seasonal flooding by salt-water. If drained, the soils would be expected to become strongly mottled or even predominantly red near the surface, and to become extremely acid in reaction. They are unlikely to be developed agriculturally for a considerable time to come. They cover only a small area and will not be discussed further here.

Keta series, developed on the coastal sand-dunes, consists of three inches or so of dark grey to pale grey-brown, humus-stained, loose and grading into a few feet of pale brown to pale yellow loose sand and then similar-coloured sand very weakly mottled orange and containing shells and shell fragments. (Near Keta, to the east of the Volta, certain similar soils contain a calcareous pan at approximately five feet, but this phenomenon has not been recorded within the Accra Plains region, although it may perhaps occur locally).

The upper part of the profile is droughty, but fresh water usually occurs at a depth of 2–4 feet. although it may fall lower during the dry season near settlement due to exploitation for domestic use.

The lower-slope lagoon margins of the soils are cultivated near Ada, apparently by mixing the sand with clay from nearby (soils presumably of Oyibi series), which improves their moisture-retaining capacity and their fertility. Only near Ada, and to a lesser extent, west of Prampram and near Labadi. is the sand-dune sufficiently broad to be considered for large-scale development.

Under natural conditions the soils are almost barren; but they have frequently been disturbed by settlement, with the consequent addition of lagoon clay (from decayed house-walls), shells, fish remains and household refuse. The influence of settlement on soil fertility is often spectacularly demonstrated by the increased vigour of coconut palms on such sites compared with those growing on the undisturbed soils.

VEGETATION

Ada soils support short grasses and sedges, and Songaw soils mixed short and medium grasses both with widely-scattered clumps of thicket in which the wild date palm is conspicuous. Oyibi soils, sometimes carry tall marsh grasses and sedges, but elsewhere occur under short *Paspalum vaginatum* grassland. Muni soils are usually bare, but on less-frequently-flooded sites have a scanty cover of low, creeping, salt-tolerant plants and short sedges or sometimes thin stands of the white mangrove, *Avicennia nitida*. Truku soils occur in *Rhizophora* mangrove swamp. Keta soils characteristically occur under scanty short-grassland with frequent coconut palms.

PRESENT LAND-USE

There is a small amount of grazing on Ada soils in the south-east, but the grassland over Songaw soils in the south-west is unused. Oyibi and Muni soils are virtually unused: grasses and sedges may be cut for thatch from the former, and pigs may forage for 'nuts' (rhizomes of sedges) over the latter soils.

Keta soils are typically utilized for coconut-growing. Around settlements and where the dune is narrow the palms may be irregularly-spaced and of irregular size and age; but elsewhere plantations have been established, especially to the west of Prampram and Ada Fuah. Here the palms are spaced approximately 12 x 12 feet. The copra appears mainly to be used locally and the husks provide an important source of fuel. There are no yields data. Palms appear conspicuously more vigorous near settlements where organic matter and lagoon clay (from decayed house-walls) have accumulated; between such sites, palms are often small and leaves anaemic in appearance.

Patches of very impoverished cassava are occasionally seen on Keta soils. There is very intensive cultivation, however, on a narrow transitional strip at the lagoon edge of the sand-dune between Songaw lagoon and the Volta estuary. Chewing-cane and tomatoes are the most important crops grown, but okro, garden-egg and cassava are grown too. Both mixed and single cropping are practised, the latter usually for cane and tomatoes which are grown as cash crops.

Sugarcane is grown on high ridges. Vegetables are grown on small raised beds. In the case of the more clayey soils, planting holes for vegetable crops have been seen to be filled with sand in which the seed is sown. This presumably provides better aeration and moisture availability to the young seedling.

Planting of sugarcane is carried out as the Volta floods recede in November–December; but the utilization of these particular soils suggest that seepage from freshwater in the sand-dune is also important. Vegetable crops may be planted at this time or at the onset of the main rainy season. Hand-watering of these crops may be practised from shallow wells dug along the sand-dune margin. It has not been established whether manure (cow-dung, bat-manure, household refuse or fish) is added, although this practice is found on similar soils across the river west of Keta where there is continuous cropping of shallots and maize. Since cultivation appears to be continuous, however, it may be implied that manure of some kind is added: annual flooding by water from the Volta is inadequate to maintain fertility. There are no yields data, but crops seen have appeared to be in good condition and yields may be expected to be fairly good.

RECOMMENDATIONS REGARDING LAND-USE

Only the soils of Ada and Songaw series are potentially suitable for development by irrigation. Their suitability requires to be checked by investigating the possible influence of their brackish water-table and whether this might effectively be controlled by drainage. Irrigation might be available from the Volta dam or, in the west, by pumping from the lower Densu or by impounding water behind the causeway at mile four on the Accra-Weija road. The soils would appear particularly suitable for the large-scale production of swamp rice. Large-scale methods of management would be required. The rainfall is too low and erractic for dry-farming to be practicable.

Improvements in the present rather informal methods of growing onions at Bonteanaw and sugarcane, tomatoes and other vegetables near Ada might be introduced when the results of manuring trials being conducted by the Division of Agriculture near Keta are available. Diversification of cropping might be encouraegd: green corn and particularly pulses would be useful additions to the present crops grown.

Increased coconut production from Keta soils can only be achieved by manuring the crop. Fish and household refuse are available for this purpose, and animal manure is also available in some places. Investigations are required to discover whether mineral fertilizers, including trace elements, would give increased yields. The possibility that fertilizers might be made more effective if cover crops were grown on the soil at the same time needs to be examined. The cover crop could be turned directly into the soil, slashed to provide a mulch or grazed by livestock folded on the soils, all of which methods would help to build up the organic matter content of the soil and increase its capacity to retain nutrients. Green-manure crops are likely to achieve little by themselves on these barren sands.

Little increase in productivity is likely from the saline soils, but the possibility that salt might be produced from other lagoons besides Songaw and Sakumo requires to be investigated.

Dry-season roads are practical over the heavy clays (except Truku), but their use must be strictly forbidden when conditions are at all wet if they are to last more than a few months. Bridges and culverts may be needed over creeks and in low spots on Ada, Songaw and Oyibi soils. Major roads should avoid these soils, especially Muni and Truku soils, if alternati e alignments can be found. Where such roads must be built, broad causeways, deep side-drains and frequent bridges or culverts will be required. Songaw and Oyibi soils are liable to cause heaving similar to that experienced in the Black Clays, and the road-surface will need to be insulated from the underlying clay by several feet of inert material in their case.

The loose sand of Keta series makes road-building difficult over these soils. As over the heavy clays, the road-surface needs to be insulated against the unstable sand below by a thick layer of inert fill, preferably resting on a substantial foundation of broken rock. The use of reinforced concrete might have to be considered for particularly unstable stretches.

Conditions on dune-sands are often better within old villages where compact clay from decayed house-walls has accumulated. This suggests that, in localities such as Ada Fuah remote from sources of suitable fill, it might perhaps be possible to use local clays of Ada or Oyibi series—ideally, perhaps, mixed with Keta sand—as fill. Such material would need protection from becoming wet by a well-sealed road-surface and by the provision of side-drains to prevent seepage from adjoining soils. Highly-saline clays, being hygroscopic, would not be suitable for this purpose; even the upper layers of Ada and Oyibi soils would benefit from 'curing' for a time before use or being sluiced with fresh water.

The nearest source of standard road materials in various parts of the tract are:—

in the east, mile 62, Accra-Lagos road, and Nyigbenya Consociation, mile 44½ on the same road;

in the centre, Nyigbenya series in Nyigbenya-Agawtaw Complex (Tract 12) and Korle Consociation (Tract 5) near Dawhwenya;

in the west, Nyigbenya Consociation in Tract 8, Nyigbenya series in Nyigbenya-Hacho Association (Tract 3), Chuim series in Chuim-Gbegbe Association (Tract 3) and Korle Consociation (Tract 5) on the Weija Hills and its outliers.

PART III

SUMMARY OF MAJOR RECOMMENDATIONS FOR THE DEVELOPMENT OF THE ACCRA PLAINS*

General

1. The Accra Plains region presents opportunities for large-scale agricultural development unparalleled elsewhere in Ghana.

2. The maximum development of the region's resources depends on the provision of irrigation from the Volta dam. Even without aid from the latter source, however, the productivity of the region is capable of being considerably increased.

3. The chief aim in development should be to produce food for consumption in Ghana itself, but certain commodities which could be produced might provide the basis for various local processing industries or be suitable for export. Development along the lines recommended would serve to broaden the basis of the country's economy and make her more nearly self-supporting.

4. Stock-rearing can play an important part in development. Crop and animal husbandry should in fact, be closely integrated from the start.

5. The whole region should be declared a Land-planning Area and control of land-use and development vested in an Accra Plains Development Authority.

6. A permanent research organisation should be set up within the proposed Development Authotity to deal with the technical problems which will continually arise during and after development.

7. The flanks of the Akwapim Range should be retired from cultivation and protected by forest reserves so as to reduce the intensity of floods in valleys draining from them onto the Accra Plains.

8. Wind-breaks should be planted at frequent intervals inland from the coast in cultivation areas in at least the southern half of the region, especially in irrigated areas, so as to reduce evapo-transpiration losses and damage to crop foliage induced by the constant sea-breeze. Wind-breaks may be needed generally to reduce possible wind-damage to crops during line-squalls ('tornadoes').

9. If the Volta dam is built, consideration should be given to the possibility of producing nitrogenous fertilizers with the aid of hydro-electric power; the possibility of manufacturing phosphatic fertilizers, using imported rock phosphate, should also be considered.

10. Since organic matter is essential to the maintenance of a satisfactory tilth in all the soils except the heavy clays and is unlikely to be available in adequate amounts from alternative sources, consideration should be given to the practicability of installing town and village sewage systems from which valuable organic manure might be obtained.

11. Regardless of whether irrigation might ultimately be possible from the proposed Volta dam or not, a number of development projects might be put in hand forthwith. These would be to some extent investigatory and would provide experience and training of value for the larger-scale development which is ultimately envisaged. Projects which could be undertaken immediately include:—

- (*a*) a trial irrigation scheme along the Lomen creek on the Volta floodplain combining controlled natural flooding with pump-irrigation from the Volta;**
- (*b*) an estate-managed, pilot cattle ranch in one of the recognized grazing areas on which particular attention would be paid to the management of rough-grazing, the development of improved pastures and the production of fodder crops along valley bottoms.

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*This is a summary of the major recommendations to be made in Part III of the final report.

**A survey of the Lower Volta Floodplain commenced under the auspices of the United Nations Special Fund in April, 1960, to assess the potentialities for large-scale agricultural development making use of irrigation and drainage. A similar survey covering the Angaw Creek basin near the mouth of the Volta was undertaken by the Dutch consulting firm of NEDECO in 1959.

12. Of a total area of 1,500 square miles (960,000 acres) which the region comprises, approximately 1,080 square miles (690,000 acres) are potentially available for irrigation from the Volta dam. Of this area, 600 square miles (384,000 ac es) are occupied by heavy impervious clays which appear potentially suitable for irrigation; a further 350 square miles (224,000 acres) are occupied by lighter soils also suitable for irrigation. A total of 950 square miles (608,000 acres) is thus considered potentially suitable for development with the aid of irrigation from the Volta dam.

13. Consideration should be given to the possibility of pumping water above the 200-foot limit of gravity supply in certain areas so as to command a further 50 square miles (32,000 acres) of valuable Black Clays along the central watershed and a smaller area of red loams on the piedmont slope of the Akwapim Range, more particularly between Agomeda and Somanya.

14. Meteorological data should be collected at a number of additional places throughout the region to provide information on potential losses of irrigation water by evapo-transpiration.

15. Investigations are required into the biology of disease vectors which irrigation farming might be expected to encourage so that suitable control measures can be devised ahead of development.

16. The heavy nature of the major soils, the lack of a local tradition of cultivating heavy clays and of the techniques of irrigation, the heavy capital investment involved in the provision of irrigation structures and agricultural equipment, and the need to have firm control over water-usage, drainage, fertilizer-application, planting and harvesting all combine to require that development—at least initially—should be by large-scale, mechanized methods organized on estate lines. Development by independent peasant farmers would be appreciated on lighter-textured soils.

17. Since the cultivation, manurial and water requirements of all the soils, particularly the heavy clays, are practically unknown at present, experimental stations on which comprehensive agronomic investigations can be pursued will be required on each of the major soil associations before their development is undertaken. Investigations should be generally along the lines of those recommended for the Black Clays in the Report on the Detailed Soil Survey of the Kpong Pilot Irrigation Area.

18. Drainage control on developed areas should receive particular attention. To this end, development should proceed by way of complete drainage-units. The design of drainage systems must take into account the high rainfall intensities which periodically occur, the high run-off rates from the heavy clays, the susceptibility of some of the soils to erosion and the fact that storms may occur on soils saturated by recent irrigation.

19. Crops which appear suitable for cultivation include swamp rice, sugarcane, cotton, jute, tobacco, maize, sunflower and a variety of beans. Trials should be made, too, with sisal, pineapples, citrus, mangoes and other fruits, various oil-bearing plants, sorghum, millet, finger millet as well as local subsistence crops. It may be expected to take plant-breeders a number of years before varieties of some of these crops can be produced which are suited both to the environmental conditions and to mechanized irrigation farming.

20. Since significant increases in productivity appear unlikely to be forthcoming, in the short term at least, from traditional methods of animal husbandry, it is recommended that consideration be given to the introduction of large-scale methods of stock-rearing with scientific management. (cf. Recommendation 11*b*). Such development would require the production of large amounts of fodder grasses and legumes from irrigation areas.

21. (*a*) Extension from the Kpong Irrigation Research Station onto the Black Clays belt should only proceed when satisfactory and economic methods of handling and cropping these soils have been elaborated.

(*b*) The Black Clays belt should then systematically be developed, drainage-basin by drainage-basin.

(*c*) The first extension areas might be along the route of the proposed Volta-Tema pipeline using pumped water supplies for irrigation. The design of such scheme should be such that they can readily be converted to gravity irrigation later.

(*d*) When irrigation from the Volta dam becomes available, pump-irrigation schemes on the Black Clays should first be converted to gravity irrigation. Development should then continue outward from the main irrigation canal running along the central E.–W. watershed of the region.

(*e*) Following suitable preliminary investigations, development should then be extended to the other major irrigable soils of the region.

22. All extensions of development should be proceeded by detailed soil topographical and hydrological surveys.

RECOMMENDATIONS RELATING TO DEVELOPMENT WITHOUT THE AID OF IRRIGATION FROM THE VOLTA DAM

23. Increased productivity without the aid of irrigation from the Volta dam depends on:—

(*a*) making more effective use of natural water supplies;
(*b*) introducing more-advanced techniques of crop and stock production;
(*c*) introducing new crops or improved crop varieties;
(*d*) developing better standards of crop and animal husbandry.

24. Stock-rearing would be of relatively greater importance in development. Large-scale methods of organisation would appear to be required (cf. recommendation 20). Particular attention would require to be paid to the management of rough-grazing and the development of valley bottom soils for fodder production.

25. The improvement of water supplies would require greater attention. In the case of domestic supplies, greater use might be made of roof-catchments and of water-holes protected from contamination by stock and domestic effluents. More water-holes need to be excavated along valley bottoms for the benefit of stock; bitumen-lining might be required in certain soils. Reservoir margins need to be protected against trampling and over-grazing, and should be cleared of trees liable to harbour tsetse-fly.

26. Development by local irrigation schemes might be possible in a number of localities. Since in most cases the soils involved are heavy clays, the crops which could be grown and the methods of production required would be similar to those detailed in recommendations 16–19 above; more emphasis on fodder-production would be desirable, however. The projects considered possible include:—

(*a*) the development of parts of the Volta floodplain by controlled natural flooding and pump-irrigation from the Volta (cf. recommendation 11(*a*));
(*b*) gravity-irrigation schemes in valleys, mainly within the Black Clays belt, where the construction of earth dams is practicable;
(*c*) gravity-irrigation schemes on the coastal flats involving the utilization of the causeways, at mile 55½ on the Accra-Lagos road and mile 4½ on the Accra-Weija road as dams; in the latter area, pump-irrigation from the lower Densu might be preferable;
(*d*) the development of valley bottoms generally by flood-control measures.

N.B.—Any such development projects would need to be preceded by detailed soil, topographical and particularly, hydrological surveys.

27. The achievement and maintenance of a satisfactory level of production from the non-irrigable lighter-textured soils of the region depends on:—

(*a*) the maintenance of a satisfactory organic matter status in the soils: this can best be achieved at present by rationalizing the traditional practices of bush-fallowing and mixed cropping;
(*b*) introducing crops, such as sorghum, millet and finger millet more tolerant of drought;
(*c*) cultivating, in suitable localities, plantation crops such as sisal, pineapples and oil palms and market-garden crops such as tomatoes, garden-eggs, onions, spinach and salad vegetables;

(*d*) increasing the economic value of certain crops produced by simple methods of processing;
(*e*) cultivating greater amounts of pulses to provide ground-cover and much-needed protein food.

28. If farmers in the Krobo hill-foot areas cannot be persuaded to practise less-destructive farming methods than at present then enforcement of rational land-use principles by means of a special land-use ordinance should be considered.

29. Investigations are required to examine the potentialities of bush-fallowing on the red earths in both forest and savannah areas.* Investigations should aim at:—

(*a*) selecting fallow species most efficient at restoring fertility to the topsoils fallowing cultivation;
(*b*) controlling the regrowth so that it can be mechanically cleared;
(*c*) producing an economic by-product from the fallow vegetation;
(*d*) in stock-rearing areas, providing a fallow cover that will not harbour tsetse-fly.

30. Only limited extension of cocoa-growing in the region is practicable. Increased production from the areas suitable for cocoa must come from improvements in standards of husbandry.

31. Investigations are required to determine to what extent the use of dry-farming techniques might make crop-production possible on the heavy clays of the region without the aid of irrigation. If development along such lines were shown to be practicable, it would need to be organized on the basis of large-scale, mechanized units.

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*These investigations need not necessarily be undertaken on the Accra Plains since the problems to be examined are of country-wide importance. A solution to these problems would be of particular interest in this region, however, since the red earths are the most heavily farmed soils in the region at present and may be expected to remain so if irrigation development is not generally practicable.

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GLOSSARY

This section is intended to give simple definitions and explanations of some of the technical terms which it has been necessary to use in describing soils, vegetation and land-use in this report. It will be observed that some of the words used are given a more restricted meaning than they have in everyday usage. Where such words are used in the report they have the precise meaning given in this glossary unless the context makes it obvious that they have been used in their general sense.

This glossary is not intended to be encyclopaedic. Readers interested in seeking further information on some of the terms and subjects discussed—and of those not treated, since they are not referred to in this report—should consult soil science, ecology, botany or agriculture text-books or technical dictionaries, copies of which are usually available in the main central libraries.

Acid (reaction)—See *Reaction.*

Alluvium (adj. alluvial)—Sedimentary material deposited by streams and rivers.

Alkaline (reaction)—See *Reaction.*

Arable Crops—Crops, usually annuals, requiring tillage (by plough or hoe) of the soil.

Available nutrients—The part of the store of plant nutrients in the soil which plants can make ready use of.

Available moisture—The part of the supply of moisture in the soil which can be extracted by plant roots.

Rocky (structure)—See *Structure.*

Bottom—See *Topographical site.*

Boulder—Fragment of rock, etc., exceeding 8 inches (200 mm.) in diameter.

Bund—Ridge of earth erected on the soil surface across a slope (or valley bottom) to check the flow of water across the soil surface. Bunds may be required to prevent soil erosion on slopes or to hold water on the soil surface for the cultivation of rice or other crops in valley bottoms.

Calcareous—Containing calcium carbonate (See *Lime*).

Clay (1)—The finest-textured part of the soil consisting of mineral particles less than 0.002 mm. (=approximately 0.00008 of an inch) in diameter. This is the most active part of the mineral portion of the soil providing it with the ability to hold moisture and plant nutrients and with properties such as plasticity, coherence and stickiness.

Clay (2)—Soil textural class in which clay particles are dominant. (See *Texture*).

Cloddy—See *Structure.*

Cloud-water—Water precipitated from clouds or mist enveloping obstacles, especially trees, and dripping or flowing to the ground.

Colluvium (adj. colluvial)—Sedimentary material deposited by surface wash or creep at the base of slopes.

Compact—Dense; with the soil particles fitting tightly against each other.

Complex—(See *Soil Association*).

Compost—Well-rotted organic matter made from waste plant remains.

Concretion (adj. concretionary)—A concentration of a chemical compound cementing soil particles together.

Ironstone concretions are usually hard, almost spherical in shape and orange, red or black in colour. They vary in size from pin-head to several inches in diameter, but are most commonly ¼-¾ of an inch in diameter. Where abundant, they provide a source of 'laterite' gravel for road-making.

Lime (calcareous) concretions are usually white in colour and almost spherical in shape. They may be either hard or soft and vary in diameter from sub-microscopic to more than two inches. Very hard concretions may be dark grey in colour; some of these are irregular in shape and more than 6 inches across their greatest diameter. Some concretions have thin orange (iron) or black (manganese) surfaces.

Manganese concretions are spherical, black, brittle, and usually less than $\frac{1}{4}$-inch in diameter. They are sometimes found intermixed with ironstone and lime concretions.

Consistency—The property of the soil governing its resistance to pressure applied to it (as with the hand or an implement). Resistance is also affected by the moisture content of the soil. Different descriptive terms are used according to whether the soil is wet, moist or dry. The terms used in this report are explained below.

Wet soil

Plastic—Changing shape continuously when pressed.

Sticky—Adhering to other objects.

Moist soil

Loose—Soil particles easily fall apart when disturbed.

Friable—Soil easily crushed (as between thumb and forefinger).

Firm—Soil not easily crushed.

Dry soil

Loose—Soil particles easily fall apart when disturbed.

Hard—Soil not easily crushed or broken.

Consociation—(See *Soil Association*).

Contour—A line on the ground-surface joining points of equal height. (A contour line on a map joins places of equal height above Mean Sea Level).

Crumb (structure)—See *Structure*.

Cover-crop—Crop planted especially to give protection to the soil surface against erosion.

Cucurbits—Plants (of the *Cucurbitaceae* family) such as gourds, melons, etc.

Deficiency-symptoms—Characteristic changes in colour or shape of plant leaves which may indicate that the plant is not obtaining adequate amounts of a particular nutrient or combination of nutrients. (Discoloration or distortion of leaves can also be caused by plant pests and diseases)

Drainage (1)—The relative rapidity with which water is removed from the soil by run-off (*external drainage*) or flow through the profile (*internal drainage*). In well-drained soils, drainage is neither too rapid nor too slow for optimum plant growth. In excessively well-drained soils, drainage is so rapid that plants are liable to suffer from lack of water in the intervals between rainstorms. In poorly-drained soils, drainage is so slow following rainfall (or flooding or irrigation) that the roots of ordinary crop plants are unable to function properly (for lack of oxygen). Impeded drainage refers to poor internal drainage due to the occurrence of an impervious layer within a soil profile.

Drainage (2)—The artificial removal of excess water from the soil surface or from within the soil profile by means of open ditches or internal drains.

Drift—Soil parent material not derived by the direct weathering of the underlying rock *in situ*; transported material. Soils with 'drift' profiles are characterized by the occurrence of a discontinuity—often marked by a stone-line (*q.v.*) in the lower layers. Six types of drift are recognized (in this region), viz.—

plant growth is restricted. The length of the dry period before drought conditions are experienced will vary between soils according to their individual moisture relationships (*q.v.*).

Peneplain—Fine-earth or concretionary material residual on former peneplain surfaces.

Colluvial—Lower-slope colluvium (See *Colluvium*).

Piedmont—Special case of colluvial drift occurring at the foot of steep rocky hills.

Alluvial—Alluvium (*q.v.*).

Terrace—Alluvium deposited by a river (or the sea) at a time in the past when it stood at a higher level than it does at present.

Biotic—Material transported by animals and insects living in the soil (e.g. termites).

Drought—A dry period, usually one of sufficient length to allow soils to dry out to the extent that

Dry (land) farming—Cultivation techniques used in dry areas for the production of crops without irrigation.

Edaphic—A general term for soil influences, especially used in connection with soil conditions in relation to plant growth and distribution.

Erosion—Wearing away of the land surface by running water, wind, etc. This is a natural process which normally proceeds at a very slow pace. Where the soil surface is left unprotected by vegetation, as may happen when land is prepared for cultivation, erosional processes may speed up leading to rapid removal of soil material: this is termed *soil erosion*.

Evapotranspiration—Loss of moisture from the soil by evaporation and plant transpiration.

Fallow—Land left uncropped following a period of cultivation in order to recover fertility before it is again cultivated.

Fallow vegetation—Vegetation growing naturally on fallow land: *grass fallow* where grass regenerates on fallow land; *thicket (or bush) fallow* where woody vegetation regenerates. (See also *Forb regrowth* and *Secondary forest*).

Fertility (Soil)—The inherent property of a soil to provide adequate amounts of plant nutrients for proper plant growth.

Fertilizer—Material added to the soil to supply one or more plant nutrients. The term is generally applied to mineral rather than organic materials. (See *Manure*).

Flood irrigation—See *Irrigation*.

Floodplain—The flat land alongside a stream or river which is subject to periodic flooding.

Forb regrowth—Fallow vegetation consisting mainly of semi-woody herbs and soft-stemmed shrubs.

Friable—Easily crushed (See *Consistency*).

Gilgai—Characteristic, small-scale, mound (or ridge) and hollow, surface relief sometimes occurring on heavy clays, especially those of the Tropical Black and Brown Earths.

Gleisol—Soil in which poor drainage has been the dominant factor in its formation. Gleisols are usually grey in colour but may also be mottled, usually weakly, with yellow, orange or red. Certain soils included in this group on the Accra Plains are black or brown.

Gneiss—Relatively coarse-grained crystalline rock in which the minerals (mainly quartz, feldspar, mica and/or hornblende) appear to be drawn out in thin bands. (See also *Granite* and *Schist*).

Granite—Relatively coarse-grained crystalline rock consisting mainly of quartz, feldspar mica and/or hornblende the crystals of which are more or less regularly distributed. (See also *Gneiss*).

Grassland—Land on which grasses are the most important plants. Subdivisions are made according to the height and nature of the main grasses.

High-grassland—grasses (when in flower) more than 6 feet in height (over-head heigh).

Tall-grassland—grasses 4–6 feet in height (shoulder high).

Medium-grassland—grasses 2–4 feet in height (waist high).

Short-grassland—grasses less than 2 feet in height (knee-height or less).

Swamp-grassland—grassland associated with (fresh-water) swamp; height classes are recognized within this type.

Marsh-grassland—grassland associated with saline or brackish marshland; height classes are recognized within this type.

Gravel—Fragment(s) of rock (especially quartz), concretionary material, etc., between 2 mm and 20 mm (c.1/12th—¾ of an inch) in diameter.

Green manure (crop)—Crop grown especially to be ploughed into the soil in order to increase its organic matter content, at the same time adding to the soil the nutrients it contains and improving the condition of the soil.

Grit (adj. gritty)—Angular (sharp) coarse sand and fine gravel.

Groundwater—Water filling all the pores and fissures in the soil or rock. (See also *Water-table*).

Hardpan—Soil horizon which has become hardened due to cementation with a chemical compound e.g. iron) or to close-packing of the soil particles.

Horizon—One of the natural layers, usually parallel with the ground-surface, occurring within a soil profile.

Humus (adj. humous)—Organic matter in the soil so thoroughly decomposed that its original form is no longer recognizable.

Illite—A mica-like type of clay mineral often associated with alluvial sediments.

Impervious—Not allowing the ready through-passage of water or air.

Inselberg—Isolated, steep-sided, rocky hill rising abruptly above surrounding almost-flat land. The word is German for 'island mountain.'

Ironpan—Soil horizon cemented with iron. This term is preferred to the popular, but less precise, term 'laterite.'

Ironstone—Iron concretion or fragment of ironpan.

Irrigation—The artificial application of water to soils in order to sustain plant growth. *Flood irrigation* involves covering the whole soil surface with water either continuously or periodically. *Furrow irrigation* involves running water along furrows between the ridges on which crops are planted. *Overhead irrigation* involves the application of water to the whole ground-surface by jets or sprays (sprinkler type) from permanent or portable pipes in which the flow is under pressure.

Kaolinite—A common type of clay mineral usually found in well-drained soils, especially those derived from acidic or intermediate rocks under humid conditions.

Landscape—The surface appearance of a tract of land. A natural unit of the landscape is a tract of land having distinctive characteristics in the way of topography, vegetative cover, soil pattern, etc., the combination of which serve to differentiate it from other tracts.

Land-rotation cultivation—The system of cultivation in which land is cultivated for one or more seasons and then abandoned for a few years (in order to restore fertility) before coming under cultivation once more although not necessarily by the same cultivator or within the previous boundaries.

Laterite—Hard, iron-cemented soil. (See also *Ironpan* and *Ironstone*).

Latosol—Well-drained tropical Soil of red or yellow colour characterized by the thoroughly-weathered state of the weatherable mineral matter. In Ghanaian Latosols, the clay mineral is predominantly kaolinitic with variable, but apparently usually low, proportions of iron and aluminium sesquioxides.

Leaching—The removal of fine material or soluble matter down or out of the soil by water draining through the profile.

Legumes (adj. leguminous)—Plants producing their seeds in pods. The term is particularly applied to plants of the pea and bean family. Leguminous plants are important in fallow vegetation (or as cover crops) because of their ability to bring up nutrients from difficultly-available sources in the deeper layers of soils and the association with their roots (in some cases, at least) of bacteriae able to 'fix' nitrogen from the air.

Ley—Pasture (*q.v.*), usually sown, which is used in rotation with arable crops in mixed farming (*q.v.*).

Lime—Used in this report as a popular word for calcium carbonate. Lime occurs naturally in relatively small amounts in certain alkaline soils. Agricultural lime is either ground limestone, slaked lime or burned lime which can be used to reduce soil acidity.

Loam—Soil textural class intermediate between clay and sand (or silt) implying a moderate content of clay, silt and sand. (See *Texture*).

Manure—Animal or vegetable wastes or mineral fertilizers added to the soil to supply one or more plant nutrients. The term is particularly applied to animal and vegetable matter; besides supplying plant nutrients this form of manure also serves to improve the condition of the soil in respect of moisture-retention, structure and, thereby, resistance to erosion.

Mixed farming—Farming system in which both crops and livestock are produced; ideally, the two forms of husbandry are closely integrated.

Mixed cropping—The farming practice in which two or more different crops are grown at the same time on the same piece of land. The individual crops are usually planted at different dates and their growing and harvesting periods overlap.

Moisture relationships—(Strictly, soil-moisture relationships). Conditions in the soil in respect of moisture supply, drainage, and moisture retention and availability of moisture to plants.

Montmorillonite (adj. montorillonitic)—A platy type of clay mineral usually associated with soils derived from basic rocks in sub-humid to sub-arid regions. This type of clay swells on wetting and shrinks on drying, is very sticky and plastic when wet and has a high base-exchange capacity.

Morphology (Soil)—The arrangement of soil horizons with their various properties which serve to characterize a soil profile.

Mottled—Marked with patches of different colours.

Mulch—Material such as crop residues placed or left on the soil surface as a protection against erosion, evaporation of soil moisture or insolation.

Neutral (reaction)—Neither acid nor alkaline in reaction. (See *Reaction*).

Nitrogen (adj. nitrogenous)—One of the major plant nutrients. Supplies are held in the soil by organic matter and released as this decomposes. Nitrogen can also be added by way of chemical fertilizers. This nutrient is easily leached from the soil.

Nutrients (, Plant)—Elements absorbed by a plant which are essential for its growth.

Organic matter—Animal and vegetable material. (See also *Humus*).

Pan—See *Hardpan*.

Laterite—Hard, iron-cemented soil. (See also *Ironpan* and *Ironstone*).

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Nutrients (, Plant)—Elements absorbed by a plant which are essential for its growth.

Organic matter—Animal and vegetable material. (See also *Humus*).

Pan—See *Hardpan*.

Sandstone—Rock consisting mainly of quartz sand cemented together with silica, iron or other chemical compounds.

Savannah (vegetation—A general term for vegetation in which grasses are ecologically dominant (i.e. by their susceptibility to burning, grazing, etc., control the type of woody vegetation which can grow). Savannah vegetation ranges from pure grassland to grassland in which trees or shrubs are so frequent as to form a contiguous, but not complete, cover. (See also *Grassland*).

Parent rock (or material)—The rock (or material) from which a soil profile has developed.

Pasture—Improved grazing land.

Pegmatite—Very coarse-grained crystalline rock of the granite variety. (See *Granite*).

Peneplain—A land-surface worn almost flat by (geological) erosion.

Perched water-table—See *Water-table.*

pH—An index of relative acidity or alkalinity.

pH.7.0 indicates a neutral reaction. Lower values indicate increasing acidity; higher values indicate increasing alkalinity. (See also *Reaction*).

Phase (, Soil)—A subdivision of a soil series (*q.v.*) varying from the normal soils of the series because of disturbance to the profile, usually by man. It is assumed in the case of a soil phase that if environmental factors were allowed to operate without further disturbance the normal profile of the series would be restored. Examples of phases are—eroded phase; cultivated phase; thicket (fallow) phase (of a forest soil). See also *Series* and *Subseries*).

Phosphorus—One of the major plant nutrients. Phosphorus is held in the soil both by clay and organic matter. Only a small fraction of the total content may be usable by plants, especially in soils rich in iron or lime. A higher proportion is usable in horizons containing organic matter. Phosphorus can be added to the oil by way of chemical or natural fertilizers. It is not subject to leaching, but more or less rapidly becomes attached to clay, iron or calcium in the soil and is rendered unavailable to plants.

Phyllite—An altered, hardened, clay-like rock with a shiny lustre and soapy feel breaking into thin plates.

Piedmont—At the foot of a hill.

Pore (adj. porou)—Very small hole or channel allowing water and air to move through the soil.

Potassium (also potash)—One of the major plant nutrients. Potassium is held in the soil by clay and organic matter. It is more readily available to plants where humous is present. Potassium can be added to the soil by way of chemical fertilizers; it is present in large amounts in wood ash, compost or kraal manure added to the soil. It is not subject to rapid leaching, except in very sandy soils.

Prismatic (structure)—(See (*structure*).

Profile (, Soil)—A vertical section through the soil down to the parent rock.

Puddled—Made dense and impervious.

Pulses—Seeds of the pea and bean type used as food.
(See also *Legumes*).

Quartz vein— Band of quartz rock passing through another rock.

Reaction—Degree of acidity or alkalinity. This can be described either in words or by ph values. The corresponding terms are as follows:—

Verbal description	*pH range*
Extremely acid	less than 4.0
Very highly acid	4.1-4.5
Highly acid	4.6-5.0
Very acid	5.1-5.5
Moderately acid	5.6-6.0
Slightly acid	6.1-6.5
Moderately alkaline	8.1-8.5
Very slightly acid	6.6-6.9
Neutral	7.0
Very slightly alkaline	7.1-7.5
Slightly alkaline	7.6-8.0
Very alkaline	8.6-9.0
Highly alkaline	9.1-9.5
Very highly alkaline	9.6-10.0
Extremely alkaline	more than10.0

Slightly acid to neutral conditions are generally considered best for the production of most crops, but individual crops vary in their tolerance of greater acidity or alkalinity. Acidity can be reduced by adding lime to the soil. Alkalinity is more rarely reduced, but this can be effected by improving soil drainage or adding sulphur to the soil (either alone or in compounds containing other nutrients).

Rough-grazing—Unimproved grazing land.

Run-off—Water flowing over the ground-surface.

Saline—Containing, or affected by, salts.

Salts (, Soluble)—Salts occurring in soils which are soluble in the soil water. Certain salts such as sodium chloride (common salt) are harmful to plants when present in the rooting zone in more than very small amounts (about 0.2 per cent).

Sand (1)—Mineral particles in the soil between 0.02–2.0 mm. (approximately 0.0008–0.08 of 1 inch) in diameter. Sand particles can be felt as individual grains between the fingers. Sand normally consists of quartz and similar unweatherable rock particles which have no capacity to retain moisture or nutrients. Where plentiful, sand helps to keep the soil 'open', the interstices between the grains providing passages for the movement of air and water through the soil. The size-class is sometimes subdivided into:

Coarse sand—particles between 0.2-2.0 mm.

Fine sand—particles between 0.02-0.2 mm.

(*Medium sand* is occasionally referred to. This term applies particularly to particles between 0.25–0.5.mm).

Sand (2)—Soil textural class in which sand particles are dominant. (See *Texture*).

Savannah regrowth—Vegetation consisting mainly of grasses which regenerates on abandoned farmland, especially in savannah areas.

Schist—Fine-grained crystalline rock in which the minerals (mainly quartz, feldspar, mica and/or hornblende) appear to be drawn out into thin bands giving the rock marked cleavage. (See *Gnesis*).

Secondary forest—Forest vegetation which has regenerated on land previously cleared for farming, settlement, etc. Secondary forest differs from undisturbed (primary or high) forest in floristic composition, structure and, usually, height. It differs from thicket vegetation (*q.v.*) regenerating on former farmland in (usually) its greater age (more than about 10 years), greater height (20–60 feet according to age) and in the fact that the main woody species possess proper trunks.

Sedentary profile—Soil profile developed directly in the products of rock weathering which have remained more or less in place (See *Drift*).

Seepage—Flow—mainly laterally—of water through the soil.

Series (Soil)—A group of soils with closely similar profile features developed in similar parent materials under similar conditions of climate, vegetation, slope and drainage. This is the normal individual soil unit recognized in this report, but in a few cases *subseries* and *phases* (*q.v.*) have been subdivided. Soil series (and important subseries) are given place names to identify them, e.g. *Akuse series*. The use of such names does not imply that the soils of the series are found only near the place after which they have been named but that they were first identified in that locality. Akuse series, for instance occurs extensively on the Accra Plains between the coast and Akuse and extends across the Volta onto the Ho-Keta Plains.

Sesquioxides—Oxides of (in this report) iron and aluminium. (These oxides have the formulae Fe_2O_3 Al_2O_3, i.e. they contain $1\frac{1}{2}$ units of oxygen to each unit of iron or aluminium).

Shale—A somewhat hardened, clay-like, sedimentary rock.

Silt (1)—Mineral particles in the soil between 0.002–0.02 mm. (approx. 0.000008–0.0008 of 1 inch) in diameter. Between the fingers, silt feels soft and slippery, like talcum powder. Silt particles have a very low, if any, capacity to hold moisture and nutrients.

Silt (2)—Loose term used for alluvial sediment, particularly that consisting mainly of particles of the approximate size of true silt.

Skeletal (soil)—Soil whose profile consists predominantly of hard rock fragments.

Slope—The inclination of the ground-surface. This is usually measured in terms of percentage variation from the horizontal; e.g. a slope of 2 per cent is one with a vertical rise or fall of 2 feet in a horizontal distance of 100 feet. (See also *Topography*).

Slope (Upper, middle, lower)—See *Topographical site*.

Soil—The natural combination of mineral and both living and dead organic materials on the surface of the earth in which plants can grow. An individual soil is a unit within which all, or an (assumed) restricted combination of, soil properties are the same. (See also *Series*, *Subseries*, *Phase and Variant*).

Soil Association—Generally, a group of soil series occurring together within a landscape unit which can be mapped together as one unit. Three kinds of association are recognized, viz—

Soil Consociation—A mapping unit in which the whole, or almost the whole, of the area is occupied by a single soil series. e.g. *Agawtaw Consociation*.

Soil Association—Specifically, a group of soil series, each occupying a characteristic topographical site and together forming a pattern which is repeated on all valley slopes within the unit.

In the simplest case, a soil association comprises two soils developed in similar parent materials but differentiated because of upland member is better drained than the lowland member; e.g. *Aveime-Zipa Association*.

Quartzite—Sandstone so altered by head or pressure that the quartz particles have been fused and re-crystallized.

Quartzite schist—Rock resembling quartzite (*q.v.*) but containing muscovite (white mica) or sericite giving it marked cleavage.

Most soil associations are more complicated than this, however. The typical association comprise a group of soils developed over a particular rock, the upland members of which may have sedentary profiles and the lowland members profiles developed in local colluvium and alluvium. Drainage differences on different topographical sites superimposed on this parent-material pattern may involve the recognition of several soil series within the association. (Although this kind of association occurs commonly elsewhere in the country, there are no typical examples on the Accra Plains).

More complicated associations occur where the upland soils are derived from different parent rocks from those of the lowland soils. Drainage differences attributable to the varied nature of the parent materials as well as to differences of topographical site may be superimposed on this parent material pattern and involved the recognition of many soil series within such an association. *Tojet Agawtaw Association* provides an example of this kind of Association.

Soil Complex—A mapping unit within which, due to complicated geology, unrelated soils occur intermixed and not in a regular topographic sequence; or, if a topographic sequence exists, this is not repeated regularly on other valley-slopes within the unit. *Korle-Okwe Complex* provides an example of this kind of association.

Soil Conservation—The concept of land-use implying the fullest utilization of the soils of an area consistent with their preservation in a condition to resist deterioration in fertility and erosion. Soil conservation is no more than good farming. It involves adjusting the type of husbandry to suit the soil conditions. It may or may not involve the provision of special earth-works to control run-off.

Stone—Fragment of rock $\frac{3}{4}$–8 inches (20–200 mm) in diameter.

Stone-line—Layer of stones, gravel, etc. often occurring at the base of the transported material in drift soil profiles. (See *Drift*).

Structure—The property associated with the cracking or crumbling of the soil into natural fragments on drying. The terms used for various shapes of structural units (peds) are defined below:—

Crumb—Small, porous, rounded peds.

Granular—Small, rounded, non-porous peds.

Blocky—Roughly cuboid peds which may have either angular or subangular corners.

Prismatic—Rectangular (often 6-sided) peds which are longer vertically than they are broad.

Soils or horizons showing no regular or recognizable structure are called *structureless*. The term *cloddy* is applied to irregular lumps of soil, not bounded by natural cracks, produced by cultivation or digging.

Subseries—A subdivision of a soil series (*q.v.*) varying in some minor, but agriculturally significant, inherent property from the normal soils of the series; e.g. depth; greater or lesser proportion of gravel; slope. The distinction between subseries and phases lies in the fact that in subseries the differences apply to inherent properties of the soil (e.g. content of gravel) whereas in phases they apply to alterable properties of the soil (e.g. amount of organic matter in soils which are inherently similar but are found in different stages of the cultivation-fallow cycle).

Subsoil—A general term for the layer, often heavier in texture, below the humous or cultivated layer.

Summit—See *Topographical site*.

Talus—Colluvium (*q.v.*) consisting largely of boulders.

Terrace (1)—Artificial flat area retained by walls useful in checking erosion on steep slopes where these must be cultivated.

Terrace (2)—Relatively flat area near a river (or the coast) at a higher level than the present floodplain (or beach) marking the level of an older floodplain (or beach) when the river (or sea-level) stood higher than it does now.

Texture (, Soil)—Strictly, the composition of the soil in respect of mineral particles of various sizes. The relative proportions of the particles of different sizes to a large extent govern, amongst other things, soil consistency (*q.v.*) and the ease or difficulty of tilling a soil.

The textural classes used in this report take account of the facts that consistency and tillage properties are also influenced by the type as well as the proportion of clay present and also by the proportion of humus present. For instance, a soil which particle-size analysis shows to contain 25 per cent clay is much heavier to work if the clay mineral is montmorillonite than if it is kaolinite. The classes used therefore take into account both particle size and, in effect, consistency when wet.

Textural classes used in this report have been determined by a standard procedure used on all soils sampled. In this, a cubic inch of the sample passing through a 2 mm–mesh sevie (i.e. sand, silt and clay particles only) is wetted until it just does not stick to the fingers when kneaded. It is then manipulated to the point where it begins to show signs of breaking apart. The degree to which it can be manipulated determines the textural class as follows:—

Degree of manipulation	*Textural class*
Will only form a cone	Sand (or silt)
Can be rolled into a ball only	Loamy sand (or silt)
Can be rolled into a short cylinder only	Light loam
Can be rolled into a cylinder $\frac{1}{4}''$ thick, but this cannot be bent	Medium loam
Cylinder formed can be bent to a U-shape	Heavy loam
Cylinder formed can be bent to form almost a complete ring	Light Clay
Cylinder formed easily can be bent into a complete ring	Clay

Adjectives sandy, silty, gritty, gravelly, etc. are added as appropriate to the class names according to the feel of, or visible indications in, the soil.

Thicket—Vegetation type consisting of a dense growth of woody plants not possessing proper trunks, the formation as a whole generally being less than 20 feet in height. Most thicket is regrowth vegetation on fallow land.

Forest thicket is regrowth including young trees of forest species; if left undisturbed it would grow into secondary forest (*q.v.*).

Coastal thicket contains dark-and shiny-leaved species, several of them thorny. It occurs in drier, exposed areas for a few miles inland from the coast. It is often regrowth on former farmland, but when left undisturbed appears to remain stable for a long period.

Dichrostachys thicket (*or scrub*) is low (usually less than 10 feet) thicket consisting mainly of *Dichrostachys* glomerata, a straggling, spiny, acacia-like shrub.

Tilth—Physical condition of the soil in respect of its suitability for plant growth, governed particularly by structure in the topsoil.

Topography—Relief; the shape of the ground-surface over fairly broad areas. Topography is described in terms of both the shape of the landform and the predominating slope (*q.v.*). The terms used are defined as follows:—

Curved Slopes (convex-concave landforms)	*Per cent slope*	*Straight slopes*
Flat	0– ½	Flat
Very gently undulating	½– 2	Very gently sloping
Gently undulating	2– 5	Gently sloping
Gently rolling	5–12	Moderately sloping
Moderately rolling	12–25	Moderately steeply sloping
Steeply rolling	25–50	Steeply sloping
Very steeply rolling	50 +	Very steeply sloping

Topographical site—Position relative to the remainder of the landform. The normal terms used are:—

Summit—The highest part of a landform from which the land slopes away in all, or at least two opposite, directions.

Upper slope—Sometimes used as a general term for the whole of the higher part of a landform. On convex-concave landforms, upper slopes are convex; *i.e.* the slope increases downhill.

Middle slope—The transitional zone between upper and lower slopes in convex-concave landforms where convex slopes change to concave.

Lower slope—The lower, usually concave, part of a landform in which the slope diminishes downhill.

Bottom—The lowest part of a landform.

Topsoil—A general term for the surface layer of a soil, usually humous and lighter-textured and more porous than lower layers.

Trace elements—Elements taken up by plants in very small amounts (compared with the major nutrient elements nitrogen, phosphorus, potassium, sulphur, calcium and magnesium). The more important trace elements required by plants are iron, manganese, zinc, copper, molybdenum, boron and chlorine.

Tract (, Soil)—A natural unit of the landscape (*q.v.*) containing one or more soil associations (*q.v.*).

Variant (, Soil)—A subdivision of a soil series (*q.v.*) differing in one or more significant respects from the normal soils of the series. Variants are really separate series but are not so recognized either because of their small extent or because insufficient is known at the time of the survey about their properties.

Waterlogged—Condition of the soil, or a layer of soil, when it is fully saturated with water.

Watershed—The line on the land-surface separating the area draining towards one valley, stream or river from that draining towards the next valley, stream or river.

Water-table—The upper surface of the layer in the soil or rock which is fully saturated with water. Water-tables may be permanent or temporary, and usually fluctuate in level throughout the year. A *pererched water-table* is one held up above an impervious layer in the soil or rock which separates it from the main water-table below (where this occurs).

Weathered (rock)—Physically and chemically decomposed.

Wind-break—Line of plants, especially trees, planted or retained from the natural vegetation in order to reduce the force of the wind. Wind-breaks give protection to a horizontal distance of approximately three times the height of the obstacle in a line perpendicular to the direction of the wind.

PROFILE DESCRIPTIONS AND ANALYTICAL DATA FOR SOME MAJOR SOILS OF THE ACCRA PLAINS

TABLE I

TOJE SERIES

PROFILE NO: SPA 405
SERIES: TOJE
LOCALITY: approximately ½ mile west of Tema
SITE: summit
VEGETATION: grassland

0-3 inches Dark brown to brown (7.5YR 4/4), slightly humous, crumbly, loose fine sand: pH 7.9.

3-9 inches Reddish brown (5YR 4/4), slightly humous crumbly, loose fine sand: pH 7.7.

9-15 inches Weak red (10YR 4/4), rather firm; porous, structureless fine sand: pH 6.8.

15-38 inches Red (10R 4/8), rather firm; porous, structureless light loam: pH 5.5

38-72 inches Red (10R 4/8), very firm; porous, rather gritty light loam: pH 5.6.

		Particle size distribution (mm) % Pipette-Calgon B.S. 1377/1961										O.M. Percentage oven-dry basis				m.e./100g Exch. Capacity			Extractable Cations						Cation saturation % Relative to
Horizon Numbers	Dry sieve > .2 whole soil	C.S. 2-.2	F.S. - C. silt .2-.02	M. silt - F. silt .02-.002	Clay < .002	International silt .02-.002	Silt .02-.002 clay	Free Fe_2O_3 %	Free Fe_2O_3 clay x 100	$CaCO_3$ Equivalent	Total P. (ppm)	Organic Carbon	Nitrogen	C/N	O.M. (C x 1.72)	pH	T(CEC)NH_3	T(CEC)Ba	Ca	Mg.	Mn.	K	Na	S(TEB)	S/T x 100
1	.1	48.2	47.6	4.3	5.44	-	-	-	-	.005	-	.31	.026	11.9	.53	6.5	-	3.33	1.30	.71	.09	.18	.19	2.47	74
2	.1	46.1	43.0	10.9	6.87	-	-	-	-	.005	-	.15	.015	10.0	.26	6.8	-	1.92	.79	.44	.03	.11	.15	1.52	79
3	.1	48.8	45.9	5.3	12.48	-	-	-	-	.005	-	.08	.010	8.0	.14	6.9	-	1.90	.75	.56	.01	.10	.13	1.55	82
4	.1	44.0	42.1	13.9	21.85	-	-	-	-	.005	-	.09	.016	5.6	.15	6.3	-	3.85	1.45	1.03	.01	.10	.21	2.80	73
5	41.1	34.8	42.1	23.1	29.76	-	-	-	-	.005	-	-	-	-	-	6.8	-	6.58	2.92	2.10	.01	.11	.52	5.67	86
6	87.8	44.6	22.7	32.7	-	-	-	-	-	.005	-	-	-	-	-	6.9	-	14.58	6.58	4.66	.01	.46	1.01	12.72	87
7	1.2	39.6	22.0	38.4	-	-	-	-	-	.005	-	-	-	-	-	7.4	-	14.13	6.23	4.84	.01	.19	1.08	12.35	87
8	10.4	57.8	31.8	10.4	-	-	-	-	-	.34	-	-	-	-	-	8.8	-	9.37	6.29	2.10	.005	.07	.91	9.37	100

TABLE 2

AKUSE (FR/MPR/M SUB-SERIES) (2)

PROFILE NO: APA 449
SERIES: AKUSE, SHALLOW PHASE
LOCALITY: M ½ P. 28, Accra-Prampram road
SITE: Summit of gentle undulation
VEGETATION: Medium grassland.

0-6 inches. Dark greyish brown (2.5Y 4/2), nutty, friable clay with frequent feldspar grit and rare 'alluvial' calcium carbonate concretions: pH 7.4.

6-17 inches. Greyish brown (2.5Y 5/2), cloddy, tenacious clay with abundant feldspar grit and frequent large and small 'alluvial calcium carbonate concretions: pH 7.6.

17-26 inches. Greyish brown (2.5Y 5/2), cloddy, tenacious clay with patches recognizable as highly-decomposed feldspathic rock: occasional calcium carbonate concretions: pH 7.8.

26-38 inches. Pale brownish, light-clayey, highly-weathered rock: pH 7.9.

38-89 inches. Whitish, soft and friable, decomposed highly feldspathic, garnetiferous hornblende gneiss: pH 7.6.

Depth in Inches	Dry Sieve >.2 Whole Soil	C.S. 2-.2	M.S. .6-.2	F.S. + C. Silt .2-.02	M. Silt + F. Silt .02-.002	Clay <.002	(International) Silt .02-.002	Silt .02-.002 Clay	Free Fe_2O_3	Fe_2O_3 Clay	$CaCO_3$ Equivalent	Total P (ppm)	Organic Carbon	N	C/N	Organic matter (C x 1.72)	pH	T(CEC) NH_3	T(CEC) Ba	Ca	Mg	Mn	K	Na	S(TEB)	S x 100 : T	
	Particle size distribution (mm) % Pipette-Calgon-B.S. 1377/1961											O.M. Percentage oven-dry basis						Exch. Capacity (m.e./100g)		Extractable Cations (m.e./100g)						Cation Saturation % Relative to	
0-6	.1	1.99	8.27	22.93	7.65	52.93	7.65	-	-	-	.14	225	.92	.091	10.1	1.58	7.4	-	61.24	40.09	16.18	.01	.33	.96	57.57	94	-
6-17	6.4	3.52	7.66	22.02	8.09	52.89	8.09	-	-	-	.22	252	.63	.060	10.5	1.08	7.6	-	62.13	39.80	18.97	.02	.24	1.75	60.78	98	-
17-26	4.4	4.57	10.77	23.15	9.42	46.31	9.42	-	-	-	.42	391	.50	.046	10.9	.86	7.8	-	57.06	33.81	18.82	.03	.22	2.73	55.58	97	-
26-38	.1	9.14	23.08	28.37	11.41	28.13	11.41	-	-	-	.47	941	.22	-	-	.38	7.9	-	43.50	24.8	14.3	.005	-	-	-	-	-
38-89	.1	1.91	40.68	29.52	12.23	9.41	12.23	-	-	-	.05	1131	-	-	-	-	7.6	-	43.65	19.99	19.15	.005	.18	6.34	45.66	105	-

TABLE 3

AGAWTAW SERIES (1) (FROM THE WEST OF THE REGION)

PROFILE NO: AFA 509
SERIES: AGAWTAW
LOCALITY : ½ mile south of Tema junction (mile 16½ Accra-Lagos) road.
SITE: Middle-lower slope of gentle undulation
VEGETATION: Grassland

0-2 inches. Grey to pale grey (10YR 6/1), slightly humous, loose sand: pH 6.1.

2-12 inches. Pale brownish grey (10YR 6/2), rather firm, porous, fine sand crumbling loose on removal firm profile: pH 6.2.

12-21 inches. Very compact, sandy clay cracking into well-developed, hard, prismatic columns; the outside of the columns dark brown and shiny near the top, but the interior mottled pale brownish grey, black and orange: pH 6.5.

21-60 inches. Pale grey (10YR 7/1), compact, cloddy sandy clay with occasional small calcium carbonate and manganese dioxide concretions: pH 7.6.

60-74 inches. Pale yellow (2.5Y 8/4) compact sandy clay with frequent manganese stains and frequent, medium and small-sized, calcium carbonate concretions: pH 8.1.

N.B. - Bedrock was not reached in this pit.

Depth in Inches	Particle size distribution (mm) % Pipette-Calgon B.S. 1377/1961														O.M. Percentage Oven-dry basis				m.e./100g							
																			Exch. Capacity		Extractable Cations					
	Dry Sieve > 2 Whole Soil	C.S. 2-.6	M.S. .6-.2	F. Sand .2-.06	C. Silt .06-.02	M. Silt .02-.006	F. Silt .006-.002	Clay < .002	International Silt .02-.002 Clay	Silt .02-.002	Free F_2O_3 %	Free Fe_2O_3 Clay	$CaCO_3$ Equivalent	Total P(ppm)	C	O.M. = (C x 1.72)	C/N	pH	T (CEC) NH_3	T (CEC) Ba	Ca	Mg	Mn	K	Na	S(TEB)	Cation Saturation % Relative to
0- 2	.1	16.1	38.6	27.3	11.0	1.0	1.5	4.5	2.5	-	-	-	.002	30	.34	.58	13.1	6.2	-	3.48	1.37	.96	.005	.06	.07	2.46	-
2-12	.1	14.4	38.1	31.5	9.0	1.5	1.0	4.5	2.5	-	-	-	.002	29	.31	.53	12.4	6.1	-	3.29	1.10	.75	.005	.03	.08	1.96	-
12-21	.1	9.9	27.1	17.3	7.1	2.1	1.1	35.4	3.2	-	-	-	.002	158	.59	1.01	11.4	6.0	-	21.30	8.93	4.96	.005	.22	2.18	16.29	-
21-60	.1	6.8	23.5	10.9	20.6	3.7	2.1	32.4	5.8	-	-	-	.002	139	.19	.33	7.9	7.5	-	20.85	9.80	5.57	.005	.15	3.56	19.08	-
60-74	.1	7.3	23.4	19.6	12.5	3.7	2.6	30.9	6.3	-	-	-	.002	140	.14	.24	8.2	7.9	-	20.25	11.97	5.83	.005	.13	4.10	22.03	-
74-	.1	7.3	16.9	14.6	15.2	4.2	5.3	36.5	9.5	-	-	-	.195	162	.05	.09	5.6	8.2	-	26.81	13.15	7.82	.005	.15	4.65	25.77	-
-	22.9	-	-	-	-	-	-	-	-	-	-	-	1.195	-	.04	.07	6.7	8.4	-	-	9.39	7.91	.005	-	-	-	-

TABLE 4

ASHAIMAN SERIES (1) (FROM SOUTH OF THE REGION)

PROFILE NO: AP 228
SERIES: ASHAIMAN
LOCALITY: Approximately ½ - mile west of Tema X-roads.
SITE: Middle slope of gentle undulation
VEGETATION: Stunted medium grassland.
PARENT MATERIAL:

0- 3 inches Very dark greyish brown (10YR 3/2), humous, nutty clay with rare polished ironstone concretions: pH 6.3.

3-10 " Dark brown to brown (10YR 4/3), rather compact, nutty to coddy clay with occasional polished ironstone concretions and rare manganese dioxide concretions: pH 6.4.

10-31 inches Dark brown to brown (10YR 4/3), compact, cloddy clay with spheroidally-weathering boulders or pyroxenite, frequent manganese dioxide concretions and polished ironstone concretions: pH 7.2.

31-36 " Brown (10YR 5/3), light loamy decomposed rock and rare calcium carbonate concretions: pH 7.8.

36-40 " Predominantly brashy, little-weathered pryoxenite: pH 8.2

Depth in inches	Dry sieve >.2 Whole soil	Particle size distribution (mm); pipette-Calgon B.S. 1377/1961: C. Sand 2-.2	F.S.-C. Silt .2-.02	M. Silt-F. Silt .02-.002	Clay <.002	International silt .02-.002	Silt .02-.002 clay	Free Fe_2O_3	Fe_2O_3/Clay x 100	$CaCO_3$ Equivalent	Total P(ppm)	O.M. Percentage Oven-dry basis: Organic Carbon	N	C/N	Organic matter (C x 1.72)	pH	m.e./100g Exch. Capacity: T(CEC) NH_3	T(CEC) Ba	Extractable Cations: Ca	Mg	Mn	K	Na	S(TEB)	Cation Saturation % Relative to: $\frac{S}{T}$ x 100
0- 3	.6	10.6	18.4	71.0	0.18	-	-	-	-	.01	219	1.45	.121	12.0	2.49	6.3	-	40.96	16.60	12.95	.13	.37	1.18	31.23	76
3-10	.6	10.6	15.8	73.6	0.07	-	-	-	-	.02	163	1.19	.091	13.1	2.05	6.4	-	41.93	17.45	13.28	.02	.15	1.20	32.10	77
10-31	2.9	16.8	17.8	65.4	0.58	-	-	-	-	.02	159	.72	.072	10.0	1.24	7.2	-	41.75	18.34	13.41	.03	.15	1.92	33.85	81
31-36	.1	35.4	27.8	36.8	0.73	-	-	-	-	.02	154	.25	.026	9.6	.43	7.8	-	25.41	11.40	8.90	.01	.10	2.14	22.55	89
36-40	95.1	-	-	-	-	-	-	-	-	1.40	-	-	-	-	-	8.2	-	-	-	-	-	-	-	-	-

TABLE 5

DERAKU SERIES (2) (SANDY CLAY SUB-SERIES)

PROFILE NO: APL 647
SERIES: DERAKU
LOCALITY: Approximately 1 mile south-east of Dodowa along Dodowa stream
SITE: Upper slope of very slight undulation in alluvial fan.
VEGETATION: Thicket.

0- 2 inches. Grey-brown (10YR 5/2) humous, sandy heavy loam: pH 7.5.

2- 8 inches. Brown (10YR 5/3), rather loose, sandy light clay: pH 6.0.

8-20 inches. Brown to pale brown (10YR 5/3-5/4), firm porous, sandy light clay: pH 5.1.

20-34 inches. Pale brown, ironstone, firm, porous sandy light clay pH 5.1.

34-48 inches. Pale brown, slightly mottled grey, yellow and orange, very firm; porous, sandy clay: pH 5.0

48-62 inches. Pale grey, yellow and orange mottled, very firm, porous, sandy clay: pH 4.8.

62-72 inches White and red, strongly-mottled, hair, porous, cloddy clay: pH 5.3.

Depth in Inches	Dry Sieve > .2 Whole Soil	Particle size distribution (mm) % Pipette-Calgon B.S. 1377/1961: C. Sand 2 -.2	F.S.-C. Silt .2-.02	M. Silt-F. Silt .02-.002	Clay < .002	International Silt .02-.002	Silt .02-.002 Clay	Free Fe_2O_3	Fe_2O_3 Clay x 100	$CaCO_3$ Equivalent	Total P(ppm)	O.M. Percentage Oven-dry basis: Organic Carbon	N	C/N	Organic matter (C x 1.72)	pH	m.e./100g Exch. Capacity: T(CEC) NH_3	T(CEC) Ba	Extractable Cations: Ca	Mg	Mn	K	Na	Cation Saturation Relative to: S(TEB)	$\frac{S}{T}$ x 100
0- 2	.1	31.3	37.2	31.5	0.61	-	-	-	-	.015	132	1.66	.146	11.4	2.86	7.5	-	11.25	7.16	2.43	.28	.35	.56	10.78	96
2- 8	.1	41.2	32.6	26.2	0.00	-	-	-	-	.002	76	.37	.036	10.3	.64	6.0	-	5.79	1.75	1.43	.05	.12	.54	3.89	67
8-20	.1	43.6	26.9	29.5	0.37	-	-	-	-	.002	68	.30	.033	9.1	.52	5.1	-	6.75	1.65	1.21	.07	.08	.31	3.32	49
20-34	.1	42.5	23.6	33.9	0.92	-	-	-	-	.002	65	.23	.33	6.6	.40	5.1	-	6.71	1.51	.80	.06	.07	.29	2.73	41
34-48	.1	31.6	23.1	45.3	0.30	-	-	-	-	.002	59	.15	.035	4.3	.26	5.0	-	7.43	1.42	.64	.02	.09	.37	2.54	34
48-62	.1	33.4	24.2	42.4	0.37	-	-	-	-	.002	53	-	-	-	-	4.8	-	5.78	1.42	.70	.02	.08	.36	2.58	48
62-72	.1	35.0	17.0	48.0	0.99	-	-	-	-	.002	60	-	-	-	-	5.3	-	10.08	3.16	1.32	.01	.08	.74	5.31	53

TABLE 6

TETEDIM SERIES (2)

PROFILE NO: APA 209
SERIES: TETEDIM
LOCALITY: Traverse 22b/chain 380 (approximately ½-mile from western foot of Shai Hills).
SITE: Middle slope of piedmont slope.
VEGETATION: Grassland.

0- 4 inches. Very dark grey-brown (2.5Y 3/2), humous, porous granular to nutty clay with abundant, very small, manganese dioxide concretions: pH 6.4.

4-10 " Dark greyish brown (10YR 4/2), porous, granular to nutty clay with abundant, very small manganese dioxide concretions. and occasional, small period, ironstone concretions: pH 6.4.

10 inches Indistinct boundary.

10-21 inches Very dark greyish brown (10YR 3/2), compact and cloddy plastic clay with frequent, small, manganese dioxide concretions and polished ironstone concretions: pH 6.8.

21-41 inches. Dark grey-brown (2.5Y 4/2), compact and cloddy clay with frequent small, manganese dioxide concretions, frequent, very small polished ironstone concretions, and very rare, hard, calcium carbonate concretions: pH 7.8.

41-54 inches. Very dark grey-brown (10YR 3/2), very compact and cloddy clay with frequent, hard calcium carbonate concretions, frequent manganese dioxide concretions, and rare, polished ironstone concretions: pH 8.3 Sharp boundary.

54 inches. Sharp boundary

54-66 inches. Pale yellow (5Y 7/3), friable clay with very abundant, small, calcium carbonate concretions and frequent large manganese dioxide concretions: pH 8.3.

66-80 inches. Pale olive (5Y 6/2), friable, calcareous clay with dominant small calcium carbonate concretions and rare, polished ironstone concretions and quartz grit: pH 8.4.

80-96 inches. Garnetiferous hornblende gneiss, with highly weathered, friable band, against little-weathered, brashy band: pH 8.4.

96+ inches. Similar to the horizon above.

Depth in inches	Particle size distribution (mm) % Pipette-Calgon B.S. 1377/1961: Dry Sieve > .2 whole soil	C.S. 2-.6	M.S. .6-.2	F.S. - C. Silt .2-.02	M. Silt-F. Silt .02-.002	Clay < .002	International Silt .02-.002	Silt .02-.002 clay	Free Fe_2O_3	Fe_2O_3 Clay x 100	$CaCO_3$ Equivalent	Total P(ppm)	O.M. Percentage oven-dry basis: Organic Carbon	N	C/N	Organic Matter (C x 1.72)	pH	m.e./100g Exch. Capacity: T(CEC) NH_3	T(CEC)Ba	Extractable Cations: Ca	Mg	Mn	K	Na	Cation Saturation % Relative to: S(TEB)	
0- 4	.4	2.6	13.8	30.7	7.2	45.7	7.2	-	-	-	.04	-	1.94	.140	13.9	3.34	6.4	43.2	50.40	25.8	16.19	.68	.22	1.89	44.28	-
4-10	.6	3.0	13.8	25.8	6.8	50.6	6.8	-	-	-	.03	-	1.36	.106	12.8	2.34	6.5	46.0	53.71	27.8	15.34	.36	.13	1.44	44.69	-
10-21	1.0	2.2	11.2	22.1	6.7	57.8	6.7	-	-	-	.06	-	.75	.069	10.9	1.29	6.8	48.4	55.12	29.4	17.35	.14	.20	1.87	49.27	-
21-41	1.7	2.6	11.5	21.2	6.9	57.8	6.9	-	-	-	.07	-	.44	.044	10.0	.76	7.8	53.1	59.36	33.4	20.86	.01	.10	2.72	56.79	-
41.54	16.0	2.7	9.3	18.0	6.7	63.3	6.7	-	-	-	.462	-	.25	-	-	.43	8.3	54.5	83.38	36.5	22.94	.05	.04	3.40	83.38	
54-66	11.0	7.2	11.2	20.4	7.9	53.3	7.9	-	-	-	26.4	-	.02	-	-	.04	8.3	38.3	-	27.3	-	-	.37	-	-	-
66-80	24.7	24.7	17.1	18.0	5.7	47.1	5.7	-	-	-	48.3	-	-	-	-	-	8.4	21.8	-	16.2	-	-	-	-	-	-
80-96	8.8	8.6	29.0	33.3	7.3	21.8	7.3	-	-	-	.44	-	-	-	-	-	8.4	27.71	30.89	19.1	-	-	-	-	-	-

TABLE 7

TACHEM SERIES

PROFILE NO: APA 248
SERIES : TACHEM
LOCALITY : JAWPA stream, 1 mile south of Gigiduku.
SITE : Bottom
VEGETATION: Swamp-grassland.

0- 3 inches Dark grey (10YR 4/1), humous, compact, very fine sandy clay crumbling granular at the surface when dry; occasional very small, manganese dioxide concretions: pH 5.9.

3- 6 " Dark greyish brown (10YR 4/3), heavy, cloddy plastic clay with very frequent, very small, soft, iron, hydroxide concretions and occasional manganese dioxide concretions: pH 5.0.

19-39 inches Brown (10YR 5/3), heavy plastic clay, rather friable when dry, with frequent, very small, soft iron hydroxide concretions and occasional manganese dioxide concretions: pH 5.0.

39-54 " Brown (10YR 5/3), heavy, highly plastic clay, with abundant very small, soft, iron hydroxide concretions: pH 5.1.

54-77 " Mid-grey strongly mottled bright red, heavy, highly plastic clay: pH 4.7.

77-84 " Pale grey strongly mottled orange and red, heavy, highly plastic clay, the centre of some of the iron stains forming small soft, spherical ironstone concretions: pH 4.9.

Depth in inches	Dry sieve> .2 Whole soil	Particle size distribution (mm) % Pipette-Calgon B.S. 1377/1961: C.S. 2-.6	M.S. .6-.2	F.S.-C.S. .2-.02	M.S.-T.S. .02-.002	Clay .002	International silt .02-.002	Silt .02-.002 clay	Free P_2O_3 %	Free Fe_2O_3 Clay	$CaCO_3$	Total P (ppm)	O.M. Percentage Oven-dry basis: Organic Carbon	O.M. = C x 1.72	C/N	H_2O	pH	m.e./100g Exch. Capacity: T(CEC) NH_3	T(CEC) Ba	Extractable Cations: Ca	Mg	Mn	K	Na	S(TEB)	Cation Saturation % Relative to: S/T x 100
0- 3	.1	2.7	5.8	39.0	9.7	42.8	9.7	-	-	-	.04	317	2.20	.153	14.4	3.78	5.9	-	41.10	15.97	11.71	.25	.63	.10	28.66	70
3- 6	.1	1.1	8.7	32.3	8.5	49.4	8.5	-	-	-	.002	316	1.68	.127	13.2	2.89	5.8	-	43.62	16.90	13.61	.25	.48	.30	31.34	72
6-19	.1	1.3	6.9	16.8	4.7	70.3	4.7	-	-	-	.002	311	1.11	.098	11.3	1.91	5.0	-	50.12	16.16	16.46	.10	.48	.90	34.10	68
19-39	.1	1.6	7.2	18.0	5.5	67.7	5.5	-	-	-	.002	256	.88	.095	9.3	1.51	5.0	-	48.33	15.36	15.27	.03	.38	1.30	32.34	67
39-54	.1	2.5	8.8	20.0	7.2	61.5	7.2	-	-	-	.002	175	.47	.050	9.4	.81	5.1	-	45.20	16.57	15.91	.04	.22	2.10	34.84	77
54-77	.1	1.0	5.5	18.0	6.1	69.4	6.1	-	-	-	.002	181	-	-	-	-	4.7	-	53.94	19.90	20.92	.02	.47	3.20	44.51	86
77-84	.1	1.1	9.8	23.9	4.2	61.0	4.2	-	-	-	.002	-	-	-	-	-	4.9	-	-	-	-	-	-	-	-	-

*A further profile description together with detailed analytical data have been given for this series in the Report on the Detailed Soil Survey of the Kpong Pilot Irrigation Area (12).

TABLE 8

TEFLE SERIES

PROFILE NO: APA 96
SERIES: TEFLE
LOCALITY: 4 miles N. East of Mile Post 63, Accra-Ada road.
SITE: Bottom
VEGETATION: Tall swamp-grassland.

0- 4 inches greyish brown (2.5Y 5/2), humous, compact, cloddy heavy clay: pH 4.6.

4-16 " Dark greyish brown (2.5Y 4/2), humous, compact, cloddy, heavy clay with rusty root-channels and bright orange stains along cracks: pH 4.8.

16-32 inches Mid-grey, strongly stained bright orange, heavy, cloddy clay: pH 4.8.

32-60 " Pale grey, strongly stained dark grey and orange, heavy, massive clay: pH 4.9.

60-87 " Pale grey, stained orange, compact, rather silty clay: pH 5.4.

Depth in Inches	Dry Sieve > .2 Whole Soil	Particle size distribution (mm) % Pipette-Calgon B.S. 1377/1961: C.S. 2-.6	M.S. .6-.2	F.S.-C. Silt .2-.02	M. Silt - F. Silt .02-.002	Clay < .002	International Silt .02-.002	Silt Clay	Free Fe_2O_3	Free Fe_2O_3 Clay x 100	$CaCO_3$ Equivalent	Total P(ppm)	O.M. Percentage Oven-dry basis: Organic Carbon	N	C/N	Organic Matter (C x 1.72)	pH	m.e./100g Exch. Capacity: T(CEC) NH_3	T(CEC) Ba	Extractable Cations: Ca	Mg	Mn	K	Na	Cation Saturation Relative to: S(TEB)	$\frac{S}{T}$ x 100
0- 4	.1	.1	.1	2.9	12.9	84.1	12.9	-	-	-	.002	591	3.47	.350	9.81	5.97	4.6	37.23	-	10.48	9.03	1.11	1.97	.75	23.34	-
4-16	.1	.1	.1	1.6	10.7	87.6	10.7	-	-	-	.002	515	2.16	.249	8.67	3.72	4.8	35.62	-	12.28	9.31	1.01	1.45	1.27	25.32	-
16-32	.1	.1	.1	1.2	9.5	89.2	9.5	-	-	-	.002	277	.84	.091	9.23	1.44	4.8	34.29	-	11.44	11.70	.85	1.06	.92	25.97	-
32-60	.1	.1	.1	4.5	21.8	73.6	21.8	-	-	-	.002	175	-	-	-	-	4.9	30.65	-	9.35	11.26	.82	.66	2.28	24.37	-
60-87	.1	.1	.1	23.7	32.8	43.4	32.8	-	-	-	.002	499	-	-	-	-	5.4	23.14	-	6.46	8.23	.78	.35	.99	16.87	-

TABLE 9

ADA SERIES

PROFILE NO: ADA 306
SERIES : ADA
LOCALITY : M.P. 64, Accra-Ada road
SITE : Flat
VEGETATION: short-grassland

0- 2 inches — Grey to pale grey (10YR 6/1), slightly humous, rather firm; porous, very fine sandy clay with rusty root-channels: pH 5.9.

2-10 " — Greyish brown (10YR 5/2), firm; porous, very fine sandy clay with rusty root-channels: pH 3.9.

10-25 inches — Mid-grey and red, strongly mottled, very compact, plastic clay cracking into large prismatic units when dry: pH 4.0.

25-47 " — Pale grey and red, strongly mottled, very compact, plastic clay cracking into prismatic units continuous from the horizon above: pH 3.9.

47-72 " — Pale yellowish brown, orange and red, strongly mottled, compact, massive; plastic clay: pH 4.0.

72-82 " — Similar to the horizon above, but with frequent gypsum needless: pH 4.0.

	Particle size distribution (mm) % Pipette-Calgon B.S. 1377/1961												O.M. Percentage Oven-dry basis					Exch. Capacity (m.e./100g)		Extractable Cations (m.e./100g)						Cation Saturation % Relative to
Depth in Inches	Dry Sieve >2 Whole Soil	C.S. 2-.6	M.S. .6-.2	F.S.-C. Silt .2-.02	M. Silt-F. Silt .02-.002	Clay < .002	International Silt .02-.002	Silt .02-.002 Clay	Free Fe_2O_3	Fe_2O_3 Clay x 100	CaCO3 Equivalent	Total P (ppm)	Organic Carbon	N	C/N	Organic Matter (C. x 1.72)	pH	T(CEC) NH_3	T(CEC) Ba	Ca	Mg	Mn	K	Na	S(TEB)	S/T x 100
0- 2	.1	1.2	10.7	49.6	16.5	22.0	16.5	-	-	-	.002	116	1.76	.109	16.15	3.03	5.9	-	13.14	4.98	2.97	.30	.31	.01	8.56	61.5
2-10	.2	2.8	10.6	37.6	11.0	38.0	11.0	-	-	-	.002	73	1.06	.066	16.06	1.82	3.9	-	15.74	2.07	2.00	.02	.12	.01	4.21	26.7
10-25	.4	2.9	12.8	35.0	11.7	37.6	11.7	-	-	-	.002	44	.35	.032	10.94	.60	4.0	-	11.79	2.16	1.87	.02	.09	.30	4.44	37.7
25-47	.1	1.0	5.2	20.3	12.4	61.1	12.4	-	-	-	.002	58	-	-	-	-	3.9	-	19.35	4.74	3.96	.04	.13	1.59	10.46	54.1
47-72	.1	.5	5.3	21.4	17.2	57.6	17.2	-	-	-	.002	92	-	-	-	-	4.0	-	19.68	5.80	3.62	.03	.14	1.64	11.24	57.1
72-82	.1	.1	4.6	26.0	20.7	47.8	20.7	-	-	-	.002	91	-	-	-	-	4.0	-	15.80	5.63	2.05	.04	.21	1.28	10.01	63.4

TABLE 10

AVEIME SERIES

PROFILE NO: APA 312
SEIRES : AVEIME
LOCALITY : Traverse 70/chain 37 (5 miles east of Aveime).
SITE : Upper slope of very gentle undulation.
VEGETATION: Short grassland (Heteropogon contortus).

0-6 inches Dark yellowish-brown (10YR 4/4), slightly humous, porous, rather crumbly light loam: pH 6.4.

6-16 inches Dark brown to brown (7.5YR 4/4), porous, rather crumbly light clay: pH 5.7.

16-30 inches Red (2.5YR 5/6), rather firm; porous clay: pH 5.5.

30-64 inches Red (2.5YR 5/6), rather firm; porous, light clay: pH 5.1

64-74 inches Reddish yellow (5YR 6/8), very faintly mottled, rather firm; porous light clay: pH 5.9.

Depth in inches	Dry Sieve >.2 Whole soil	Particle size distribution (mm) % Pipette-Calgon B.S. 1377/1961: C.S. 2-.2	F.S.-C. Silt .02-.02	M. Silt - F. Silt .02-.002	Clay < .002	International silt .02-.002	Silt .02-.002 Clay	Free Fe_2O_3 %	Free Fe_2O_3 Clay x 100	$CaCO_3$ Equivalent	Total P(ppm)	O.M. Percentage oven-dry basis: Organic Carbon	N	C/N	Organic Matter (C x 1.72)	pH	m.e./100g Exch. Capacity: T(CEC) NH_3	T(CEC) Ba	Extractable Cations: Ca	Mg	Mn	K	Na	S(TEB)	Cation Saturation % Relative to: S/T x 100
0- 6	.1	35.5	47.4	17.1	0.96	-	-	-	-	.002	107	.61	.046	13.1	1.05	6.4	-	8.71	3.29	1.50	.29	.26	-	5.24	60
6-16	.1	32.4	39.2	28.4	0.18	-	-	-	-	.002	112	.45	.042	10.7	.77	5.7	-	7.71	2.98	1.57	.19	.19	-	4.93	64
16-30	.1	19.9	29.3	50.9	0.65	-	-	-	-	.002	74	.23	.051	4.8	.[illegible]	5.5	-	10.22	2.76	2.41	.08	.20	-	5.45	53
30-64	.1	19.6	28.5	51.9	0.59	-	-	-	-	.002	126	-	-	-	-	5.1	-	10.79	3.58	2.26	.11	.14	-	6.09	56
64-74	.1	19.2	26.9	53.9	0.92	-	-	-	-	.002	89	-	-	-	-	5.9	-	9.34	3.98	2.51	.03	.10	-	6.62	71

TABLE II

PROFILE OF OYARIFA SERIES

PROFILE NO : APA 538(1)
SERIES: OYARIFA
LOCALITY : 10 chains east of Aimensa, Accra-Aburi road
SITE: Middle of gentle piedmont slope
VEGETATION: Degraded forest thicket

0-3 inches Brown (7.5YR 5/4) friable and loose light loam: pH 5.9

3-10 inches Strong brown (7.5YR 5/6), porous, sandy-light loam; pH 5.1.

10-24 inches Reddish brown (5YR 4/4), firm, porous sandy loam: pH 4.2.

24-44 inches Yellowish red (5YR 4/6), firm, porous, sandy-light clay: pH 4.2.

44-64 inches Yellowish red (5YR 5/6), slightly mottled grey and yellow, rather hard, porous, sandy clay: pH 4.8.

64-82 inches Reddish yellow (5YR 6/6), slightly mottled grey and orange, compact, sandy-light clay matrix with slightly ferruginized, brashy, Akwapimian quartzite: pH 4.2.

Lower Depth of Horizon in Inches	International Scale					Organic Matter % oven-dry basis				Moisture Air-dry soil
	Clay <.002	C. Sand 2-.2	F. Sand	Silt .02-.002	Clay .002	C	N	C/N	O.M. (C x 1.72)	
3	8.5	43.3	34.9	13.3	8.5	1.24	.109	11.4	2.13	1.12
110	9.4	51.4	27.4	11.8	9.4	.75	.069	10.9	1.29	.96
24	17.4	36.5	32.8	13.3	17.4	.48	.048	10.0	.83	1.41
44	28.0	28.5	29.0	14.5	28.0	.36	.054	6.7	.62	2.31
64	26.0	29.4	28.3	15.7	26.6	.21	.032	6.2	.36	1.91
85	23.2	28.1	31.7	17.0	23.3	.12	.030	4.0	.21	1.66

Lower Depth of Horizon in Inches	PH	CaCO3 per cent oven-dry	Exchange Complex m.e./100 oven-dry basis										Phosphorus ppm.	
			T(CEC)	Ca	Mg	Mn	K	Na	S (TEB)	$\frac{S}{T}$ x 100	Ca/Mg	MgK	Total	Acid(Truog) Soluble
3	5.9	.002	8.57	3.81	1.82	.33	.34	.28	6.58	77	2.09	5.4	112	5
10	5.1	.002	6.72	1.79	1.29	.27	.23	.27	3.85	57	1.39	3.6	88	5
24	4.2	.002	8.36	.59	.67	.02	.19	.29	1.76	21	.88	3.1	85	2
44	4.2	.002	10.28	1.00	1.32	.01	.22	.41	2.96	29	.76	6.0	88	
64	4.8	.002	8.35	.92	1.11	.01	.17	.50	2.71	32	.83	6.5		
85	4.2	.002	7.03											

TABLE 12

PROFILE OF MAMFE SERIES

PROFILE NO: APA 595
SERIES: MAMFE
LOCALITY : Southern outskirts of Kitasi village, Akwapim summit.
SITE : Upper slope of Akwapim Range.
VEGETATION: Forest thicket

0- 4 inches. Very dark greyish brown (10YR 3/2), loose, sandy, light loam: pH 6.6.

4-12 inches. Dark brown (10YR 4/3), sandy light loam with occasional ironstone concretions and ironstained quartzite stones: pH 6.5.

12-16 inches Brown (7.5YR 4/4), sandy clay with abundant ironstone concretions, and frequent stones of weathered quartzite, sandstone and phyllite: pH 6.5.

16-32 inches Reddish-brown (5YR 4/4), sandy clay with abundant ironstone concretions and occasional stones and gravel of ferruginized Akwapim rocks: pH 5.3.

32-48 inches Pale red and yellow sandy clay with rare ironstone concretions in interstices of disintegrated ferruginized quartzite: pH 4.6.

48-72 inches Pale red and yellow, disintegrated ferruginized quartzite: pH 5.0.

Lower Depth of Horizon in Inches	Clay <.002	C. Sand 2-.2	F. Sand .2-.02	Silt .02-.002	Clay <.002	Organic Matter % Oven-dry Basis: C	N	C/N	O.M. (Cx1.72)	% Moisture Air-dry Soil
4	0.02	48.8	23.2	28.1	-	4.52	.381	11.86	7.77	3.50
12	0.41	50.9	23.2	25.9	-	1.03	.086	11.98	1.77	1.55
16	0.33	45.2	24.5	33.3	-	.80	.072	11.11	1.38	2.81
32	0.51	36.3	9.2	54.5	-	.56	.073	7.67	.96	4.49
48	0.84	47.9	10.3	41.8	-	.44	.059	7.46	.76	2.88
72	0.13	80.7	7.2	12.1	-	-	-	-	-	.56

Lower Depth of Horizon in Inches	pH	$CaCO_3$ per cent Oven-dry	Exchange Complex m.e./100 Oven-dry Basis: T(CEC)	Ca	Mg	Mn	K	Na	S(TEB)	$\frac{S}{T}$ x 100	Ca/Mg	MgK	Conductivity at 25°C mho x 10^3	Phosphorus ppm. Acid Total Soluble
4	6.6	0.05	35.61	21.21	6.52	.24	.41	-	28.38	79.70	3.25	15.90	-	434
12	6.5	0.03	12.52	6.12	2.52	.07	.14	-	8.85	70.69	2.43	18.00	-	212
16	6.5	0.02	15.04	6.83	2.94	.02	.16	-	9.95	66.16	2.32	18.38	-	283
32	5.3	Nil	18.51	4.80	3.17	.01	.18	-	8.16	44.08	1.51	17.61	-	351
48	4.6	Nil	11.77	1.74	1.55	.01	.12	-	3.42	29.06	1.12	12.92	-	206
72	5.0	Nil	1.96	.28	.25	.01	.02	-	.56	28.57	1.12	12.50	-	344

TABLE 13

PROFILE OF AKUSE SERIES

PROFILE NO: [illegible] 364
SERIES: AKUSE
LOCALITY: Kpong Pilot Area, traverse 44/11 chains
SITE: Middle slope to upper-slope of gently rolling topography M.
VEGETATION: Medium grassland.

0- 4 inches. Dark grey (5Y 4/1), weakly granular to nuciform, sandy clay with occasional very small manganese dioxide concretions; no visible calcium carbonate: pH 7.5.

4-21 inches. Grey (5Y 5/1), angular blocky to coarse, cloddy clay with frequent very small manganese dioxide concretions and rare quartz pebbles and gravel; occasional small, calcium carbonate concretions: pH 8.0, very plastic wet, very hard dry.

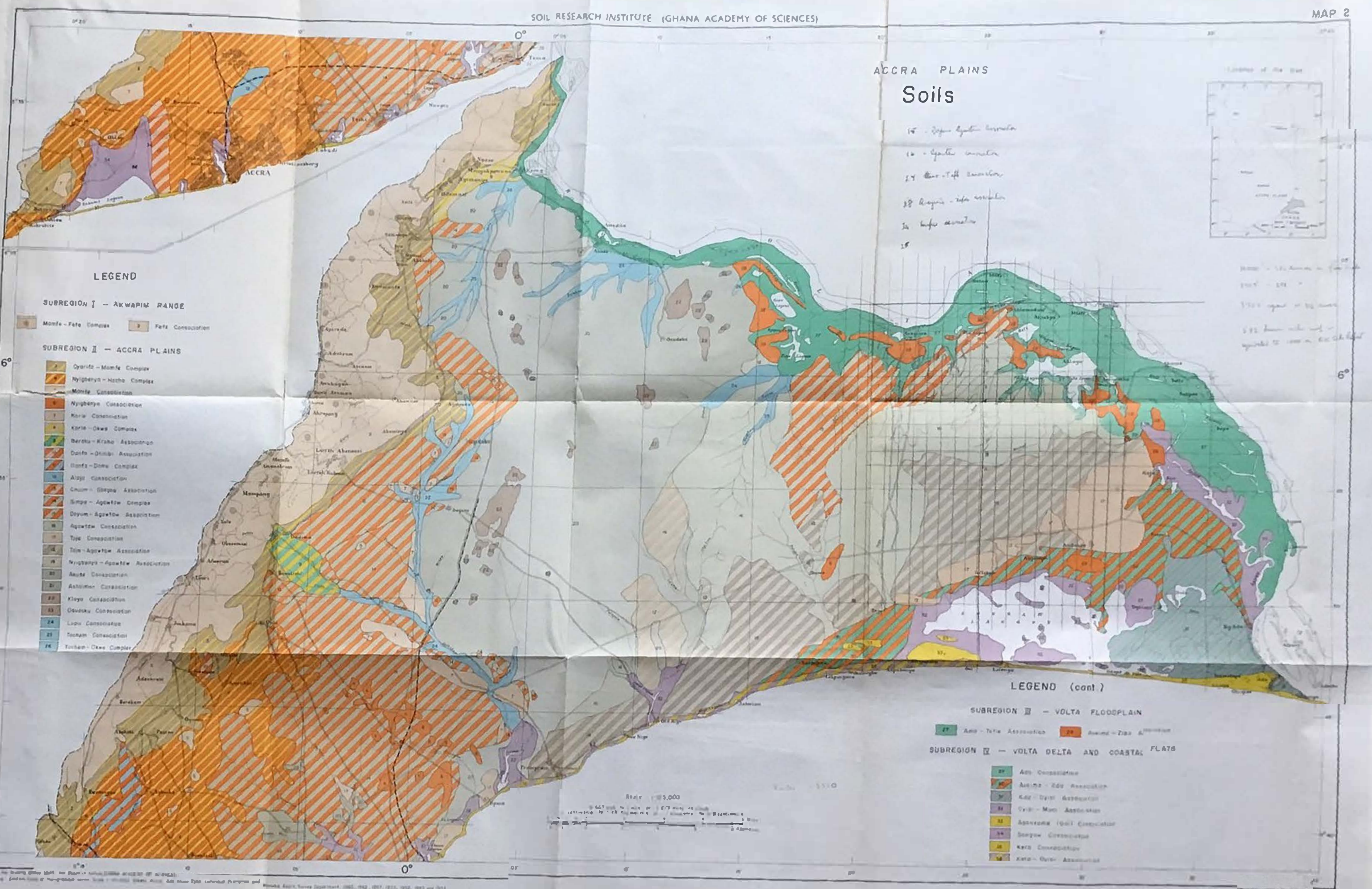
21-35 inches. Grey to pale grey (5Y 6/1), subangular blocky to coarse, cloddy, compact clay with occasional small, hard calcium carbonate concretions, frequent small manganese dioxide concretions, and rare fine quartz gravel: pH 8.5; very plastic wet, very hard dry.

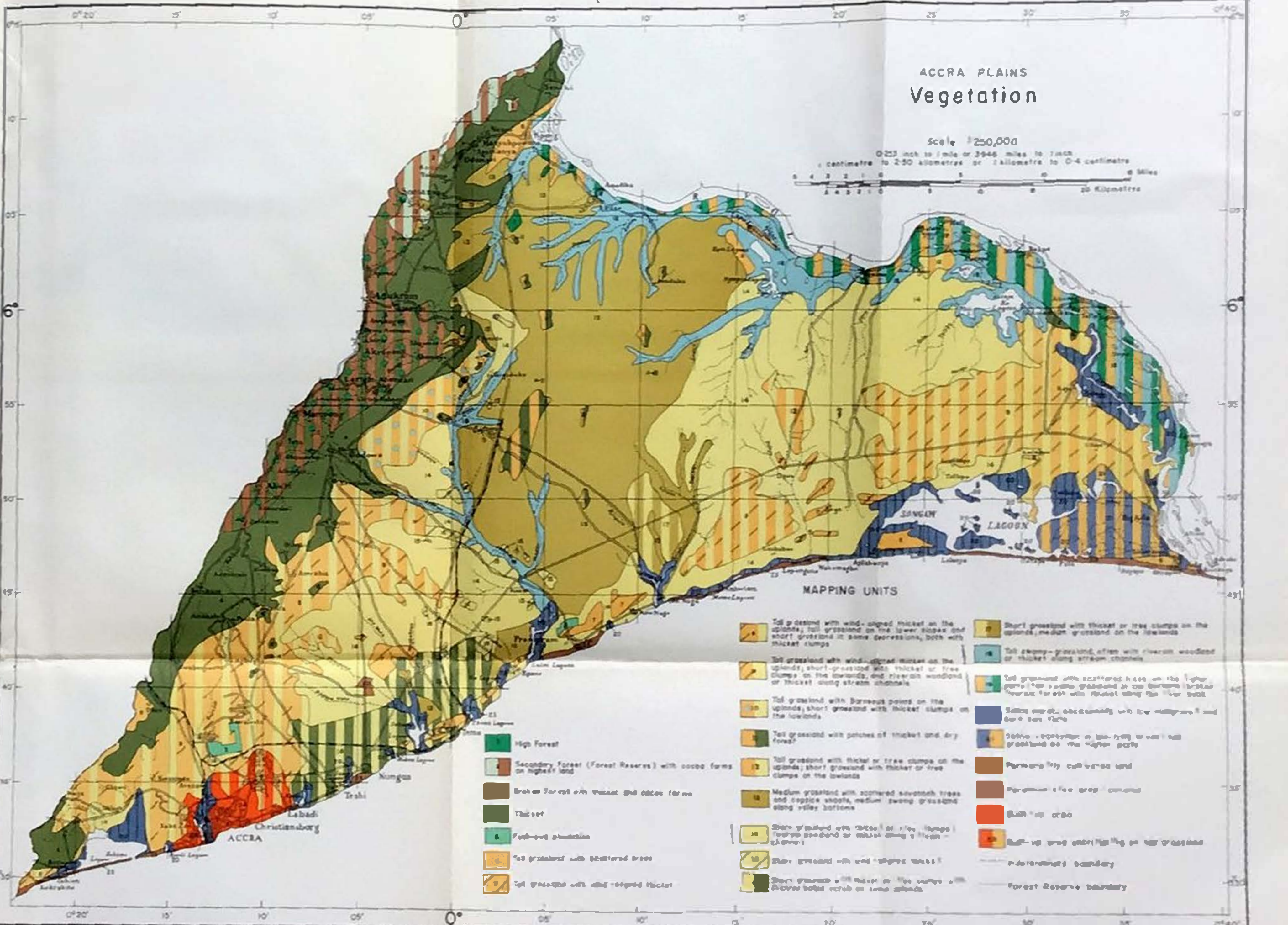
35-52 inches. Grey to pale grey (5Y 6/1), massive clay with abundant small and medium-sized calcium carbonate concretions and rare fine quartz gravel: pH 8.6, plastic wet, hard dry; occasional gravel bands.

52-70 inches. Pale grey (5Y 7/1), garnatiferous hornblende gneiss: pH 8.0, weathered into gritty sand-like particles and soft rock gragments; non-plastic and easily excavated when wet; hard and brittle when dry.

Lower Depth of Horison in Inches	International Scale: Clay <.002	Sand .02-.2	Total Coarse <2	Silt .02-.002	Clay <.002	Organic Matter % Oven-dry Basis: C	N	C/N	O.M. (C x 1.72)	% Moisture air-dry Soil
5	-	52.70	0.26	8.98	38.30	2.40	.157	15.29	4.13	(7.8)
10½	-	44.12	3.30	8.20	44.38	1.74	.112	15.54	2.99	(8.7)
25	-	37.55	2.50	8.09	51.86	1.01	.071	14.23	1.73	(9.7)
34	-	27.11	6.00	7.89	59.00	.53	-	-	.91	(10.8)
38	-	30.00	4.52	5.22	50.26	.32	-	-	.55	(9.1)
47	-	54.67	12.90	2.43	30.00	-	-	-	-	(5.6)
72	-	91.08	0.20	2.28	6.62	-	-	-	-	(3.0)

Lower Depth of Horison in Inches	pH	CaCO3 Per cent oven-dry	Exchange Complex m.e./100 Oven-dry Basis: T(CEC)	Ca	Mg	Mn	K	Na	S(TEB)	S/T x 100	Ca/Mg	MgK	Conductivity at 25° C mho x 103	Phospherous ppm.: Total	Acid soluble
5	6.5	.11	39.6	20.6	15.4	-	.52	.7	37.22	93.99	1.34	29.62	76	207	-
10½	6.8	.16	42.3	22.5	16.1	-	.32	1.0	39.92	94.37	1.40	50.31	76	177	-
25	7.0	.14	44.9	23.2	18.1	-	.22	2.1	43.62	97.15	1.28	82.97	89	134	-
34	8.0	.42	50.6	21.5	23.5	-	.86	3.7	49.56	97.94	.91	27.33	199	119	-
38	8.4	19.20	40.9	23.6	20.2	-	.38	3.3	47.48	(116.09)	1.17	53.16	348	-	-
47	8.6	56.9	24.0	14.7	14.6	-	.38	2.0	31.68	(132.00)	1.01	38.42	308	-	-
72	8.4	.04	9.0	5.0	1.5	-	.28	1.1	7.88	(87.56)	3.33	5.36	136	-	-


SOIL RESEARCH INSTITUTE (GHANA ACADEMY OF SCIENCES)
MAP 2
ACCRA PLAINS
Soils
ACCRA
LEGEND
SUBREGION I — AKWAPIM RANGE
Momfe - Fete Complex
Fete Consociation
SUBREGION II — ACCRA PLAINS
Oyarifa - Momfe Complex
Nyigbenya - Haatso Complex
Momfe Consociation
Nyigbenya Consociation
Korle Consociation
Korle - Okwe Complex
Beroku - Kraho Association
Danfa - Otimbi Association
Momfe - Dome Complex
Alajo Consociation
Chuim - Sege Association
Simpa - Agawtaw Complex
Doyum - Agawtaw Association
Agawtaw Consociation
Toje Consociation
Toje - Agawtaw Association
Nyigbenya - Agawtaw Association
Akuse Consociation
Ashaiman Consociation
Kloyo Consociation
Osudoku Consociation
Lupu Consociation
Tachem Consociation
Tachem - Okwe Complex
LEGEND (cont.)
SUBREGION III — VOLTA FLOODPLAIN
SUBREGION IV — VOLTA DELTA AND COASTAL FLATS
6°
0°


ACCRA PLAINS
Vegetation
Scale 1:250,000
MAPPING UNITS
Short grassland with thicket or tree clumps on the uplands, medium grassland on the lowlands
Tall swamp-grassland, often with riverain woodland or thicket along stream channels
Tall grassland with Borassus palms on the uplands, short grassland with thicket clumps on the lowlands
Tall grassland with patches of thicket and dry forest
Tall grassland with thicket or tree clumps on the uplands; short grassland with thicket or tree clumps on the lowlands
Medium grassland with scattered savannah trees and coppice shoots, medium swamp grassland along valley bottoms
High Forest
Secondary Forest (Forest Reserve) with cocoa farms on highest land
Forest Reserve boundary
ACCRA
Labadi
Christiansborg
Teshi
Nungua
SONGAW
LAGOON
MAPPING UNITS

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MAP 4