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SOILS OF THE LOWER TANO BASIN, SOUTH-WESTERN GHANA

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SERIAL PUBLICATIONS OF THE GHANA MINISTRY OF FOOD AND AGRICULTURE, SCIENTIFIC SERVICES DIVISION, SOIL AND LAND-USE SURVEY BRANCH

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THE GOLD COAST/GHANA DEPARTMENT OF SOIL AND LAND-USE SURVEY

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Memoirs

BRAMMER, H. 1955

Detailed soil survey of the Kpong Pilot Irrigation Area. pp.102, figs., bibl., 9 maps.

AHN, P. M. 1961

Soils of the Lower Tano Basin, South-western Ghana

Occasional Paper

CHARTER, C. F. 1958

Report on the environmental conditions prevailing in Block " A ", Southern Province, Tanganyika Territory, with special reference to the large-scale mechanised production of groundnuts. pp.37, figs.

Reports on the Department of Soil and Land-Use Survey

Report for the period 5th June, 1951 to 31st December, 1955. pp.28, 2 maps.

Report for 1956. pp.19, 2 maps, figs.

Report for the period 1st January to 31st July, 1957. pp.9, 2 maps.

Restricted Publications

(available to bona fide official enquirers)

Technical Reports (45 issues), Miscellaneous Papers, Bulletins, Occasional Papers etc. Reference should be made to the latest Branch Publications List.

Journal Articles and Conference Papers published outside the Branch

AHN, P. M. 1958

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FOREWORD

IN JUNE 1951 the Gold Coast Department of Soil and Land-Use Survey was inaugurated and charged with the soil, vegetation and land-use survey of the country as a whole.

Since this date this soil survey organization, now the Ghana Division of Agriculture, Soil and Land-Use Survey Branch, has surveyed on a regional basis some 18,620 square miles of the closed forest and coastal thicket zones and 9,500 square miles of the interior and coastal savannah zones.

This report presents the first published results of one of these regional surveys.

To pedologists working in the inter-tropical region it will be of interest because of the information it gives on the survey methods which have now been established as suitable for conditions in Ghana. Mr. Ahn's report is documentary justification of the hard work, often under very unpleasant conditions, which he and his team of assistants have put into the survey of this area of little-exploited forest, where air photographs, the modern aid to soil surveying, cannot be used to any significant extent.

More importantly, it will be of particular interest to administrators, scientists and, of course, to the general reader in Ghana and West Africa, firstly because of the suggestions it gives for the development of the Lower Tano Basin itself, and secondly because of the light it throws on the soil conditions most suitable for cocoa, rubber, oil palm and other crops of the closed forest zone.

The survey of this region was decided upon at an early date in the programme of countrywide surveys. The wisdom of this decision has been shown by the great amount of information, including soil analytical data, which the survey has provided on the environmental conditions and agriculture associated with the transition from leached, acid soils in the humid south-west of the country to the less acid soils of the central part of the forest zone. And the report as a whole amply illustrates the fact that soil surveys can, and must, play an essential role in the development of Ghanaian agriculture.

HON. F. Y. ASARE, M.P.
Minister of Food and Agriculture

ACCRA
April, 1959

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PHOTOGRAPHIC ACKNOWLEDGEMENTS

Plates 1*a* and 7*c* were photographed by Ghana Information Services and the aerial photograph (4*c*) was supplied by the Director, Survey Department. The remaining 29 photographs were taken by the author. Plates 3*a*, 4*a*, *b* and *c*, and 5*a* have already appeared in the West African Science Association Journal and are reproduced again here by kind permission of the Editor.

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INTRODUCTION

How to use this Report

THIS REPORT has been written to enable farmers, administrators and others interested in the use and development of the soils of the region to identify the soils with which they are concerned and to learn their characteristics and potentialities, as far as these are known to date. It has therefore been made as simple and as practical as possible.

The report is divided into three parts. Part I gives a general geographical account of the basin as a whole, discussing first the physical features of climate, geology, relief, vegetation and soils which form the geographical setting, secondly the social and political organisation of the area, and finally the economic activities of its inhabitants, including agriculture and forestry.

Part II, on the other hand, divides the basin into separate soil associations and discusses the soils and land-use of each of these associations in turn. In this way, a reader interested in only a part of the basin will need to refer only to those sections of Part II dealing with the soil associations that cover his area. He will find that each soil association includes a number of individual soil series which occur in a fixed and fairly regular pattern related to the relief, and that notes on land-use and vegetation and recommendations for future development are all given under each association.

Part III contains a more detailed and technical description of both soils and vegetation, and gives laboratory analytical data for many of the soils. This may be regarded as an appendix to Parts I and II, to be referred to when required.

A glossary of some of the commoner soil and vegetation terms used in the report is given at the end, pp.263-266.

Purpose of the survey

The survey of the soils of the Lower Tano Basin formed part of the systematic survey of the soils of Ghana undertaken by the Department of Soil and Land-Use Survey[1]. For this, Ghana has been divided into river basins which are surveyed by Detailed Preliminary methods (page xviii, below) so that a broad picture of the soils of the country is obtained prior to more detailed work being carried out in selected areas. The Lower Tano Basin is of particular interest since it covers an area where the rainfall increases from about 60 inches per annum in the north to over 85 inches in the south, behind the coast, where the rainfall is the heaviest in Ghana. Together with the adjacent survey of the Upper Tano Basin, already completed, this survey therefore gives a cross section of soils and vegetation from the northern fringe of the forest where it merges into savanna in the Techiman and Sunyani areas, to the wettest type of forest, the evergreen rain forest, in the extreme south.

As a result a considerable amount of new information is now available on the relationship between rainfall on the one hand and soil reaction, depth of weathering, vegetation, and the content in the soil of organic matter and plant nutrients on the other. Upland soils have been divided into two major groups according to their reaction. The more strongly leached group, the oxysols, are found to correspond closely in their distribution with the rain forest, while the less strongly leached ochrosols are associated with the semi-deciduous forest to the north.

In the north of the basin particular importance attaches to cocoa soils. In the south, where the rainfall is heavier, the upland soils are too acid for cocoa and attention is directed to their suitability for such crops as rubber, oil palm and coconuts. The survey aims at indicating what crops can be

[1] After 1st August 1957, the Ghana Department of Agriculture, Division of Soil and Land-Use Survey. After 1st July 1958, the Ghana Division of Agriculture, Soil and Land-Use Survey Branch. Since December 1959 the Soil and Land-Use Survey Branch of the Scientific Services Division of the Ministry of Food and Agriculture.

grown within the basin and, equally important, those which it would be a waste of time and money to try and establish.

The soil surveyor is responsible for the collection and presentation of a large amount of information on soils, vegetation and current land-use which is essential background information for the formulation of an agricultural policy, but it is not necessarily his duty to formulate that policy, or to carry out the agricultural trials which may be necessary on the different soil series he has established. Both the soil surveyor's observations on crop condition in the field and the available soil analyses may serve as a preliminary guide to soil potentialities, but for the formulation of an agricultural policy it is necessary to take a very broad view and also a long-term one. It would be ruinous in the long run to use up rapidly the stored fertility of the land in planting crops which will do well for a year or two only and then leave the land exhausted, when the planting of permanent tree crops may save the soils and keep them productive for many years to come, as well as avoid the continual drain on the farmers' energies involved in clearing ground which is soon allowed to revert to bush again. The needs of Ghana and the profitability or otherwise of selling abroad what can be grown must also obviously influence any development programme based on the basic information obtained during the course of this survey. The text and maps of this report together form one of the tools with which future agriculture and land-use planning will, it is hoped, be undertaken, and if used as such the money and energy expended on the survey will be more than justified.

Conduct of the survey

The field work of the survey took nineteen months to complete. It began in November 1954 and was completed at the end of 1956, there being a break of five months from May to September 1956.

Altogether 887 miles of traverse were surveyed, and over 9,500 chisel holes dug. These were supplemented by the digging and sampling of 473 pits, and about sixty of these sets of samples were subsequently analysed in the laboratory. In addition to general traverse work, nineteen detailed sample strips each 1 mile by ¼ mile were laid down, and their relief, vegetation, soils and land-use recorded in detail. This report is therefore based on 10,000 sets of soil samples involving about 60,000 individual samples, there being 5–6 samples from each chisel hole and 6–15 from sample pits, and on vegetation enumerations which, on sample strips alone, included the identification and mapping of 30,000 trees.

The lack of roads and settlements in the central part of the area in particular made the work both slow and difficult, particularly in the rainy seasons when the paths were swampy and the streams swollen. Field parties had to walk long distances and work with inadequate accommodation, while all soils and equipment from these remoter areas had to be head-loaded. Both food supliesp and local labour were often short.

All aspects of the work were under the general control of the officer in charge, who identified the samples from every p it and chisel hole, and who has written this report on the survey after the completion of the field work. In the supervision of the field work he was assisted by K. A. Asiedu, Assistant Soil Survey Officer, who sampled most of the pits and, with S. Osei Yaw, Leading Field Assistant, did the vegetation recording. The correlation section, responsible for the description of all chisel hole and pit samples, was in the charge of H. A. Appiah, Leading Field Assistant. These were assisted by a team of field assistants, soil grinders, clerical assistants, drawing office assistants, drivers and fitters, who, though too numerous to mention by name, all played an essential part in the running of the survey, while a large body of anonymous labourers did the hard work of line-cutting, digging and carrying.

Method of survey employed

This Detailed Preliminary survey is intended to delineate in broad outline the soil associations found in the area. The method employed consists in making traverses along roads, paths, forest reserve boundaries or specially cut lines and recording the vegetation and sampling the soils along these traverses at regular intervals. Chisel holes are dug at intervals of 10 chains (220 yards), so that there are eight to every mile of traverse, and samples are taken to a depth of 48 or 60 inches, the deepest sample being extracted with a soil auger. These are supplemented by the digging of a lesser number of pits, 6 x 3 feet, to any depth necessary, usually to 6–10 feet but occasionally to much more. These pits are sampled very carefully and selected samples stored for subsequent analysis in the laboratory.

This network of traverses serves to indicate the extent of associations, the drawing of the boundaries of which may be helped by a study of the relief and geology. Within each soil association, however, it is necessary to examine in more detail the inter-relationships of the individual soil series which make up the association and this is done by the cutting and recording of sample strips. Sample strips are 1 mile long and ¼ mile wide, and six traverse lines 4 chains apart are cut along the length of the strip. The strips are sited so as to be typical of a soil association and to include a range of relief from valley bottoms to hill summits. Along the traverse lines chisel hole samples are taken at 4-chain intervals so that the whole strip is therefore covered by a 4-chain grid of chisel holes, and the soil map is based on the identification of these samples. This is supplemented and checked by the digging of soil pits. At the same time maps are prepared showing the land-use, vegetation and relief of the strip. Of the trees all the emergents, 25 per cent of the canopy layer and 5 per cent of the shrub layer are identified and mapped according to height groups, and levelling of the area is used to give a detailed contour map which will show the relationship of soils and relief. Information is also recorded on the farming on the strip, if any, including the crops and their spacing. Each strip therefore provides detailed basic information on soils, land-use and vegetation.

Every chisel hole sample is described and these descriptions, together with vegetation and land-use records, are filed for future reference. Each pit sample is also described, a diagram of the profile drawn and representative soil samples boxed so that they can afterwards be inspected at the Branch headquarters by anybody interested. Sample strip maps are also available for inspection.

The field team responsible for this work forms a mobile unit equipped with tents and lorries which uses a number of convenient villages as temporary bases. The distribution of traverses is shown in Map 1. On the average there are over 30 miles of traverse for each 100 square miles. Traverse distribution is, however, uneven. This is because uniform areas need fewer traverses than more complicated ones such as Nzima, but also because some areas are so inaccessible that it would have taken too long to examine them in more detail. The reliability of the final maps depends partly on the closeness of the traverse lines. Since a map showing traverses accompanies this report it can easily be seen which areas have been relatively closely surveyed and which more generally, and the remaining maps must be interpreted accordingly.

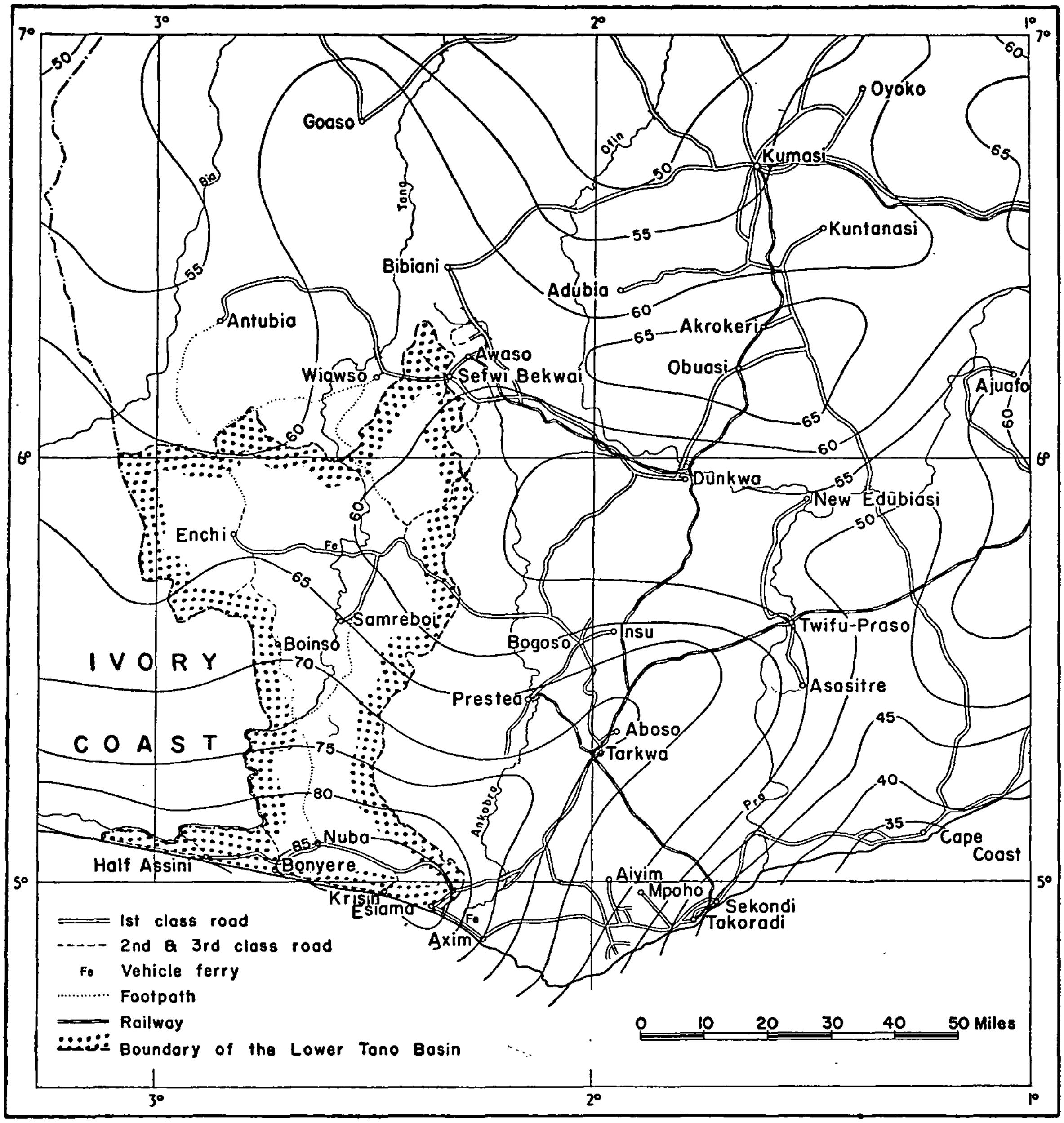


Figure 1. The location of the Lower Tano Basin in south-west Ghana, showing major roads and railways (with minor roads and some footpaths in the basin itself) and the distribution of mean annual isohyets: (From the map ' Isohyets: yearly mean,' published by Sir William Halcrow and Partners, Ltd., 1954).

PART I—GENERAL DESCRIPTION OF THE BASIN

Physical Features of the Region

Position and area of the basin

THE LOWER Tano Basin occupies the extreme south-west corner of Ghana, extending from 6° 20′ N, to the coast at 4° 55′ N. Its north-western boundary follows the watershed of the Tano with the Bia, and thence runs due south along the political boundary with the Ivory Coast which follows the Tano itself in the south-west of the basin. Its eastern boundary is formed by the watershed with the Ankobra. (*See* Fig. 1.)

To the north it has been divided from the Upper Tano Basin at a convenient point where the basin narrows. The Lower Tano Basin is therefore somewhat mushroom-shaped, with a broad area in the north, including Enchi and Asankrangwa, a relatively narrow waist in the centre, and then a broader base in the south along the coast.

The total area of the basin is about 2,767 square miles.

Climate

General considerations

The climate of the basin is characterised by a high rainfall falling in two main wet seasons and a uniformly high temperature. Such a climate is highly favourable for plant growth, which continues uninterrupted throughout the year and it is the climate, rather than the soil, which is the greatest asset of the forest zone. In some respects however the climate is too favourable, for plants develop little resistance to fungus or disease which are also encouraged by the high temperatures and rainfall. Plants grow rapidly even where the soil is poor, and this fact has sometimes been responsible for exaggerated ideas of soil fertility based on the lushness of the vegetation supported. Since there is little seasonal change of temperature, the seasons vary mainly in their rainfall. The annual distribution of rainfall regulates agriculture and the seasonal rhythm of clearing, burning, planting and harvesting.

The enervating effects of high temperature and humidity on the health and working capacity of both the indigenous inhabitants and European immigrants have often been exaggerated, but there is little doubt that the temperature is well above the optimum for both physical and mental work and that the high humidity also reduces energy, while there is a lack of any cold season to brace and stimulate. Many of the supposed lowering effects on human activity of the climate however, are due rather to the diseases associated with it than to the climate itself. Under hot wet conditions bacteria and insects multiply rapidly. Malaria and other fevers undoubtedly reduce the capacity for work of those affected, and most local people suffer from chronic mild malaria to which they are only partially resistant.

The effects of the high temperature and rainfall on the soil are both direct, causing deep weathering and leaching, and indirect through the influence of the vegetation and the high level of bacterial activity in the soil. Climate, where it is as extreme as that of the basin, becomes the predominant soil forming factor, so that soil fertility usually depends more on climate than on parent rock.

Type of climate

The climate of the area is classified as equatorial monsoon and owes its rains to low pressure areas over the Sahara attracting winds from south of the equator. These winds reach the West African coast as south-westerlies and the angle at which they cross the coast as well as the interior topography affect the amount and distribution of the rainfall. The Lower Tano Basin is situated in the south-west corner of Ghana, the wettest part of the country, and falls within a heavy rainfall area which extends west along the coast to include part of the Ivory Coast. This is separated by a relatively dry area in the central Ivory Coast from the larger area of still heavier rainfall in Liberia, Sierra Leone and French Guinea.

West African weather in general is influenced by three principal air masses which oscillate north and south with the seasons, their passage being about one to two months behind the apparent movement of the sun. The most southerly of these masses is the moist monsoon air mass coming from the South Atlantic ocean and the most northerly is the dry Harmattan from the Sahara area. Between the two are equatorial air masses of generally ascending air known as the Inter-Tropical Convergence Zone. In January this zone reaches its southern limit and is then above the Lower Tano Basin. As it moves north, the basin comes under the influence of the monsoon mass. The harmattan air mass, which brings dry conditions with little cloud, has little influence on the climate of the basin which therefore comes under the effect of the monsoon and equatorial air masses alternately: these produce variable weather which includes moderate to very heavy rain.

Further details on these air masses can be found, if required, in numerous recent publications, such as in Walker, in press. The following notes on various aspects of the climate will probably be found to be sufficient to define the climate in more general terms.

Temperature

Temperatures within the basin are uniformly high, with little difference between day and night temperatures and little change from season to season.

Table 1, p.3, shows mean monthly temperatures for Axim, and these figures can be taken as typical of the southern half of the basin. August is the coolest month throughout the area partly because of the high amount of cloud cover: at Axim the mean August temperature at 3 p.m. is 78·7° F. This rises to 86·7°F in March, the hottest month, so giving a mean annual range of only 8°. The coolest time recorded in the 24 hours is at 6 a.m., and these mean minima show even less seasonal change. They vary between 73·3° in August to 77·3° in March, a range of only 4°. The annual mean shows a daily variation from 75·3° at 6 a.m., to 83· 1° at 3 p.m., a mean daily range of only 7·8°.

In the north of the basin the temperature differs only slightly from that near the coast. No long period figures are available for stations within this part of the basin, but figures for Wiawso and for Bibiani, just outside the basin, suggest that mean minimum temperatures are very similar, while mean maximum temperatures are either similar to or very slightly less than those quoted for Axim.

Rainfall

The annual rainfall of the basin and adjoining areas is shown in Fig. 1, p.xx. This shows an area of over 85 inches per annum in the extreme south of the basin, with a progressive lowering of the total rainfall further inland to a minimum of under 60 inches per annum at Asankrangwa.

These average figures hide a considerable amount of year-to-year variation. At Aiyinasi Agricultural Station, for example, complete annual records are available only since 1950 (Table 3, p.0.) but in the seven years recorded the annual total has varied between 62·5 inches in 1950 and 125·02 inches in 1951. In June alone, the month with the heaviest rain, total rainfall was 20·51 inches in 1949 and 50·23 inches in 1957, while May has varied between 9·36 and 20·23 inches and October between 4·49 and 26·45 inches in the same short period. These figures represent a very great variation on either side of the average. At Bisao, near Samreboi, rainfall records kept by Messrs. A.T.P. Ltd., show annual totals as high as 90 inches while the month with the heaviest rain has been a different one nearly every year since records were begun in 1949. Table 4, p.4 shows extremes of monthly and annual rainfall totals for Axim, Wiawso and Bibiani: these figures suggest that the heavier rainfall near the coast varies more than the less heavy rainfall in the north of the basin. The effect of these variations on plant growth is not usually critical in the basin, where total rainfall is generally high and the dry season short, but undoubtedly has some influence on crop yields. This subject requires further research but it has recently been shown (Haines & Benzian, 1956) that oil palm yields, for example, in a similar high rainfall area in Eastern Nigeria showed a delayed but distinct fall after years in which the rainfall was lower than usual.

TABLE 1

Time	*Jan.*	*Feb.*	*March*	*April*	*May*	*June*	*July*	*August*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Annual Mean*
Midnight ..	77·6	78·4	79·6	69·8	78·6	77·1	75·6	74·0	74·6	76·7	77·2	77·6	77·2
3 a.m. ..	76·4	77·2	78·2	78·3	77·3	76·2	75·1	73·6	74·1	75·9	75·7	76·3	76·2
6 a.m. ..	75·3	76·2	77·3	77·0	76·2	75·6	74·8	73·3	74·0	75·1	74·2	74·6	75·3
9 a.m. ..	78·5	79·8	82·0	82·5	81·0	78·7	77·5	75·9	76·5	78·7	80·8	80·2	79·3
12 noon ..	83·7	84·8	86·2	86·1	84·0	80·9	79·9	78·5	79·1	81·4	84·4	84·7	82·8
3 p.m. ..	84·7	85·8	86·7	86·0	84·1	80·8	79·9	78·7	79·4	81·5	84·5	85·4	83·1
6 p.m. ..	81·5	82·4	83·3	83·0	81·4	78·8	77·5	76·1	76·6	78·5	80·3	81·4	80·1
9 p.m. ..	79·2	79·8	80·9	81·1	79·5	77·5	76·1	74·5	75·2	77·4	78·4	79·3	78·2

Mean monthly temperatures for Axim (°F).

TABLE 2

Station	*Jan.*	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*August*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*	*No. of Years*
Axim ..	2·02	2·42	5·06	5·61	16·52	21·07	6·16	2·13	3·44	8·07	7·55	3·77	83·82	41
	4	5	9	11	18	19	11	9	12	14	13	8	133	
Half-Assini ..	1·36	2·32	5·05	5·91	15·07	22·95	5·36	1·42	2·68	8·27	7·48	4·78	82·65	34
	3	3	7	8	13	16	6	5	7	11	12	7	98	
Wiawso ..	0·84	2·25	5·27	5·84	7·41	9·88	5·22	2·55	6·24	8·07	4·03	1·31	58·91	40
	2	4	9	10	13	17	13	10	15	15	9	3	120	

Mean monthly rainfall in inches and number of raindays for three stations in and near the Lower Tano Basin.

TABLE 3

Year	1949	*RD*	1950	*RD*	1951	*RD*	1952	*RD*	1953	*RD*	1954	*RD*	1955	*RD*	1956	*RD*	1957	*RD*
January	—	—	1·06	3	1·22	3	·65	3	0·53	3	0·12	1	3·05	7	0·07	1	1·33	4
February	—	—	·41	4	·38	5	·98	4	1·62	3	2·70	6	2·32	7	4·55	3	1·05	3
March	—	—	6·03	9	4·56	9	3·88	9	3·53	5	10·72	10	6·89	11	8·35	14	3·33	7
April	—	—	4·00	10	4·00	10	1·78	5	6·67	10	13·31	13	7·60	8	4·55	13	4·89	8
May	4·65	16	8·27	14	20·35	19	4·36	11	8·87	19	12·34	14	12·83	18	17·16	21	19·68	19
June	20·51	22	21·69	23	33·50	21	29·38	24	24·65	24	22·49	23	27·36	24	29·90	21	50·23	18
July	11·27	9	3·47	11	18·27	13	5·91	13	16·24	15	7·93	12	13·17	18	6·19	11	14·30	22
August	3.16	6	1·31	8	1·87	4	1·19	9	1·79	20	1·66	10	2·11	13	1·06	8	3·85	17
September	2·48	9	3·08	12	2·98	13	15·52	18	2·39	9	6·44	13	5·24	17	8·69	19	4·00	15
October	6·15	10	4·49	13	26·45	27	5·22	18	15·06	20	16·08	22	12·66	18	7·82	22	16·38	18
November	3·62	10	4·13	10	10·28	17	6·93	14	1·48	9	6·00	11	6·64	14	6·15	16	1·98	10
December	3·27	5	4·56	10	1·16	4	3·84	8	5·34	4	1·75	6	4·59	8	3·68	12	6·98	8
Total	—	—	62·50	127	125·02	145	79·64	136	88·17	141	101·54	141	104·46	163	98·17	161	128·00	149

Rainfall recorded at Aiyinasi Agricultural Station, 1949–1957. (Figures in inches. The column headed RD indicates the number of raindays (with more than 0·01 inches of rain) in the month. From data kindly supplied by the Agricultural Officer in charge.)

As important as the total amount of rain is its distribution through the year. Throughout the basin there are two long wet seasons separated by two short relatively dry seasons, i.e., periods with less than 3 inches of rain per month, in which humidity and cloud cover however remain high. The more marked of the two dry seasons occurs in January and February, though in the north of the basin this dry season is a little longer and includes December. The minor dry season occurs in August. The two wet seasons therefore cover March to July and September to November or December. In the north of the basin the maximum monthly rainfall in the first of these wet seasons is only a little above that of the second wet season. In the wetter south of the basin there are also two distinct peaks, but the additional rainfall falls mainly in the first wet season and the May–June peak is very much higher than the October peak which is much the same throughout the area. The very high concentration of rain in a six-week period covering the end of May and the whole of June is the most striking feature of the climate near the coast. Immediately behind the coastline, as at Esiama and Half Assini, the average May–June rainfall is about 37 inches: a few miles inland, as at Aiyinasi, where almost 70 inches were recorded for these two months in 1957, it may be still higher. Such concentrated downpours, including up to 7 inches in a day, are sufficient to cause widespread flooding and to make the laterite roads temporarily impassable, while this is the only time of year when the very porous and absorbent sandy soils of the Tertiary deposits of Nzima cannot immediately absorb all the rain falling on them.

It will be noted that a figure of 3 inches is taken to separate dry months from wet. In the absence of information on the actual amount of water lost by transpiration and evaporation from the soil it is not possible to calculate an accurate water balance (as in Thornthwaite, 1951, for example) and this figure is therefore open to modification. Nevertheless, almost nowhere in the basin does the short dry season seem sufficient to cause serious drying out of any of the soils except exceptionally porous or shallow crustal examples.

The high rainfall is contributory to the fact that well drained red soils are very seldom found in the area, the predominant colour being yellow to orange-brown. It also means that, in the wetter parts particularly, less importance attaches to the water-retaining capacity of the soil than it does in the drier parts of Ashanti, for example, where this factor has an important effect on soil productivity. The corresponding disadvantage of a high rainfall is the tendency towards the development of leached and therefore acid soils: these aspects are discussed more fully under soils, below, pages 24–30.

Relative humidity

Relative humidity throughout the forest area is, as would be expected, very high: it can be assumed to be at least 90 per cent during the night and early morning, falling to about 75 per cent when temperatures rise in the afternoon. Figures for Axim (Walker & Swan, 1952) show average monthly readings of 82–90 per cent at 9 a.m., 72–81 per cent at 3 p.m., and 84–92 per cent at 7 p.m.

Winds

Air pressures when reduced to sea level show little variation from place to place within the basin and normal inland wind speeds are low, being usually under 5 m.p.h., except in the mid afternoon when they may rise to 5–10 m.p.h. Near the coast, however, there are welcome land and sea breezes which are felt for several miles inland. These blow from land to sea at night and in the early morning, and from the sea inland during the rest of the day and in the evening. These have a normal speed of 10–15 m.p.h: only rarely do they exceed 20 m.p.h. (Walker, in press).

During storms and squalls winds are very much stronger and may reach 50 m.p.h. for short periods. It is these strong local winds which do damage to such crops as plantain, which has only a shallow rooting system, and uproot even very large forest trees. At the beginning of the main wet season high winds are at their most frequent and roads are then frequently blocked by fallen trees. These local winds are associated with convectional thunder storms and with line squalls. During March and April line squalls may be as frequent as four or five a month.

Sunshine

Hours of sunshine depend on the amount of cloud cover. At Axim, where a cooler August is well marked, the August cloud cover averages 6·3 eighths, and throughout May to October the average

TABLE 4

Station		Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Year
Axim	..	9·04	11·06	12·25	15·78	35·12	44·70	28·78	11·76	16·86	21·16	19·24	12·82	130·39
		0·09	0·03	1·20	0·81	5·75	4·70	0·38	0·05	0·34	0·12	0·08	0·55	47·64
Bibiani	..	1·99	4·78	8·45	8·13	13·46	12·99	10·19	8·56	14·13	14·02	7·69	4·60	71·92
		0·00	0·05	2·42	3·24	3·36	6·01	0·65	0·72	2·54	3·53	1·50	0·00	45·12
Wiawso	..	3·83	5·77	9·37	12·35	14·46	15·31	11·54	8·33	13·35	16·38	8·14	3·44	72·90
		0·00	0·03	1·87	2·53	2·64	6·33	0·69	0·15	2·14	2·92	1·38	0·00	46·60

Extremes of monthly and annual rainfall totals (in inches) for Axim, Bibiani and Wiawso. (From Walker, in press.)

is over 6 eighths. This falls to 3·7 eighths in January. This probably means an average of little more than four hours direct sunshine in the wet months, rising to six to seven hours in January. Measurements by the author, however, suggest that light intensity is very little reduced by a moderate cloud cover even though there is no direct sunshine.

Influence of physiography

The highest parts of the basin are 1,000–1,200 feet above sea level and at these heights there is usually some development of mist at night. Topography also influences local wind direction. Little is yet known as to whether, in a climate where the rain is convectional and cyclonic rather than orographic, the higher areas get much more rain than the lower ones.

Geology

The bulk of the area is underlain by three main geological formations, the Lower Birrimian, the Upper Birrimian, and the granites (Fig. 2). In the extreme south there is a relatively small area of Tertiary sands and a still smaller area of Recent dune sands. The areas occupied by soils developed over each of these formations are as follows:—

	Square miles	*% of Basin*
Lower Birrimian	1,324	47·9
Upper Birrimian	694	25·1
Granites	379	13·6
Tertiary sands	279	10·1
Quaternary sands	91	3·3
	2,767	100%

Of the above formations, the Lower Birrimian is the oldest in the area, and extends over the widest latitude, from the extreme north of the basin almost to the sea in the south-east of the basin behind Kikam.

The Lower Birrimian consists mostly of phyllites with injected quartz veins, while the Upper Birrimian consists predominantly of volcanic rocks and relatively minor amounts of phyllite. These formations later became granitised in one or two places and have massive granite intruded into them in others. These intrusions form the major granite areas.

Lower Birrimian (*B*1)

The normal soil parent rock in Lower Birrimian areas is phyllite, a clay sediment of Pre-Cambrian age hardened and foliated by heat and pressure. It is not usually seen in its original state since the high temperature and humidity of the region have weathered this rock to great depths. When seen in pits and road cuttings it is more or less soft, with its fine laminated structure very noticeable. Its colour varies from black to blue, grey, brown, orange and red. It breaks up easily, often crumbling into flattish fragments, and is sometimes soapy to the touch. Nevertheless, because of variations both in the nature of the original deposits and in their subsequent history, some phyllites are sandier than others and some, due to heat and pressure changes, more resistant. Phyllite occasionally grades into harder rocks such as slates and sericite schists, and odd patches of greywacke and tuffs occur, though within the basin these were not often found. The harder rocks usually stand up as hills.

Veins and stringers of quartz injected into the phyllite break up during weathering to give stones and gravel. Because of the uneven distribution of these veins the amount of quartz stones and gravel in the soil varies considerably, and may locally be very abundant.

Broadly speaking, however, the phyllite areas are relatively uniform and give rise to similar soils and relief over wide areas.

Upper Birrimian (*B*2)

The Upper Birrimian formations are slightly younger than the Lower Birrimian, and consist mostly of volcanic rocks. The volcanic rocks are metamorphosed basic and intermediate lavas, broadly

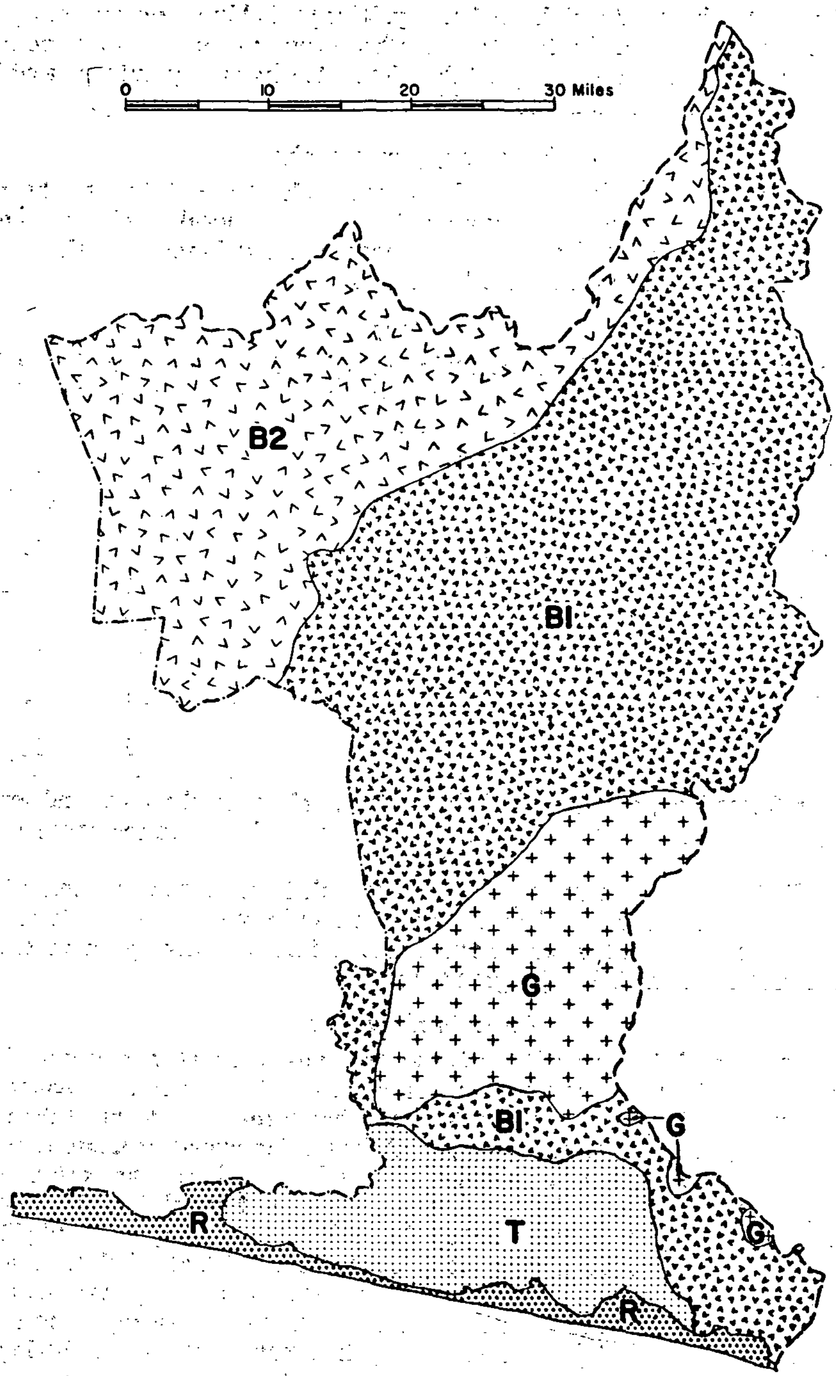


Figure 2. Main geological formations of the basin (based on observations made during the survey and field records of Geological Survey Department). B1—Lower Birrimian; B2—Upper Birrimian; G—Granite; T—Tertiary sands; R—Recent (coastal) sands. Both B1 and B2 formations include minor granite areas.

termed greenstones, including small amounts of epidiorites, diorites, amphibolites, rhyolites, andesites and similar rocks. There are occasional granite intrusions, and various schists and phyllites, so that these formations are more varied and complicated than the Lower Birrimian.

Upper Birrimian formations have been strongly folded with dips often steeper than 60°, and with a general north-south or north-east to south-west strike. They have been highly sheared and usually form high hill ranges which stand out above the lower relief associated with the Lower Birrimian phyllites. Thus they form the long line of hills known as the Bibiani Range and the high upland areas of the Boin and Yoyo forest reserves near Enchi. These areas are often steep and strongly dissected.

The identification of the soil parent rocks of Upper Birrimian areas is sometimes difficult. In some areas, as in the Boin River forest reserve, phyllites are found side by side with greenstones and, because of deep weathering, the two rocks are not always easy to distinguish, especially as B2 phyllites are often sandier and harder than the typical laminated B1 phyllites. Pieces of phyllite, greenstone and other rocks are often found in stream beds, but do not necessarily form the local soil parent rock. Epidiorite is easily recognised by its spheroidal weathering and the yellow colour of its outer layers when partly weathered, whereas various porphyries and tuffs weather deeply and are hard to identify. Hard greenstone fragments may be found abundantly on the summits and steep upper slopes of the higher, often flat-topped hills, but the gentler intermediate hills which cover most of the area have deeper soil mantles and little visible rock. The small granite intrusions within the Upper Birrimian area, on the other hand, are quickly recognised by the grittiness of the soils and by the unweathered parent rock which is often found relatively near the surface.

Granites

The granite was intruded into the older Birrimian formations, particularly the Lower Birrimian where very large areas of granite are found. Small dykes and minor intrusions are fairly frequent in both Upper and Lower Birrimian formations. The heat, vapours and pressure associated with these intrusions also affected surrounding rocks, altering phyllite, in particular, to biotite schist. There is often a transition therefore from granite through biotite schist and other metamorphic rocks to phyllite, while in marginal areas both biotite schist and granite are frequently closely associated and the two rocks may be found in a single soil pit. Such mixtures and transitions are common, for example, on the road from Samreboi to Prestea. Biotite schist weathers more easily than granite and the soft weathered rock is recognised by its typical purplish colour and the included biotite (black mica). Aplites (fine-grained granites) and pegmatites also occur in relatively small quantities.

The normal granites or granodiorites of the area sometimes weather rather slowly so that fresh hard granite may be found a foot or two below the surface and can be quarried out for road foundations or for building. This is, in fact, the only rock within the basin which remains hard enough to be used in this way. In other cases the granite may be weathered so that it is quite soft but still retains its original appearance and structure. The usual granite of the basin is pale in colour, medium-grained and speckled with black biotite: muscovite (white mica) granites are found occasionally. The feldspar in the granite softens relatively easily under the action of dilute acids to become kaolin, in which the very resistant quartz remains embedded. This quartz gives granite soils their characteristic grittiness, and varies in size according to the grain of the rock, which depends in turn on the rate of the original cooling. In certain areas books of white mica two to three inches across are found and these split up to give numerous mica flakes in the soil.

Ghana granites are often divided into two main groups, the G1 and G2, or Cape Coast and Dixcove types, separated according to their chemical composition. The granite in the basin is mostly of the G1 or Cape Coast type, described as containing more potassium than sodium, which is usually associated with Lower Birrimian formations. The granite intrusions in the Upper Birrimian are usually of the G2 type, and may contain hornblende: there are transitions between these and surrounding greenstones in the same way as there are between G1 granites and associated phyllites.

Tertiary sands

The three geological formations discussed above are all Pre-Cambrian, and were formed very early in the geological time scale. The Tertiary deposits of the south-west of the basin are very much younger and represent a relatively recent addition to the ancient African massif of which the other formations form part.

These deposits form a mantle of uniform sandy clays overlying a number of different geological formations below. The maximum thickness of the Tertiary sands is probably of the order of 70 feet: a shaft dug north of Nuba reached 62 feet without coming to the lower limit, though further east between Mpataba and Aiyinasi underlying formations were found at 22–25 feet, while near Bonyere several drillings for limestone showed the superficial sandy clay layer to be 30–50 feet in thicknes.

Under most of the overlying sandy clays are the Apollonian formations which consist of vsry thick layers of sediments, mostly sands, clays and limestones. Recent drilling for oil along the coeast has shown these to be 10,000 feet thick and to be underlain by sediments believed to be Voltaian in age. Elsewhere the Tertiary sands overlap and mantle areas of phyllite and granite to the north and east of the Apollonian formations, but where the deposits thin out towards their edges, valleys may cut through to the underlying material: at Aiyinasi Agricultural Station for example, some of the valleys have cut through to granite (Ahn, 1957).

From the soil point of view the material underlying the Tertiary sands is of little importance. No soils are developed in the Apollonian formations, as these do not reach the surface, and only in a pit or two near the Nauli Scarp can the limestones and black plastic marine clays of these formations be seen. In the areas where the Tertiary sands are only 22–25 feet thick, several pits reached very pale coarse loose sands at this depth, presumably of cretaceous age, and though these do not affect the overlying soils directly, they no doubt accelerate still further the drainage of the deposits above them.

Recent sands

The Recent or coastal sands consist of very young sand and alluvial deposits along and behind the shoreline which date from Recent or Quaternary times and are still being added to in some cases. They include raised beaches, sand spits and other marine deposits, supplemented on the landward side by alluvial material from inland.

The present coastline is remarkably straight and is the result of the cutting back of higher land and headlands, and the filling in of intervening bays. The sands here are sometimes similar to the Tertiary sand deposits, from which some of them may have been derived, but contain less clay and may be coarser, while the most recent deposits immediately behind the present beach usually still contain shell fragments. These formations include small areas of very fine sands which are thought to occupy the sites of former lagoons (Ahn, 1959).

Geomorphology, relief and drainage

Geomorphology

The present relief (Fig. 3) and land forms have not been studied sufficiently closely to reveal in detail the complicated erosional history of the basin. It is clear, however, that this area of very old rocks has been lifted up and worn down several times, so that there are areas where the relief and soils are inherited from previous cycles of erosion. Certain flat-topped hills once formed part of extensive peneplains which were later mostly eroded away, leaving isolated remnants behind. A flat-topped hill near Asemkrom, for example, with a height of 600 feet, once formed part of the same fairly flat area as is left on the top of other hills north of Enchi at 900 feet. The soils on these two summits are older than the younger ones which mantle most of the hills of the basin, and are often characterised by the more advanced formation of iron or bauxitic pan due to the longer action of soil-forming and modifying processes.

Two major surfaces were distinguished during the surveys of the Upper Tano Basin and of the Kumasi Region[2] (Radwanski, 1956, and Crosbie, 1957), but they are much less well represented in the Lower Tano. These are the older, higher Aya surface and the younger Akumadan surface. The Aya surface can be traced as flat summits of the high hills bordering the Upper Tano, these being found at about 2,400 feet above sea level in the north but decreasing to about 1,000 feet in the south where the Upper Tano Basin joins the Lower Tano Basin. Numerous hill summits in the Enchi area

[2] Comprising the basins of the Ofin and Oda rivers.

at 900 feet and over and the remarkable flat summit on the high hill near Asemkrom already mentioned may be assumed to belong to this Aya surface. Within the Lower Tano Basin these summits are covered with shallow indurated soils which are more or less the same whether the underlying rock is Upper or Lower Birrimian. The bauxite deposits of the Afao hills belong to the same surface.

The lower, Akumadan surface is so dissected in the Lower Tano Basin as to be difficult to trace. It is thought to be represented at 5–600 feet near Asankrangwa, and to come to as low as 200 feet near the coast.

Rise and fall of the land relative to the sea have also resulted in the formation of river terraces at various heights above the level of the present river floodplains. Some of these terraces still remain and give rise to distinctive soils which, though developed in alluvial material, are older than those developed in current alluvium and have characteristics between those of alluvial and those of sedentary soils. These terraces may be up to 100 feet above the present stream level (Hirst, 1938 and *see* also Part III, page 157).

The raised beaches found along the coast (Ahn, 1959) are also the result of land movements relative to sea level.

Relief

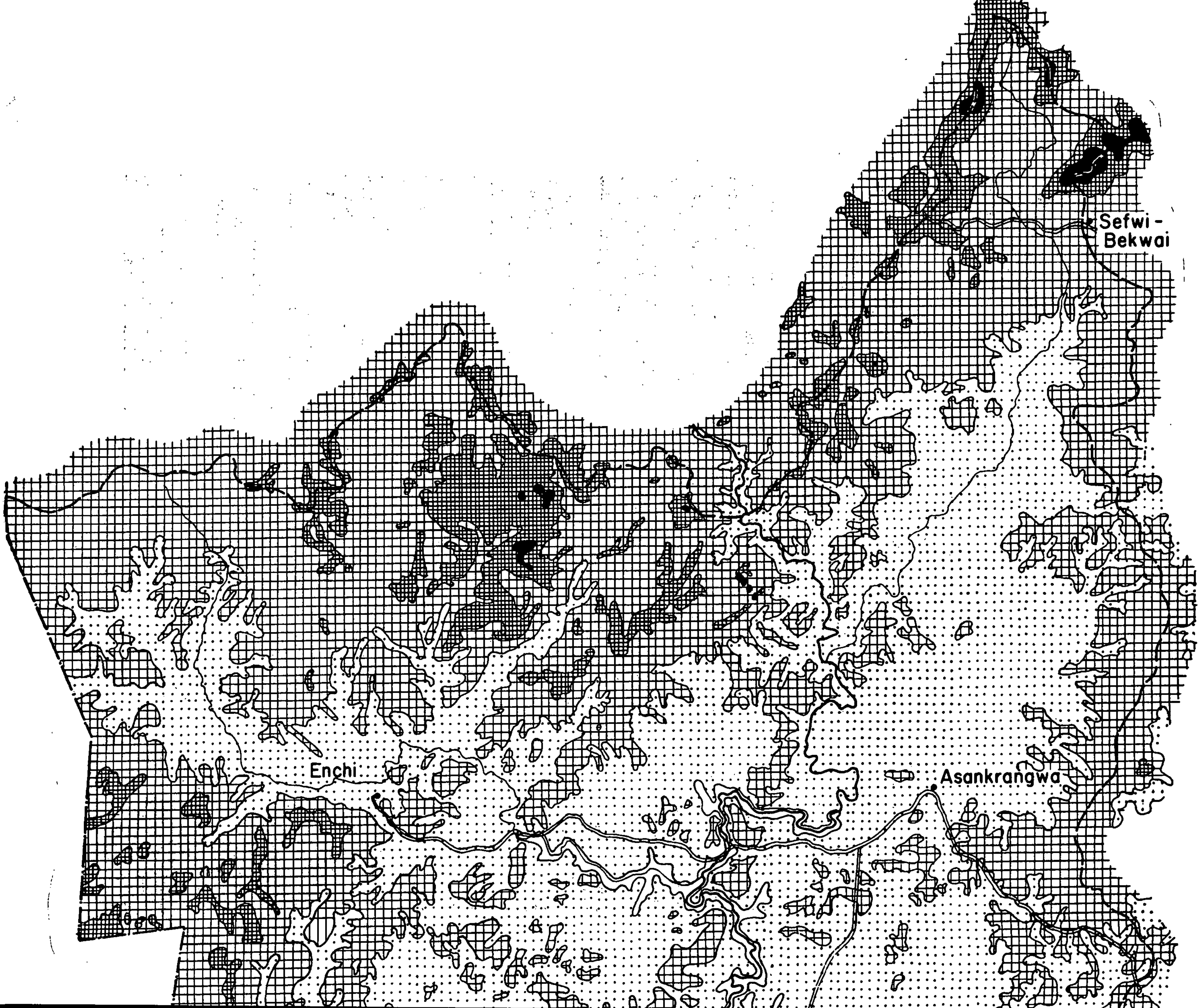
In detail the relief is strongly influenced by the geology, though broadly speaking the basin represents an intermediate erosional stage in which only very limited areas of the former peneplain surfaces discussed above remain, but there are not yet any extensive flat lowland areas, so that most of the basin consists of dissected hills of various degrees of steepness. The Upper Birrimian areas are the highest and are very strongly dissected. Lower Birrimian areas are generally less high, but the Lower Birrimian hills of the Tano-Anwia area and of the Tano-Ankobra watershed are also very strongly dissected and noted for their steep slopes (Ahn, 1958*a*). Granite topography, on the other hand, is somewhat more regular, being very strongly rolling throughout, while that of the Tertiary sands in the south consists of flat or gently sloping upland areas separated by deep steep-sided valleys. This youthful topography might suggest recent uplift and rapid downcutting of the valleys, but is due rather to the porous nature of the deposits and the near-absence of any surface run-off.

The basin as a whole can be divided into a number of physiographical units (Fig. 3). The northern tip of the basin, the Sefwi-Bekwai area, is dominated by the high but narrow Bibiani range which flanks it on the western side, though to the east the watershed with the Ankobra is very low and poorly defined. To the south-east the Bibiani range meets the line of hills which flank the Tano on the other side, and these together merge into the broad upland area which surrounds Enchi. Here the summits reach a common level of about 900–1,200 feet, representing remnants of the Aya surface, and the area is steep and well dissected.

To the east of the Enchi area, a broad area of Lower Birrimian phyllites covers most of the centre of the basin, including the Asankrangwa area, and extends northwards to Sefwi-Bekwai. The relief here includes several lines of steep hills composed of particularly resistant phyllites and schists which extend across the Tano in a NNE-SSW direction. The Tano cuts through these hills in a number of places and gives an example of superimposed drainage. The hilly Tano-Anwia area also has flattish summits at 500 feet (Akumadan surface), with remarkably long and steep slopes below them which would make road building and agricultural development difficult. This hilly area continues to the west and merges with the Upper Birrimian upland areas, so that the division between the two systems is not well marked. Elsewhere, as north and south of Asankrangwa, these same Lower Birrimian formations are associated with uniformly rolling topography at a lower level.

The southern central area, including the Ankasa River forest reserve, is an area of rolling granite topography, consisting of frequent steep-sided small round hills rising to 200–600 feet, with little or no flat uplands and no broad valleys. The area is at the intermediate erosional stage of maximum slope, and is well dissected by an extensive and regular dendritic drainage system.

Further south between these granites and the sea the relief is lower, consisting of the flattish upland areas and steep valleys of the Tertiary deposits, low but still steeply dissected Lower Birrimian areas, and low-lying and fairly gentle areas of recent sands just behind the coast. A minor relief feature here is formed by a ridge of highland running NW to SE from the Tano to Bonyere, which terminates on its northern side in the Nauli scarp.


Sefwi - Bekwai
Enchi
Asankrangwa

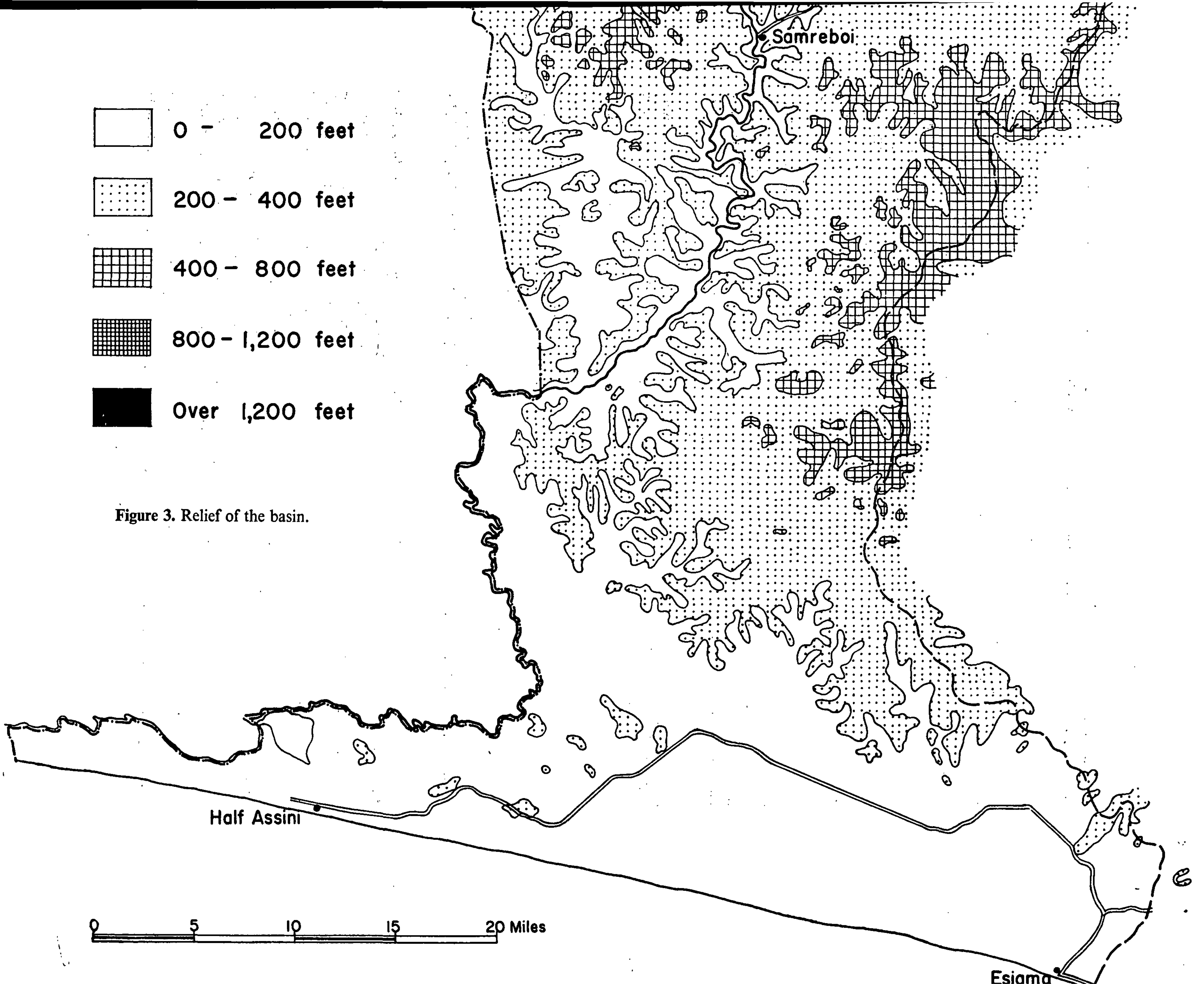


Figure 3. Relief of the basin.

The sample strip maps included in Part II give examples of the type of relief found in each of the main geological areas and the gradients associated with them.

Drainage

The Tano meanders considerably in its progress through the basin, and its valley and associated alluvial soils vary considerably in width. Occasionally the valley is steep, narrow, and almost gorge-like, particularly where it appears to have cut down through areas of resistant phyllites which now stand out as hills, as at the point where it is crossed by the Asankrangwa–Enchi road. Elsewhere the valley may broaden out to a width of 1 or 2 miles, with large areas of alluvium, including well developed pebble beds and low terraces. This is well shown at Samreboi. The river is at about 340 feet above sea level where it enters its lower basin, and, assuming a length of about 170 miles, it has a gradient of about 1 in 2,500. The speed of the water varies with the season and may reach 6–8 m.p.h. Water is at its lowest in February, and then rises steadily throughout the rains, reaching a maximum in about October. Its regime is of course influenced by the rainfall regime of its upper headwaters, where the dry seasons are more strongly marked, as well as by the rainfall in the Lower Tano Basin itself.

Of its principal tributaries, the Boin and the Disue from the west have particularly well marked valleys with extensive alluvial areas similar to those of the Tano itself. On the eastern side, the Suraw in the north is the most important tributary; further south the basin is narrower, and the streams generally correspondingly small.

In the south, the area described in this report includes parts of Nzima which do not drain to the Tano but flow to the sea, either directly, or via Lake Amansuri. This lake is at the centre of a marshy area where drainage to the sea is difficult due to a line of slightly higher dunes along the coast.

Water resources

Almost all the inhabitants of the area still rely on the local streams or rivers for their water supply. These suffer from the disadvantages of being contaminated by helminths and bacteria as well as being more or less visibly muddy, of shrinking during the dry season, and often of being a fair distance from the village. Usually the village is on a hill or rise and the water has therefore to be carried uphill from the stream in the valley bottom.

In a few villages, particularly in Nzima, shallow wells have been dug. These are convenient, but collect water from the upper layers of the soil, not pure water from deep down. Towards the end of 1956 and the beginning of 1957 deep wells sunk at some of the coastal towns (Half Assini, Bonyere and Esiama) by the Department of Rural Water Development tapped large quantities of pure water at 200 feet and more, which now supply these towns. More modern installations are urgently needed in the bigger towns inland, such as Asankrangwa, Enchi and Sefwi-Bekwai where the water supplied by local streams is inadequate both in quality and quantity, especially in the dry season, while numerous small wells, such as the tube wells used in Indian villages, are required to supply the smaller villages.

Vegetation

The Lower Tano Basin lies within the forest belt of Ghana and forms one of the few remaining parts of the country where there are still very extensive areas of little-used original high forest.

The vegetation map included in this report (Fig. 4) divides the basin into a number of vegetation units distinguished by the percentage of forest which remains in each. These units are the following:—

1. *Forest reserves in which the vegetation is usually original high forest and cultivation is not allowed.*
2. *Areas of broken forest, in which less than* 10 *per cent of the original forest has been cut down for farms, though certain species may have been felled by timber extractors.*
3. *Areas of incipient land rotation cultivation in which at least half of the area is still original forest, but farms and regrowth vegetation (including secondary forest) account for* 10–50 *per cent of the total area.*
4. *Areas of well developed land rotation cultivation in which most of the area is either farmed or, having been farmed in the past, is under secondary vegetation of one of the types described below. Such areas have between* 10–50 *per cent of original forest left, often in the less accessible areas, and usually include cocoa or coconut farms in addition to the more temporary food farms.*
5. *Areas of relatively intensive land rotation cultivation. These areas are usually close to towns where population densities are relatively high, and little if any original forest is left standing (less than*

10 *per cent). Fallow periods may be relatively short, with the result that there is a greater proportion of the younger regrowth vegetation (forb regrowth and thicket) to the older secondary forest than there is in areas in unit 4.*

6. *Major areas of swamp forest, little disturbed for cultivation.*

Original forest is constantly being partially cleared for farms, but after the farm has been cropped for several years, and declining yields indicate that the soil has become exhausted, the area is abandoned and allowed to revert to a regrowth vegetation. This is divided into three types, according to its age and floristic composition. The initial growth of weeds and soft stemmed herbs persists for about two years and is mapped as *forb regrowth.* This is succeeded by *thicket*, a higher denser growth in which shrubs and coppice shoots predominate, which in turn merges, six to ten years after the clearing is abandoned, into *secondary forest.* Secondary forest is characterised by numerous quick-growing light-demanding trees and thus has a different composition from the original forest. Within the basin as a whole the percentages of original high forest, regrowth vegetation and cultivated land have been estimated as follows:—

	Square miles	*% of total*
High forest:		
(*a*) reserved	773	28
(*b*) unreserved	1,269	46
Total high forest	2,042	74%
Major areas of swamp vegetation (mainly the Lake Amansuri area)	73	3%
Regrowth vegetation, all types	489	17%
Cultivation and semi-permanent tree crops	163	6%
	2,767	100%

The following paragraphs discuss the floristic composition and physical structure of the original forest, and the types of regrowth vegetation which succeed the forest after it has been felled.

Composition of the original forest

The original high forest of Ghana is not uniform throughout but can be divided into a number of belts which differ in their floristic composition and general character. The distribution of these belts is connected with rainfall and soil acidity.

The evergreen rain forest in the extreme south of the forest area is found where the rainfall is 70 or more inches per annum and the dry seasons are shorter than in the rest of the forest zone. This survey has shown that the distribution of the rain forest is similar to the distribution of upland soils with a topsoil more acid than pH 5·0. The particular species which characterise this forest, referred to as indicator trees, are *Cynometra ananta* (ananta)[3] *Lophira alata* (kaku) and *Tarrietia utilis* (nyankom), and the forest is known as the *Cynometra-Lophira-Tarrietia* association. This association is characterised equally by the complete absence of two trees very common in the forests to the north, *Celtis mildbraedii* (esa) and *Triplochiton scleroxylon* (wawa). A fuller list of species found in the various associations and their distribution is given in Part III, pages 248–259 below.

In the Lower Tano Basin the approximate boundary between the evergreen *Cynometra-Lophira-Tarrietia* association and the moist semi-deciduous forest to the north of it is thought to pass through the latitude of Samreboi (Fig. 5), and to continue west of Samreboi through the Tano-Nimri forest reserve to the southern part of the Boin River forest reserve. There is a fairly well defined and narrow zone where, going from south to north, *Tarrietia* disappears and *Celtis* and *Triplochiton* begin to occur.

[3] Names in brackets are local names. The standard botanical reference work used throughout the survey was Hutchinson and Dalziel, 1931 - 57. In some cases where up-to-date information not contained in this work is available, the authority name has been added in the text; otherwise the authorities are in every case those given in the work under reference. In the case of some well known names which have recently been changed, the old name is given in parentheses. The Appendix to the Flora of West Tropical Africa (Dalziel, 1937) was referred to for the local names of the species listed.

There are, however, considerable exceptions to even this simplified pattern of distribution since large numbers of *Cynometra* and smaller quantities of scattered *Lophira* occur north of this boundary.

To the north of the rain forest or *Cynometra-Lophira-Tarrietia* association, Taylor (1952) describes a broad zone called the *Lophira-Triplochiton* association which was thought to be transitional between the rain forest and the extensive *Celtis-Triplochiton* association of the moist semi-deciduous forest to the north. Field observations made during the course of the survey, however, indicate that since both *Celtis* and *Triplochiton* are found in large numbers immediately to the north of the rain forest this so-called transitional association is poorly represented or even absent within the basin. For this reason the rest of the basin has been mapped as belonging to the *Celtis-Triplochiton* association.

The *Celtis-Triplochiton* association, in which *Celtis mildbraedii* and *Triplochiton scleroxylon* form the two commonest species, also contains many other species which are rare or absent to the south. In Part III the results of detailed vegetation enumerations undertaken during the survey are summarised. These emphasise the fact that the division into associations is, at best, only a useful simplification which hides many minor differences and exceptions. It should also be remembered that the total number of different species is very great indeed, and that many of these, such as the silk cotton (*Ceiba pentandra*) and *Piptadeniastrum africanum* (Odan) are found throughout the area. Moreover, to emphasise the distribution of one or two indicator trees may be misleading if it suggests that the various associations differ greatly from each other: in actual fact the forest appears more or less similar throughout the area and it requires a trained eye to notice the slight changes in floristic composition which occur.

Identification of forest species is difficult because the leaves and flowers are often high up, out of sight and out of reach: as an aid to identification therefore, attention is also directed to the general appearance of the tree, to its branching system, and to the trunk, particularly its shape and colour, the thickness, hardness, colour, texture, taste and smell of the bark and the inner wood, and the nature of the sap, if any.

In particularly wet places, swamp forest occurs. The commonest species is the Ràphia palm and with it are found other spiny palms and shrubs, such as the climbing calamus palm, and various broad-leaved trees, shrubs, herbs and sedges adapted to the wet conditions. These communities are also analysed more fully below (Part III, pages 243–247).

Structure of the original forest

It has become conventional to divide the original high forest into a number of height layers. Normally the upper canopy formed by the crowns of the larger trees reaches 100–120 feet above ground level, there being a small number of still higher trees, the emergents, which rise above this upper canopy. Below this, however, the so-called medium and lower canopies are so irregular that it is possibly more accurate to speak of a confused mass of small and medium sized trees without suggesting any well developed layers below the upper canopy. Nearer the ground one can, however, distinguish a layer of shrubs and shrubby climbers (up to about 20 feet) with higher climbers and lianes ascending to the top of the forest. Grasses may or may not be present: in well developed forest they are usually absent.

In places where the forest is broken, as along roads and rivers, the extra light let in encourages the growth of numerous smaller quick-growing light-demanding shrubs and trees which form a thick and impenetrable-looking mass. From the outside the forest may therefore appear much denser and more tangled than it really is. Inside a well developed forest with a good upper canopy, relatively little light gets through to the forest floor and the undergrowth is thin or absent. Such forest is therefore easy to walk through, and has an open appearance, like an English woodland. Numerous gigantic trunks, often with wall-like butresses, are surrounded by many smaller trees, some with trunks only a few inches thick, but there may be relatively few shrubs and little undergrow th to impede movement. This is particularly true of the oldest and finest forests, in which a high roof of leaves lets in almost no sunshine to lighten the gloom below. Where the forests are lower and poorer, or have been disturbed, the undergrowth may consist of frequent spindly shrubs and be somewhat more impenetrable. On steep slopes and poor soils the poorer quality of the forest is reflected in the greater number of thin pole-like trunks. The Afao hills, near Sefwi-Bekwai, for example, support poor pole forest of this kind on their flat tops.

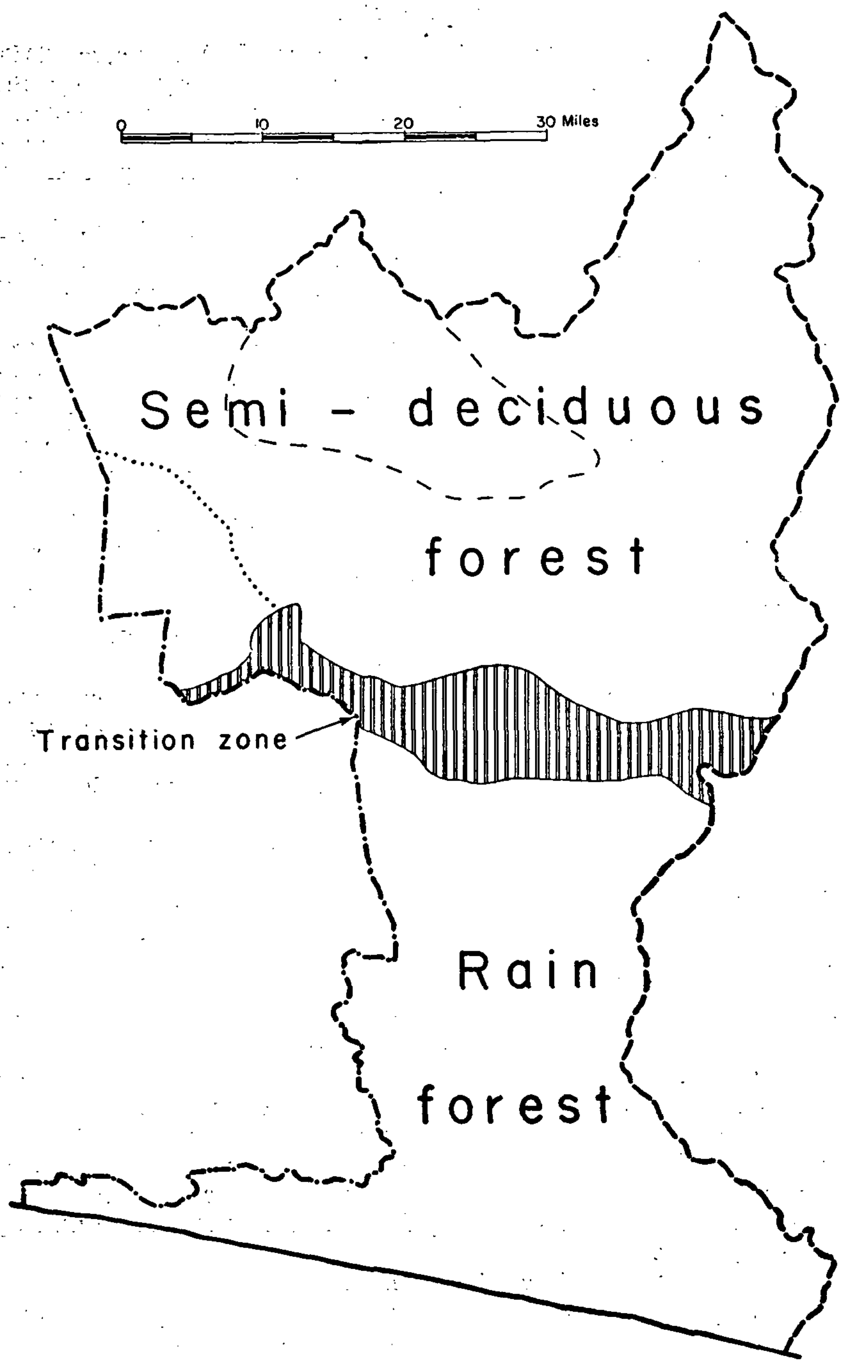


Fig. 5. Forest associations within the basin. The dotted line shows approximately the northermost extension of *Tarrietia* sp. and the broken line encloses an outlier of *Cynometra.*

Regrowth vegetation

The normal farming system of the forest zone, described below under land-use, results in small annual clearings and the formation of a patchwork or mosaic of small areas of regrowth vegetation of different ages, farms, and varying amounts of original forest. Typical examples of such mosaics are shown in the sample strip maps (Figs. 16, 18 & 19). Within the basin regrowth vegetation is still much less extensive than the original high forest, but in most of the Ghana forest zone this proportion is reversed, there being large areas where nearly all the vegetation is now regrowth.

Each of the successive regrowth stages of forb regrowth, thicket and secondary forest is fairly uniform throughout the basin, being relatively little influenced by the floristic composition of the original high forest discussed above. The differences that do occur depend more on the length and intensity of previous cultivation, the fertility of the soil, the number of shade trees spared during the original clearing and the type and extent of the surrounding vegetation. Thus, forb regrowth and thicket in long-cultivated areas of relatively exhausted soils near towns, where there are few shade trees left standing, is less varied in composition than forb regrowth and thicket which grow up in newly cleared forest patches which have been cultivated for only a season or two, and where there are still numerous large shade trees. In the poorer areas the thicket stage also persists longer than usual before becoming secondary forest (Ahn, 1958*b*).

The initial clearing of the forest is almost always only partial since considerable numbers of large trees, forming a skeleton of the original forest structure, are left standing to give some shade to the farm. In all the regrowth stages, therefore, there are present greater or smaller numbers of original forest trees, particularly silk cotton, wawa and *Celtis*, which may stand out above the younger vegetation.

Forb regrowth (Plate 3) consists mainly of soft stemmed leafy herbs, mostly the weeds which appear in farms and have to be cut down regularly. Once the farm is abandoned these quickly establish themselves and form a dense mass of foliage 4–6 feet high, sometimes more. Remnants of food crops, particularly cassava and pineapples, are usually present and coppice shoots grow from the stumps of felled trees. Some of these herbs become tall and woody as they get older and climbers, shrubs and very young trees appear. At one and a half to two years after the farm was abandoned, woody stemmed shrubs predominate and the regrowth merges into the thicket stage.

Thicket is a relatively impenetrable mass of shrubs, climbers, coppice shoots and young trees, difficult to cut through or clear, which may reach a height of 20 feet. As this matures, the young quick-growing light-demanding trees begin to predominate, particularly the umbrella tree (*Musanga cecropioides*), and under favourable conditions the thicket becomes young secondary forest five to six years after the farm was abandoned, though in poorer areas the thicket may persist much longer.

Secondary forest (Plate 3) is characterised by a number of quick growing soft-wooded trees. It differs both in appearance and composition from the original forest, the trees (apart from those original forest trees spared in the original clearing) being smaller and of considerably fewer species. Fairly large numbers of oil palm may be present. Young secondary forest may be only 30-40 feet high but in those cases in which it is allowed to mature it gradually increases in height, so that old secondary forest becomes progressively less easy to distinguish from the original high forest.

When swamp forest is cleared, and then abandoned again, the succeeding vegetation is classified, in the same way, as swamp forb regrowth, swamp thicket, and secondary swamp forest (Plate 5).

A detailed analysis of the species commonly found in the various regrowth stages is given in Part III, pages 244–247, below.

Remaining vegetation types

Immediately behind the coast are very minor areas of coastal thicket differing somewhat from thicket regrowth (Part III, page 243) which are now mostly cleared to make way for coconuts. Associated with these are several small poorly drained savanna patches (Plate 4) which support only grasses and sedges (Part III, page 243 and Ahn, 1959). Mangrove swamps are found at the mouths of some rivers and streams but are very limited in extent and are unimportant.

Vegetation as an index of soil conditions and fertility

No evidence has been found during the survey which associates particular species with specific soil series, or with soils of a specific degree of fertility. Many trees grow throughout the basin and others, though unevenly distributed, are gregarious and occur here and there in relatively large numbers apparently irrespective of site. On the other hand, many species are sensitive to drainage conditions and others to soil acidity.

Swamp forest and swamp regrowth vegetation indicate poor drainage. Even if such sites appear well drained in the dry season, they are probably marshy or even waterlogged during the rains. Edaphic short grass patches such as occur near the coast in Nzima indicate soils which are waterlogged part of the year but dry out at other seasons.

The distribution of many forest species has already been mentioned as reflecting rainfall and soil acidity. A branching fern, *Lycopodium cernum L.*, and stagshorn moss, *Gleichenia linearis*, are fairly reliable indicators of acid soils with a topsoil pH below about 5·5. These and certain blue-berried herbs, such as species of *Pollia*, are aluminium tolerant and adapted to acid soils. They may contain up to 1,000 times the normal plant aluminium content (Chenery, 1952).

The stage reached by regrowth vegetation indicates the number of years the ground has been left fallow and therefore the extent to which the soil has probably been able to increase its content of organic matter and plant nutrients after their depletion during previous cultivation. In general, the condition of both the original high forest and of regrowth vegetation may give the experienced observer an indication of soil potentialities. Particularly poor soils support thinner, lower original forest than usual, and relatively exhausted soils are also reflected in the appearance and composition of regrowth vegetation (pages 244 to 247, below).

Soils

Soil forming factors

The most extensive soil parent materials in the Lower Tano Basin, the Birrimian formations and associated granites, are also widespread in the remainder of the Ghana forest zone. The soils of the basin and of adjacent forest areas where the rainfall exceeds 65–70 inches a year are, however, different from those developed over the same parent materials in the less wet and more extensive Ghana forest areas to the north and east. From a scientific point of view therefore one of the chief interests of the survey was to observe the effect of climate and vegetation on soils developed over rocks which have already been studied elsewhere in Ghana under different climatic conditions.

Modern soil classification is usually based, at least partly, on the origin and history of the soil, i.e., on soil genesis. The major soil forming factors are the parent material in which the soil is developed, the climate, the vegetation supported by the soil, the relief associated with the soil and its drainage, and, finally, the age of the soil, i.e., the time during which the remaining soil forming processes have had to work. These together are reflected in the morphology and fertility of individual soil series.

The heavy rainfall and constant high humidity and temperatures of the basin, and the fact that almost all the soils have been developed under high forest, account for the fact that most of the soils of the basin have certain important characteristics in common irrespective of site or parent material, though site, parent material and other factors produce other differences which have resulted in the division of the soils of the basin into seventeen associations and seventy-two individual soil series.

The important common characteristics of the soils of the basin associated with the influence of climate are :

(*a*) *The great depth to which parent rocks have been weathered* : high temperatures and humidities have softened many rocks to 100 feet or more below the surface. In such cases the zone of weathering rock where plant nutrients are released may be too far down to be accessible by plant roots. Such deep soils suffer from old age.

(*b*) *The intense weathering of the upper parts of the soil profile* : almost all the weatherable soil constituents have been broken down, leaving only relatively insoluble and unweatherable residues such as kaolin and quartz sand and gravel.

(*c*) *The associated high degree of leaching of bases from the soil* : the removal of calcium, magnesium, manganese, potash and other bases is reflected in soil acidity. This varies with the rainfall and other factors and has led to a subdivision of many of the upland soils according to the reaction of the topsoil (page 26, below).

(*d*) *The relatively low organic matter content of the soils* : high temperatures and the associated high level of bacterial activity cause the rapid breaking down of plant and animal remains, so that humus and raw organic matter are not allowed to accumulate. The humous topsoil and the leaf litter layer are correspondingly thin for soils under forest, though organic matter content is nevertheless much higher than that of Ghana savanna soils. The base exchange capacity of the soil and its nitrogen and phosphorus content are closely related to the type and amount of organic matter present, and most of this is in the top 2–3 inches of the soil.

(*e*) *The pale colour of the soils compared with those of the less wet forest areas* : the better drained upland soils of Ashanti are often brownish red or reddish brown, whereas red soils in the Lower Tano Basin are rare or absent, and the usual upland soil is yellow-brown to orange-brown. This is thought to be due to the higher rainfall and shorter dry seasons, so that the soils do not dry out sufficiently to allow oxidation of iron.

A further important soil characteristic probably due partly to climate as well as to the parent material is the nature of the clay mineral, which within the basin is mostly kaolinitic. Kaolin has a lower base exchange capacity than illitic or montmorillonitic clays, which are generally absent from the basin, or present in only minor quantities.

The extreme climate of the basin is therefore contributory to the poverty and fragility of its soils, even though it also produces on them a forest growth suggesting a fertility which they do not possess.

The very varied parent materials of the basin are responsible for differences in texture of the soils, depending on the relative amounts of sand, silt or clay they contain or break down to. Sedentary soils associated with Upper and Lower Birrimian rocks are usually kaolinitic and structureless (except in the humous topsoil), and light clay in texture in the subsoil, though certain Upper Birrimian igneous rocks, rare in the basin, give rise to heavier soils thought to contain some montmorillonite. Sedentary soils over granite are also kaolinitic and light clay in texture though they contain more sand and grit than Birrimian soils. Soils developed over the Tertiary sands of Nzima are sandy light clays to sandy loams, while the texture of those developed in the recent coastal sands is particularly light, being sandy loam to sand. Soils developed in transported colluvial and alluvial material derived from upland soils vary in texture from loose sands to clays, with light clays predominating.

Parent materials differ very greatly in the mineral nutrients they contain or liberate on weathering. Broadly speaking, Upper Birrimian crystalline rocks containing hornblende and other dark minerals, such as are found in the north-west of the basin, are richer than the phyllites and pale granites of the remainder of the basin, while many of the soil parent materials, particularly the Tertiary and Recent sands of the south, contain little that can weather to provide plant nutients. Alluvial soils are often similar in this respect, and have suffered leaching during transportation, though they may receive some nutrients in solution when the associated stream or river is in flood. Due to the climate, however, the nutrient status of the soils of the basin does not differ as widely as the differences between the various parent materials might suggest. In the south of the basin, in particular, all the soils have been leached to a common low level irrespective of parent material and differences between soils are more differences of texture, depth, ease of working and accessibility than of nutrient status.

Soil site and morphology

Soil morphology, i.e., the nature and arrangement of the soil horizons which together make up a soil profile, is closely associated with relief and with geomorphology. The distribution of the individual soils of the basin and their origin cannot be fully understood without reference to both present day relief and land forms, and the way they have developed in the past.

The soils of the basin are of three main types, sedentary, colluvial and alluvial. Sedentary soils, the most extensive, are usually found on upland sites and are developed directly from the parent material below. Colluvial soils occur on the lower slopes of hills below the sedentary soils and are developed in slope-wash material derived from them. Alluvial soils are developed in water-borne deposits of alluvium, either in recent alluvium in valley bottoms or in older material on river terraces.

In each type of soil, two main processes are involved. The first is the geomorphological sorting and transport of material, in particular the removal of fine material and the resultant concentration of residual gravel in upland soils, and the deposition by rivers and streams of alluvial sands and clays in lowland areas. The second is the action of soil-forming processes themselves, including the work of plants and soil animals and bacteria, which act on this material and result in the development of soil horizons.

The *sedentary soils* of the forest zone are usually found on middle to upper slopes and summits. A typical sedentary soil is shown in Fig. 33. The first 5 to 7 inches consist of relatively loose, humous loam, usually dark greyish brown in colour. Below this, in the upper subsoil, is a layer containing fairly frequent to abundant gravel. This gravel, upon close examination, is seen to consist of small angular quartz gravel, occasional larger quartz stones (usually still angular or nearly so), frequent ironstone concretions of various sizes, but typically about pea size or a little larger, and minor amounts of small and large rock fragments which have been hardened by being impregnated with iron. These are referred to in this report as ferruginised rock brash, the smaller pieces being easily mistaken for concretions. Other materials may be present (e.g. cubes of oxidised iron pyrites or manganese dioxide concretions) but in much smaller quantities.

This gravel zone often extends from 4–7 inches to 3–5 feet, though the upper part of this zone contains the largest proportion of gravel and stones which in some soils may reach 70 per cent or more by weight of the total soil. In the lower subsoil the gravel is usually less abundant and at varying depths the subsoil grades into the weathered substratum. This may begin, in a normal sedentary soil, at 5–6 feet or more below the surface and consists of soft clay or loam derived from the weathered products of the original underlying parent rock. Traces of this parent rock become more and more frequent further down the weathered substratum, which is usually somewhat mottled, until eventually soft weathered parent rock is reached.

Sedentary soils developed over the Tertiary and recent sands of the south of the basin are quite distinct from the normal gravelly sedentary soil of most of the forest zone described above. In these areas the upland soils are developed in deep uniform sands or sandy clays and are usually without included gravel.

Colluvial soils (Figs. 38 and 51) are usually relatively inextensive and may be locally absent from the soil sequence. Typically, they are associated with concave lower slopes between sedentary soils on the higher slopes and alluvial soils in the valley bottom. Below the grey-brown humous topsoil is a yellow-brown fairly uniform light clay subsoil, usually with little or no included stones or gravel, consisting of fine material washed down-slope from the soils above. The subsoil varies in thickness, being usually 3–5 feet deep, and overlies fairly abruptly a weathered substratum consisting of weathered material derived from the underlying rock. The junction between these two zones is sometimes, but by no means always, marked by an accumulation of stones or gravel known as the stone-line. These yellow colluvial soils are less well drained than the higher sedentary soils, though drainage is still quite adequate. Because of the absence of stones and gravel in the upper part of the profile, colluvial soils are often easier to work than sedentary soils and more suitable for root crops.

In the valley bottoms a variety of *alluvial soils* (Figs. 40,41,45) are found. Streams and rivers are able to sort the material carried, simply because it takes a stronger current to carry the larger particles and these are the first to be deposited when the water slows down. Thus alluvial deposits include sands and clays and even stone or pebble beds if the river is large enough. The typical deposit is a yellowish brown light clay, slightly mottled in the lower parts of the profile because of poor drainage. Badly drained soils subject to waterlogging are usually grey in colour.

Older alluvial soils also occur above the present floodplain of the associated stream or river. These have developed in the material of former river terraces deposited when the river was at a higher level than it is now. They resemble the yellow-brown light clays developed in more recent alluvium, and may contain pebble beds, but are better drained (page 157, below, Figs. 42–3 and Plate 11).

Indurated horizons occur in some soils (Figs. 34–5). The iron present in most of the soils of the basin is responsible both for the formation of the ironstone concretions, in which successive layers are deposited round a central starting point, and for the development of indurated layers and of sheets of massive ironpan in the soil. Many of the upland soils of the basin have a coarsely mottled slightly indurated layer below the gravel zone and this contemporary induration seems to be the beginning of a process which, under favourable conditions, has sometimes culminated in thick sheets of hard iron or bauxitic pan. These sheets are found mostly in very old soils situated on the summits of flat-topped hills, where the pan is usually about three feet below the surface (see for example, Nsuta series, pages 60 and 144). The formation of indurated layers seems to be connected with drainage conditions in the soil and is favoured on flattish sites, as on peneplains. When only small remnants of these peneplains are left on high upland sites, leaching out of other soil constituents gives the concentration of iron or aluminium necessary to form iron or aluminium pan.

It will be seen therefore that in addition to the normal sedentary soils described above, other soils with indurated layers or with ironpan are also found, though in lesser quantity. A further complication is the presence of *immature sedentary soils* in which the gravel layer is absent. These are simply very young soils which due to the steep slope or the resistant parent material have not been able to develop a subsoil and consist only of a humous topsoil overlying directly the weathered substratum (Fig. 36). Parent rock may be found within a foot or two of the surface. These soils may be difficult to use because of the steep slope and the danger of accelerated erosion and topsoil removal, but they do not suffer from the disadvantages of the more common over-mature sedentary soils of the basin, principally their great depth which puts the zone of weathering rock out of reach of plant roots, and may have a relatively good nutrient status.

Soil productivity

Factors affecting productivity.—The natural fertility of the soil, that is the amount and availability of essential plant nutrients it contains, is only one of many factors influencing its productivity, which can in any case be considered only in relation to the particular crop to be grown. A soil may have a high productivity for coconuts but be quite unsuitable for a crop such as cocoa which has different requirements. Apart from the suitability of the climate, factors affecting soil productivity in relation to any one particular crop fall into two groups, the physical and the chemical. What can be grown profitably (and commercial agriculture is the science of growing crops profitably, not just of growing crops) depends also on economic questions such as the accessibility and ease of clearing of the land, amount and quality and cost of labour supply, communications, markets, and other factors, though these are not discussed further here.

On the physical structure of the soil depends, broadly speaking, the availability to the plant of water and oxygen, the two primary essentials for growth. While external drainage of the soil depends on the site and degree of slope, internal drainage depends on the texture of the soil, the sandier soils being better drained but less able to retain moisture during the dry season. Flattish valley bottom soils of the basin are often subject to seasonal flooding. Most upland soils are relatively well drained, though in a few soils ironpan or an indurated layer in the subsoil impede both drainage and root penetration. Downward root penetration may also be limited by a water-table in valley bottom soils, but again, most upland soils are deep and provide ample root room, the gravel layer not usually interfering with root development. In these respects different crops have very different requirements: coffee needs better drainage than cocoa, oil palms send their roots deeper than plantains, and the tubers of cocoyams and the seeds of the groundnut grow best in gravel-free soils and in soils with very loose light-textured topsoils respectively. The normal forest topsoil has a good physical condition since it is well aerated by soil fauna (though these may be less numerous in the more acid soils) and has usually developed a weak crumb structure. The subsoil immediately below is gravelly in the case of most upland forest soils within the basin, heavier in texture, less well aerated and less easy to work: that of alluvial and colluvial soils on the other hand is usually free of stones and gravel.

Physical conditions are of particular importance since they are not easily modified. Although water relationships can be altered by drainage and irrigation, this is often too costly to be economic, while attempts to improve the structure by mulching, green manuring and the addition of organic matter have met with little or no success on comparable forest soils.

The chemical properties of the soil, more than the physical, govern the availability of plant nutrients. Although these chemical properties can be modified more easily than physical aspects, these modifications may also often be quite uneconomic. This is particularly true in the case of soils of the basin, since little is yet known as to what fertilisers and what level of their application can be recommended for most of them, so that the natural nutrient status of the soil will probably remain one of the most important factors affecting productivity for a long time to come.

This natural nutrient status depends on many factors, some little understood as yet. To some extent this differs between soils much less than might be expected, since within the basin the most important soil forming factor is the climate, and leaching has reduced many soils to a common low level of fertility. Except for a few shallow soils and soils over particularly nutrient-rich rocks, differences between soil associations developed over different parent materials and differences between individual series in any one association are therefore more differences of site, drainage, and texture.

In some cases particularly high contents of stones and gravel reduce fertility by reducing the amount of fine earth in which the nutrients are stored, but the biggest single factor affecting the nutrient supply is the relative capacity of this fine earth fraction to hold mineral bases and to supply them to the plant. Since the storage capacity of the kaolinitic clays of the basin is low, the total storage capacity of the soil depends very largely on the organic matter content which has a relatively very high base exchange capacity (de Endredy, 1954). This accounts for the fact, well illustrated in all the analyses in Part III, that most of the nutrients are in the humous topsoil and that the amounts in the subsoil are very low indeed by comparison.

It follows therefore that the greatest care must be taken in keeping up the organic matter content of the topsoil and in protecting topsoils, particularly those on sloping sites, from physical removal through accelerated erosion. The heating of the soil surface by the sun after clearing is also destructive of soil fertility since the higher temperature speeds up the rate of bacterial activity and thus of the destruction of organic matter in the soil.

A soil under original forest is protected from both sun and rain, and is being replenished by the leaves and branches which fall onto it from above. The nutrients therefore travel from soil to tree and back to the soil in a closed cycle in which the very minor losses due to washing out of nutrients are probably replaced by very small quantities brought up from the lower parts of the soil by plant roots. These stored nutrients are contained in the topsoil and in the trees themselves: when the forest is felled, the cycle is broken. The trees are burnt and most of their nutrients lost. There is little leaf-fall to replenish uptake by the new plants introduced. At least some of the topsoil is washed away after the protective vegetation is thinned or removed, and the resultant heating of the ground now exposed to the sun leads to still further losses of organic matter. Thus much of the fertility accumulated over hundreds or even thousands of years may be lost in a year or two. The local system of partial clearing helps to reduce these losses, which would obviously be still further increased by complete clearing along European lines.

Soil fertility may be built up again slowly by allowing regrowth vegetation to develop during fallow periods. The regrowth vegetation that follows the abandoning of a farm is described in detail elsewhere (Part I, page 18; Part III, pages 244–247): the ability of fallow regrowth to restore soil fertility is due to the fact, first, that it increases the nutrient storage capacity of the soil by increasing the organic matter content and, second, that it brings up nutrients from the whole root zone, from the subsoil as well as the topsoil, which are stored in the vegetation itself and are then transferred to the topsoil through the decay of the litter layer. The total amount of nutrients in the topsoil is increased, but particularly important probably is the increase in available phosphorus, usually the major nutrient in shortest supply. The early, leafy, stages of regrowth probably add nutrients at a greater rate than the later stages when additional growth is largely wood. The total amount of nutrients stored in the vegetation itself is high, though the greater leaching of the wet areas of the basin as compared with the drier forest areas reduces the levels to which these nutrients can also be stored in the topsoil.

Individual plant nutrients available in the soils of the basin.—The major plant requirements are phosphorus, nitrogen and potash and, to a lesser degree, calcium, magnesium and sulphur. In addition, a wide range of trace elements are required in extremely small quantities. Little is known as to the availability of sulphur and the trace elements within the basin. The lack of large or consistent responses to trace element applications on trials elsewhere in Ghana suggest that these are present in sufficient quantities in most forest soils, though possibly this is less true of the particularly acid areas of the southern half of the basin. Outside the basin, zinc deficiency has been observed where dumps of decomposing cocoa pods have upset the nutrient balance in the soil (Greenwood & Hayfron, 1951).

The relatively small number of figures for total phosphorus included in the analyses in Part III must be interpreted with caution. Available phosphorus can probably not yet be accurately measured in the laboratory, but those few figures given are somewhat low by usual standards and suggest that the soils of the basin are deficient in this element. This is probably due to the very small amounts of apatite, the source of soil phosphorus, originally present in the soil parent rocks of the basin, and to the long period of leaching to which most of the soils have been subjected. In addition, the relatively high acidity of the soils of the basin appears to reduce still further the amount available to plants since much of the phosphorus is locked in compounds of iron, aluminium and calcium which dissolve only very slowly. The most important source of available phosphorus is therefore organic phosphorus which is mineralised in the soil at the same rate as the organic matter as a whole and added to the soil reserve.

Phosphorus applications elsewhere in the forest zone show responses only on soils cropped for some time, and it is probable that even in the particularly acid soils of the basin the available phosphorus in an uncultivated forest soil is sufficient for a year or two of cropping, provided that the level of organic matter as a whole is adequate. The phosphorus absorption capacity of the soils appears in any case to be low, so that only small applications might be economic even in those cases where a deficiency was proved. Fallow vegetation is thought to increase the availability of phosphorus more by concentrating it at certain points within the topsoil from which plants feed than by adding to the total amount present (Nye & Stephens, in press).

Nitrogen is even more closely connected with organic matter than phosphorus, analyses of soils within the basin showing that nitrogen content is almost a function of the organic matter content. Almost all the nitrogen is in the organic matter itself and is not available to plants until converted to ammonium and nitrates by bacteria. The amounts of these present have been shown (Greenland, 1958) to vary with the season, there being a slow rise during the dry season, to a relatively high peak during the first few weeks of the rains, followed by a rapid fall due to leaching and removal by plants which account for the low level of the rest of the wet season. Within the wetter areas of the basin, however, where the dry season is shorter than in most of the rest of Ghana, this cycle may be less well marked and the particularly acid reaction of the topsoils probably reduces very considerably the rate of nitrification as compared with soils of the drier forest areas.

Most soils of the basin have a better supply of nitrogen than of phosphorus or potash, since total reserves under forest conditions are relatively high and the amount made available appears sufficient for at least several years of cropping at low local levels of intensity provided again that organic matter levels are not seriously depleted through careless cultivation and exposure of the soil to sun and rain. Moreover, the total nitrogen content of the soils of the basin varies relatively little with soil acidity (Table 5, page 25), though the rate of nitrification almost certainly does. The sandy soils of the coastal areas have relatively low organic matter contents and form an important exception: at Atuabo nitrate applications have given encouraging yield increases with coconuts (page 122, below) and would benefit food crops too.

Potash also appears to have given increases in yields when applied to the Atuabo coconut plantations and can be expected to improve coconut and food crop yields on the similar soils of the Tertiary sands, but elsewhere in the basin the supply of potash appears adequate for at least a year or two of cropping, except possibly in the case of cassava, a high potash feeder, which might respond somewhat earlier on the poorer soils.

The amount of available potash varies much less in the climate and soil acidity zones of the basin than does calcium and magnesium (Tables 5 & 6), the increase in soil acidity under the heavier rainfall conditions being due mainly to the removal of these two bases.

Although the supply of both calcium and magnesium is much reduced in the more acid soils of the south of the basin the amounts present may still be quite sufficient to supply the relatively low requirements of plants. The low amounts present are probably more important for their indirect effects on soil reaction and thus on the availability of other nutrients. Possible exceptions are again the soils of groups 4 and 5, the Tertiary and coastal sands (pages 113–125 and 217–238) where magnesium figures in particular appear extremely low indeed.

Soil acidity.—Soil fertility depends as much on the rate at which nutrients become available to the plant as on the total amounts present in the soil. The availability is closely related to the proportion of the storage capacity of the soil (i.e. its base exchange capacity) actually occupied at any one time by metallic bases. A very small total quantity of bases may nevertheless be readily available to the plant if the storage capacity of the soil is also low enough for this small total to occupy a good proportion of it. This important proportion to which the capacity is occupied is reflected in the reaction of the soil, lower proportions lowering the pH value and increasing soil acidity. Soil acidity therefore reflects the availability of these plant nutrients, as well as indicating to some extent the total amounts present

TABLE 5

TABLE COMPARING ANALYTICAL DATA FOR FORTY-TWO LOWER TANO BASIN LATOSOLS DIVIDED INTO ACIDITY GROUPS

Series	*Lower depth of horizon in inches*	*pH*	*Percentage fine earth*	*Exchangeable Bases in m.e. per* 100 *gm.*					*Ca*	*Mg*	*C*	*N*	*C/N*	*O.M.*
				Ca	*Mg*	*Mn*	*K*	*Total*	*Mg*	*K*				
Average of 12 Lower Tano Basin ochrosols	2·7	6·1	73	14·42	3·81	0·32	0·55	19·10	3·78	6·93	4·35	0·383	11·36	7·23
	7·9	5·8	63	2·87	1·26	0·08	0·17	9·38	2·78	7·41	1·24	0·130	9·54	2·09
	20·8	5·2	63	0·73	0·60	0·02	0·09	1·44	1·22	6·67	0·83	0·080	10·38	1·38
	44·4	5·2	58	0·45	0·49	0·01	0·09	1·04	0·92	5·44	0·51	0·060	8·5	0·98
Average of 8 Lower Tano Basin ochrosol-oxysol intergrades	2·0	5·1	74	3·50	1·64	0·18	0·38	5·70	2·13	4·32	2·90	0·246	11·38	5·196
	7·6	5·0	65	1·05	0·73	0·03	0·11	1·92	1·44	6·64	1·14	0·112	10·18	2·02
	19·0	5·03	62	0·52	0·35	0·02	0·08	0·97	1·49	4·38	0·74	0.082	9·02	1.33
	35·9	5·14	66	0·69	0·52	0·03	0·08	1·26	1·52	6·50	0·53	0·063	8·41	0·90
Average of 22 Lower Tano Basin oxysols	2·2	4·4	85	2·26	1·02	0·14	0·32	3·74	2·22	3·19	3·49	0·275	12·69	5·98
	6·5	4·5	69	0·65	0·42	0·05	0·14	1·26	1·55	3·00	1·44	0·129	11·16	2·48
	17·2	4·8	50	0·41	0·30	0·02	0·09	0·82	1·37	3·33	0·85	0·087	9·77	1·45
	33·2	4·9	55	0·34	0·29	0·01	0·07	0·71	1·17	4·14	0·58	0·071	8·17	1·01

in soils of any one type. Soil acidity is therefore an important guide to the nutrient status of the soil.

The direct harmful effects of soil acidity on plant roots are probably felt only in soils with a reaction below pH 3, in which free acids may be present. Although a very few topsoils in the basin appear to have a reaction of between pH 3 and 3·5, most of the soils have reactions above pH 4. Even in the wettest areas, topsoil reaction probably averages not less than 4·4. Direct effects of acidity are therefore absent. The important effects of acidity are, however, indirect: in addition to lowering the availability of whatever bases are present and of phosphorus, there is an excess of aluminium which may be present in amounts sufficient to be toxic to some plants. By accumulating in the roots, aluminium may reduce the power of plants to absorb what little phosphorus is available. The exact effects of soil acidity in tropical forest soils are little understood as yet, but soil acidity appears of the greatest importance to plant growth and hence the emphasis which it has received in this report. At the same time, however, all pH values given must be considered only as approximate. They are difficult to measure with accuracy in the field and vary in the soil with the seasons, with soil moisture content and possibly with other factors. On cultivated soils in Europe, Russell (1950) considers these factors may cause a difference of as much as one unit, though under the forest conditions of most of the basin this variation may be somewhat less, perhaps half a unit.

Soil classification based on soil reaction.—Recent investigations on the acidity of soils in the Lower Tano Basin and in much of the rest of the Ghana forest zone have led to the division of the highly weathered latosols of most of this area into two groups distinguished by their respective profile reaction and the difference in nutrient status this represents. The less acid soils with a topsoil pH above 5·5 are grouped as *ochrosols*, a name suggested by the late C. F. Charter. These soils are usually distinctly more fertile than the more acid *oxysol* group in which the topsoil pH is 5·0 or below. Between the two groups is a minor intergrade group with characteristics somewhere between the two. This division is based both on laboratory data and on field observations, which tend to confirm the practical effects on plant growth of the theoretical aspects discussed above. The distribution of the oxysol group coincides fairly closely with the distribution of the true evergreen rain forest of the *Lophira-Tarrietia-Cynometra* association (pages 15–17 and 239–242) and with areas having a rainfall of above 65–70 inches. This group is thus particularly well represented in the Lower Tano Basin.

A characteristic forest ochrosol within the basin has a topsoil reaction of about pH 6, becoming a little more acid down the profile so that at 5–6 feet, in the weathered substratum, a pH of 5·0 would be usual. A typical oxysol, on the other hand, has an acid topsoil of about pH 4·4 to 4·6, occasionally somewhat less, but becomes less acid with depth, the pH rising to about 5·0 in the weathered substratum. The difference between the two groups is mainly in the topsoil, therefore, and since the reaction lower down is much the same in both, the trend down the profile in each group is opposite in the two groups.

Table 5 shows the average analytical results obtained for twelve ochrosols, eight ochrosol-oxysol intergrades and twenty-two oxysols within the basin, summarising the reaction and the content of bases, carbon and nitrogen for each of these major groups. This table is important because it shows clearly not only the differences between the two groups and the effects of increasing acidity, but also the very low general nutrient level of the soils of the basin. A comparison of the data for these groups shows the following:

(*a*) *Carbon and nitrogen* are slightly less in the oxysols than the ochrosols, but the differences are relatively small and may not be important. In both cases levels are high compared with savanna soils, though much lower than totals normal in temperate forests. It is possible, however, that the more acid humus of the oxysols has a lower base exchange capacity than that of the ochrosols (de Endredy & Montgomery, 1956).

(*b*) *Calcium*, on the other hand, decreases very rapidly with increasing acidity so that quantities present in the oxysols are only a fraction of those in the ochrosols. Expressed as millie-equivalents per 100 gm. of the fine earth fraction this is only 2·26 in the topsoil of the average oxysol analysed from the basin, as compared with 14·42 in the average ochrosol, or 6–7 times as much. Expressed as lb. per acre present in the whole of the first 30 inches these ratios are 671 lb. for the average oxysol and 2,698 lb. for the average ochrosol (Table 6).

(*c*) *Magnesium* also decreases with increasing acidity, but at a lesser rate than calcium. The average for the upper topsoils of the oxysols is about one-third of the ochrosol average. With increasing leaching, more calcium is removed than magnesium, therefore, so that the proportion of the two is altered. The calcium/magnesium ratio is 3·78 in the upper topsoil of the average ochrosol, falling to 2·22 in the average oxysol. In both groups the ratio falls rapidly below the topsoil: here absolute amounts of both bases are very small and ratios are not much above unity.

(*d*) *Exchangeable potash* also decreases with increasing acidity, but considerably more slowly than either calcium or magnesium, being 0·55 millie-equivalents per 100 gm. in the average ochrosol topsoil and 0·32 m.e., or about 60 per cent of this figure, in the average oxysol. In terms of lb. per acre calculated for the first 30 inches of the soil the difference is even a little less, the totals being 348 lb. as compared with 248 lb. The proportion of potash to the total exchangeable bases increases therefore in the more acid soils even though the absolute amount falls somewhat.

(*e*) All the figures in the table stress the fact that most of the nutrients are stored in the topsoil. The fact that the average ochrosol upper topsoil is half an inch thicker than that of the oxysols further increases the differences between the total base content of the two soils. This is shown in the following table which shows the total amounts of bases, expressed in lb. per acre, in the first 30 inches of the average ochrosol and the average oxysol within the basin[4].

	Calcium	*Magnesium*	*Manganese*	*Potash*	*Carbon*	*Nitrogen*
Ochrosol (average of 12 examples).	2,698	723	90	348	66,962	6,771
Oxysol (average of 22 examples).	671	265	44	248	61,436	5,991

Table 6. Average content, in lb. per acre, of exchangeable bases, carbon and nitrogen in the first 30 inches of twelve ochrosols and twenty-two oxysols from within the Lower Tano Basin.

(*f*) *Exchangeable manganese*, as distinct from the other bases, occurs so erratically in the soils analysed that, although it is also subject to leaching, average figures have little value. Kwaben series (page 77 and page 170 below), an acid gleisol associated with the latosols discussed here, which supports relatively good cocoa, has an unusually high manganese content.

It appears likely that similar differences to those observed above between oxysols and ochrosols occur in varying degrees between the remaining soils of the basin, mostly alluvial soils, of differing topsoil reaction.

Soil associations of the basin

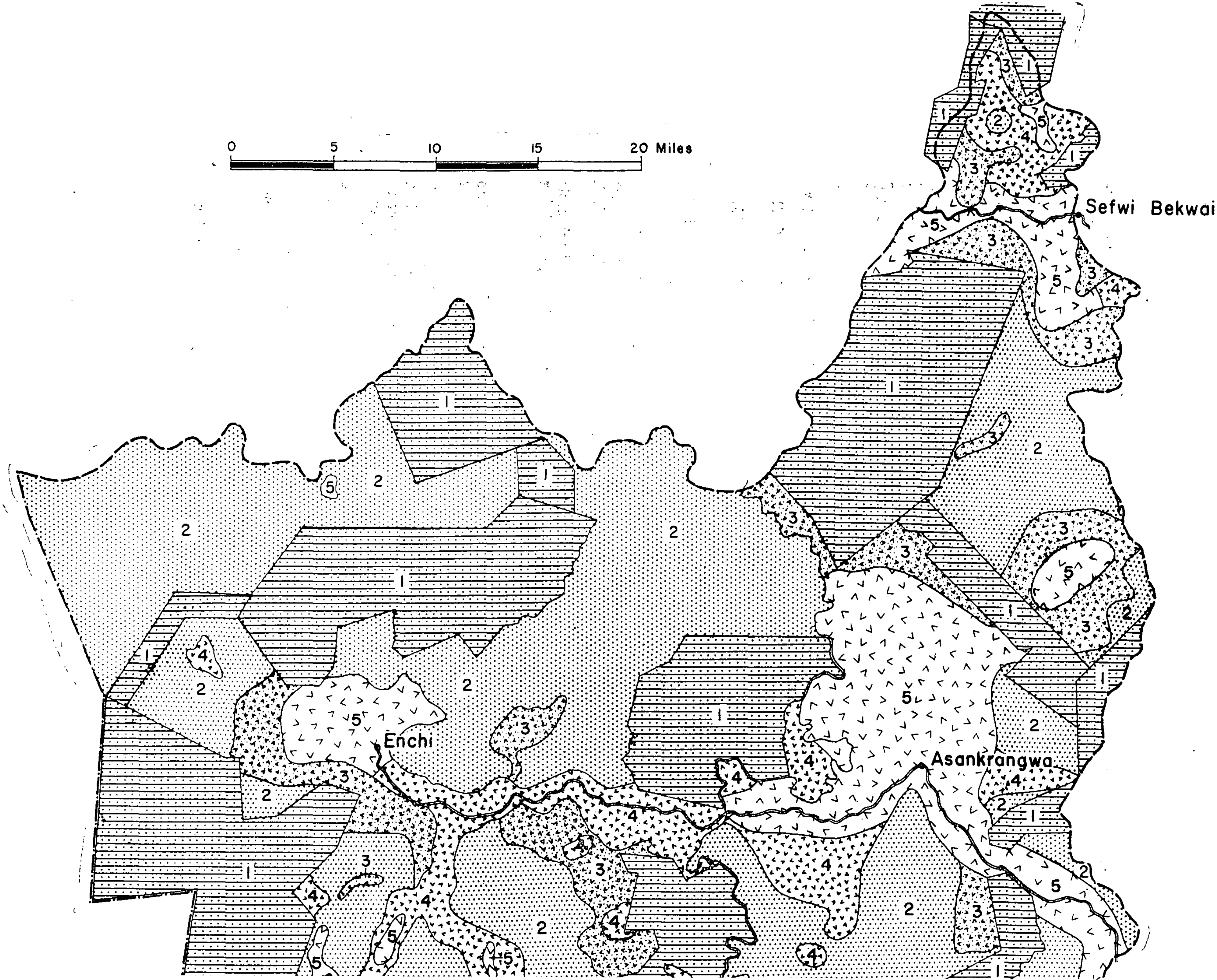
The soil associations of the basin are listed in Table 7, pages 56–7. It will be seen that they fall into five major groups, each corresponding to one geological area, though on the soil map the major expanses of alluvial soils occurring within the other groups have also been indicated.

Soil associations developed over the same geological formation are distinguished from each other by minor differences in parent rock and by differences in climate, as reflected in soil acidity.

The three main Lower Birrimian associations (1B, 1C and 1D) differ mainly in the extent to which they have been leached, there being the normal ochrosol association in the north, its oxysol equivalent in the wetter south, and a third association in the centre which consists of oxysols and ochrosols intermixed. The granite associations, on the other hand (Group 3), are divided both according to reaction and according to whether the parent rock is biotite schist (3B and 3C) or granite, and if granite, whether this is micaceous (3A) or non-micaceous, fine grained (3E) or coarse grained (3F). Soils developed over Upper Birrimian rocks (Group 2) are divided in a similar way, but here the range and complexity of the parent rocks is greater and the associations mapped include soils developed over several differing rock groups.

Within the normal forest associations, that is within all those associations in groups 1, 2 and 3

[4] Recent modifications in the Branch's analytical methods make these figures somewhat more reliable than the earlier high figures of Charter (1955*b*) which also attempted to correlate acidity with available bases, though the general trends observed were the same.



0
5
10
15
20 Miles
Sefwi Bekwai
Enchi
Asankrangwa

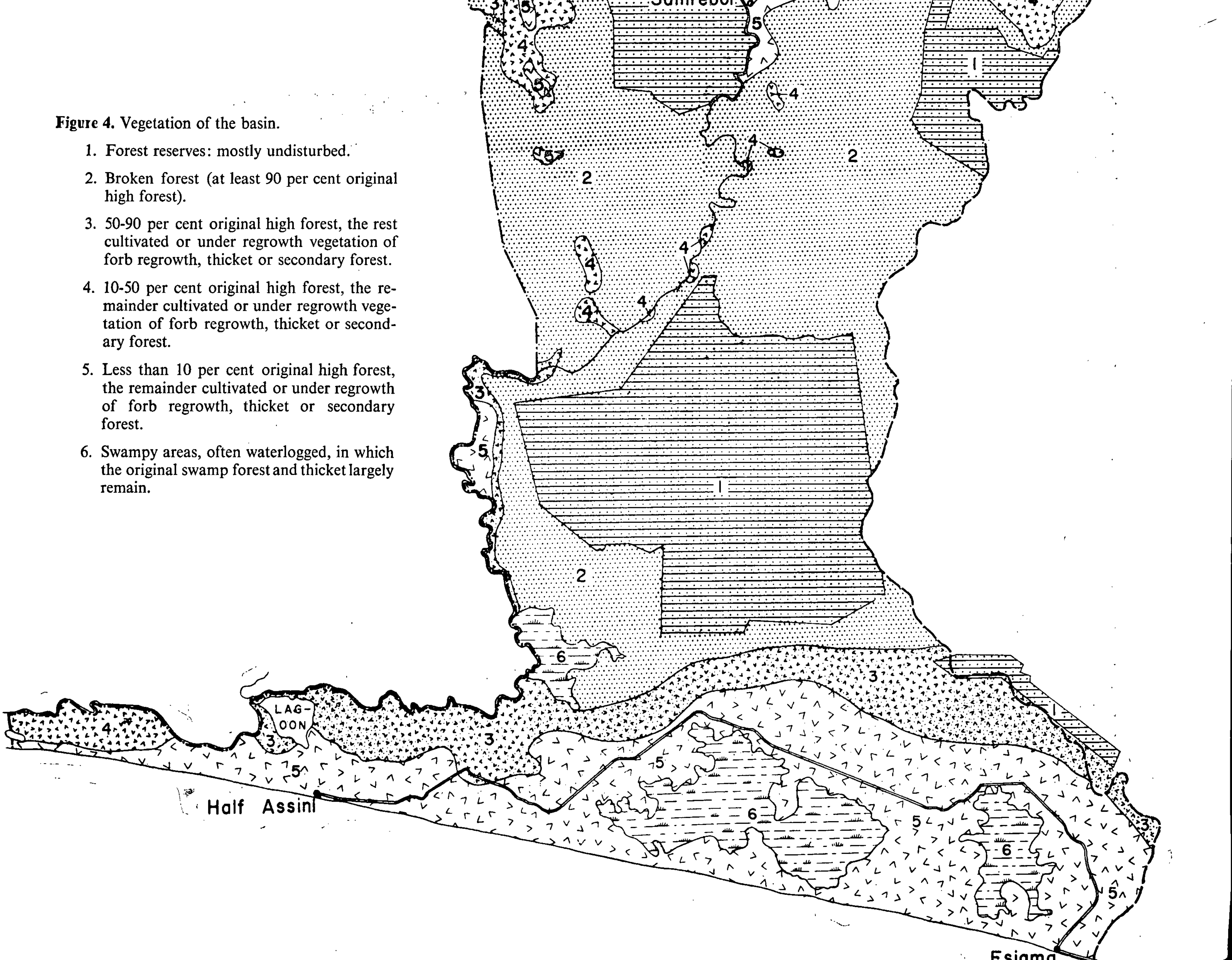


Figure 4. Vegetation of the basin.

1. Forest reserves: mostly undisturbed.
2. Broken forest (at least 90 per cent original high forest).
3. 50-90 per cent original high forest, the rest cultivated or under regrowth vegetation of forb regrowth, thicket or secondary forest.
4. 10-50 per cent original high forest, the remainder cultivated or under regrowth vegetation of forb regrowth, thicket or secondary forest.
5. Less than 10 per cent original high forest, the remainder cultivated or under regrowth of forb regrowth, thicket or secondary forest.
6. Swampy areas, often waterlogged, in which the original swamp forest and thicket largely remain.

discussed above, there is a regular succession of normal sedentary soils, immature sedentary soils, upland crustal soils, colluvial and alluvial soils. Most soils in any one association have a close counterpart in the other associations, from which they differ in parent material or acidity, so that all soils of one type—e.g. colluvial soils—are somewhat similar in morphology irrespective of the association to which they belong. The division of associations into individual series follows therefore a fairly simple and regular pattern closely linked with the relief.

Groups 4 and 5, soils developed over Tertiary and coastal sands, differ from the other associations of the basin in that the regular catena is less well developed. In the Tertiary sand areas, for example, most of the area consists of only one soil, Tikobo series.

Summary of soil potentialities within the basin

Most of the basin is too wet and the soils too acid for cocoa. The crops best suited to these conditions are tree crops such as oil palm and rubber which require a high rainfall and have relatively low nutrient requirements. Many of the important forest food crops such as plantain and cocoyam also seem to do best in the cocoa areas so that these too grow less well in the basin, particularly in the central and southern parts of it, than they do in Ashanti, to the north. On the other hand, coconuts grow better in the deep well drained soils of Nzima than they do further inland.

It has already been shown that the forest soils with the best nutrient status are the less acid ochrosols, and these are the soils with which successful cocoa is usually associated. Ochrosols in the basin are confined to the northern tip, near Sefwi-Bekwai, and to scattered areas a little to the south of this, particularly in the Upper Birrimian hills north of Enchi. The major part of the basin is south of this ochrosol zone, and the normal upland soils are too leached and acid for cocoa, though a little cocoa is still grown in the alluvial soils of valley bottoms, particularly those found along the banks of the Tano and its major tributaries. These soils are distinctly more fertile than the associated upland sedentary soils, which, because of the high rainfall, are best suited to oil palm and rubber.

The following brief summary of soil productivity within the basin refers to the areas demarcated in Fig. 6.

In the northern Sefwi-Bekwai area the Lower Birrimian phyllite soils (area 1*a*) include occasional moderately good upland cocoa soils and fairly well developed areas of alluvial soils along the river Suraw which are considered locally to give higher cocoa yields than the upland soils. In addition to cocoa a wide range of food crops are grown and yields are high enough to permit the export of cocoyam and plantains to towns outside the basin. Despite the fact that this is an area of mixed soils, including some more acid and less fertile examples, the area is therefore able to produce both cocoa and a food surplus. The adjacent Upper Birrimian areas to the east (area 1*b*) include parts of the Bibiani range and are somewhat higher, with hills rising to 1,000–1,800 feet. These areas include small expanses of very fertile and productive soils, but the bulk of the upland soils are of moderate fertility, comparable to those over the nearby Lower Birrimian rocks.

This relatively productive and fairly closely cultivated northern tip, comprising those parts of areas 1*a* and 1*b* which are not under forest reserves, has an area of 84 square miles and therefore covers only about 3 per cent of the basin. To the south of this ochrosol area stretches a broad area (2*a* and *b*) extending to Samreboi at its southermost point, of mixed ochrosols and oxysols which are probably present in approximately equal proportions in the area as a whole, though one or the other group may predominate locally. The eastern part of this area (2*a*), with its centre at Asankrangwa, is over fairly uniform Lower Birrimian rocks and here cocoa is generally of only poor quality on the upland soils, with some better areas on the valley alluvial soils. The major food crops also grow less well here than to the north, though rice in the valleys is fairly successful. Rice is exported but there is little or no surplus of other food crops.

The Upper Birrimian area north, west and south of Enchi (area 2*b*) also belongs to this zone of mixed oxysols and ochrosols but the parent materials and hence the soils are more varied than in the Asankrangwa area. The soils fall into three groups. There are inextensive areas of very good upland sedentary soils in which hornblende schist, epidiorites and other basic igneous rocks weather near to the surface and supply mineral nutrients within reach of plant roots. Unfortunately these soils are usually found only on scattered high hills and are often inaccessible. Their total area is very small

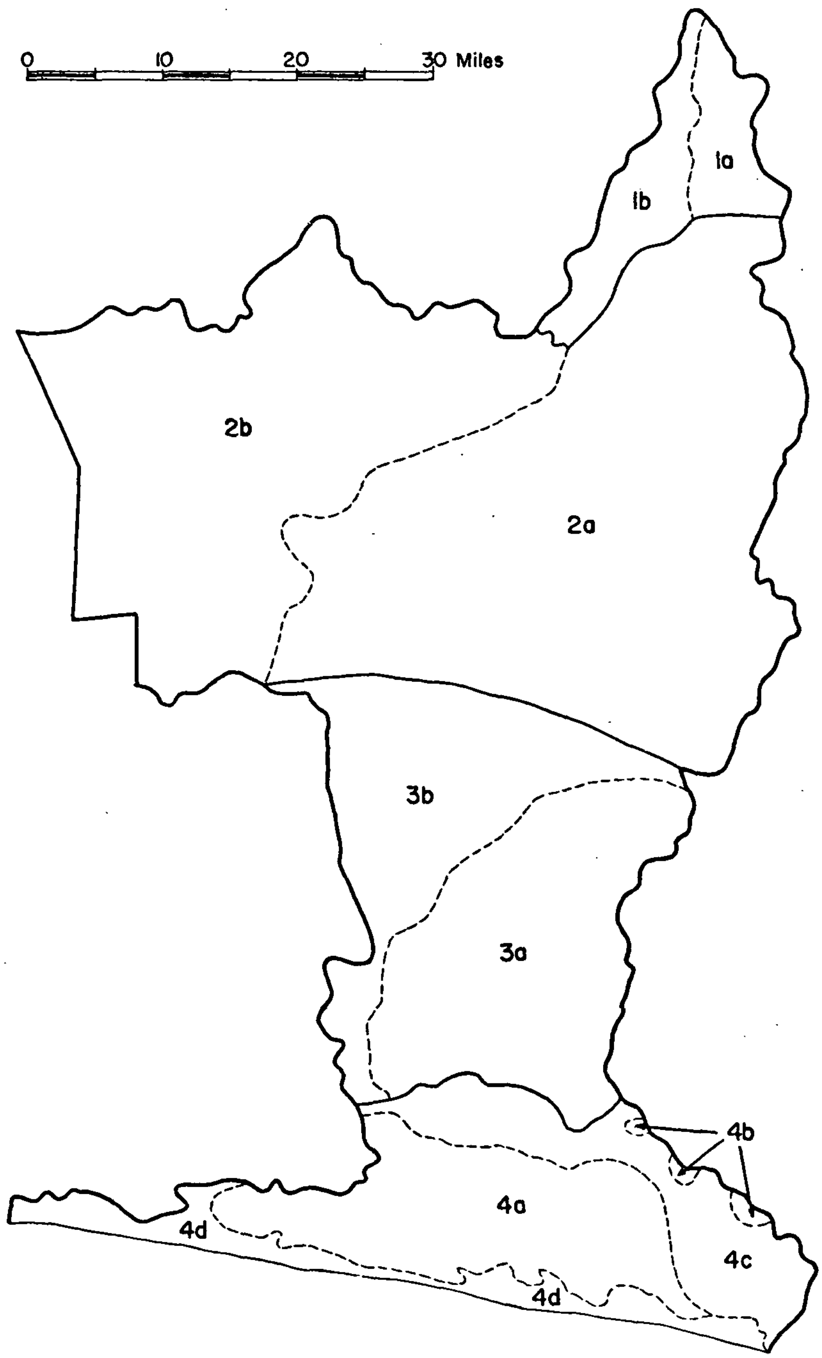


Fig. 6. Major soil/agricultural areas of the basin. (For explanation *see* text.)

compared with the main group of moderately fertile to rather infertile very deeply weathered and often acid, yellow to orange-brown sedentary soils which are found on most of the middle and lower hill slopes. These soils are approximately equivalent or slightly superior in nutrient status to the mediocre upland soils of area 2*a*. The third group of soils in the Enchi area comprises those developed over local alluvium. These are not as extensive as the second group of lower grade sedentary soils, but they are distinctly more fertile, and most of the cocoa grown in the area is on these soils. They have the advantage of being flat and relatively accessible. The area as a whole has been little developed as yet and farming standards are low, but potentially it is considerably more productive than the Asankrangwa area.

The narrow central part of the basin (areas 3*a* and 3*b*) has a rainfall of over 70 inches per annum, and here the upland soils are all oxysols. These are leached and of such low potential productivity that it is doubtful whether they will be cleared and farmed for a very long time to come. Most of the area is over granite (area 3*a*) and these acid granite soils are among the most infertile in the basin. Food crop yields are very low, particularly after the first year, and cocoa fails on all the upland soils. Only oil palm, rubber and possibly coffee would be worth trying on such leached soils. Inextensive areas of relatively fertile yellow alluvial soils occur on the banks of the Tano and of smaller streams, and it is only here that cocoa can be grown, and large villages such as Cocoatown and Elubo are found.

A considerable proportion of this central area is included in the Ankasa River forest reserve. South of it the basin broadens out to include all that coastal area between Kikam and Newtown (areas 4*a*, *b*, *c* and *d*). This is the most densely populated part of the basin, although the greatest density is in the extreme south near the sea. The rainfall is even higher than in the area to the north just described, and the soils are also oxysols, but there is a greater variety of soils and only a very small percentage of these are developed over granite (4*b*). A somewhat larger area (4*c*) consists of acid phyllite soils but the most extensive soils are those developed over Tertiary sands (area 4*a*). These sandy soils are quite unlike most of the other soils of the basin. Though they are highly leached and very low in plant nutrients, they are deep, uniform, well drained and light textured, so that they are easy to work and well suited to groundnuts, oil and coconut palms. The latter in particular have spread rapidly in the last thirty years and an increasing export of copra provides the area with its main source of revenue. Of the food crops, cassava is the most widely grown: yields are fairly low, but this is the arable crop best suited to the infertile but well-drained soils. Rice was once important in the extensive swampy areas but production has now declined. Oil palm would undoubtedly do very well here, but little has been planted as yet due to a local preference for coconuts, which involve less labour. The sandy soils, partly because of their uniformity over considerable areas, are probably more suited to manuring than the other soils of the basin.

The soils developed over the more recent coastal sands (area 4*d*) are similar in texture and ease of working to the Tertiary sand soils, but are still poorer in nutrients. Food crop yields are low, but coconuts grow moderately well and now cover extensive areas. The initial responses obtained from fertiliser applications at Atuabo (Gordon, 1956) have been encouraging enough to suggest that manuring would be economic and that the productivity of the area could be increased considerably (page 122, below). The associated small savanna areas are relatively unimportant: these are not capable of being developed economically and should be left for rough grazing.

Future development possibilities

The main problems confronting agriculture in the basin are:

1. The evolving of a system of agriculture which protects and preserves the fragile fertility of the soils, but which gives higher yields than at present and also avoids the continual drain on the farmers energies involved in clearing forest or regrowth vegetation for only a year or two of cropping.

2. The accumulation of greater knowledge and experience of the best methods of managing the individual soils of the basin. Laboratory analyses are not yet any more than preliminary indications of soil fertility, since they cannot predict what is actually available to any particular plant, and there is as yet little correlation between laboratory analyses and actual yields of specific crops on specific

soil series. For these reasons, analyses must be supplemented by agricultural trials.

3. The introduction of better crop strains and better tools, the organisation of marketing, the improvement of communications and of living and working standards of the farmer in general. These aspects are beyond the scope of this report.

With regard to the major requirement, the evolving of a system which does not rapidly destroy soils merely for the sake of a few seasons of cropping, it is first necessary to examine the present system in order to see to what extent it is adapted to local conditions and what aspects of it should be preserved. The advantages of this system of land rotation cultivation can be briefly summarised. Firstly, it does not involve complete clearing of the land, since some trees are always left to shade the soil, to protect it from the direct force of the rain and to anchor it, and clearing is in any case usually confined to small and irregular patches. Secondly, mixed cropping is the rule, and the crops grow between trees, shrubs and often weeds which also help to supply a soil cover. Thirdly, the later stages in particular of the farm are marked by a good weed growth and fallow vegetation rapidly takes over once the farm is abandoned. The successive stages of regrowth build up the fertility of the soil by adding organic matter, available phosphorus and bases, so that after six to eight years rest the soil, though below the fertility of its original virgin state, is able to support another two to three years cropping at the low yield levels which prevail. Fourthly, the annual cycle of clearing, burning and planting is well adapted to the seasons, the planting during the first rains coinciding with the higher nitrate level of the soil at this period, so that crops get off to a good start. Fifthly, the amount of actual cultivation and soil disturbance is very minor: a little casual cutlassing or hoeing of the soil and the digging of small holes for planting suckers, for example, does not have the harmful effect on soil structure that more intense working would have.

The disadvantages of the system can also be summarised briefly. Yields are generally low. Only a small area of the total land available is cropped at any one time, and as soon as cropping becomes too frequent soil productivity declines: with lower yields more land has to be cultivated and thus, once both the land area available and fallow periods become inadequate, soil fertility may be rapidly reduced. The farmer spends much of his time clearing ground which is only to be abandoned again soon, and thus he is usually kept at a low standard of living. The total population supported by such a system is low relative to the land available. The introduction of higher yielding crops may not necessarily improve matters if they place a greater strain on the limited resources of the soil.

Modifications to this system must accept the principle that complete clearing of the forest would not only be costly but disastrous to the fertility of the soil. Mechanised farming with the plough has no place within the basin, and there is no example of successful mechanised agriculture on similar forest soils under similar environmental conditions anywhere else in the tropics. Such a system would have to solve innumerable problems connected with fertilising and the maintenance of organic matter, protection of the soil from erosion, problems of land-ownership and problems posed by the hilly relief and intricate soil patterns of the forest zone. Any schemes for development on these lines are likely to be costly failures. It is better to make slow but real advances on existing lines.

The presence of large tracts of virgin forest and unused soils within the basin presents both opportunities and a challenge. If the soils are not generally of very great fertility, they are certainly potentially more productive in their present state than they would be if allowed to be misused in the future, and hence the challenge to plan their most profitable long-term exploitation now. To some extent the particularly wet climate of this part of the forest zone, and the leached soils associated with it, present problems and possibilities differing from those of the rest of the forest zone. The best way to use such an area of forest is so obvious that it is often unnoticed: it is simply to replace the present tree vegetation by other trees of more use to man.

The planting of tree crops should be viewed in the light of the advantages and disadvantages of the present system of modified land rotation cultivation discussed immediately above. It will be seen to combine the advantages of providing a continuous soil cover, with the avoidance of the disadvantages of using the soil for a brief crop, a small reward for the labour of clearing, and then having to abandon the land to fallow. Tree crops can be introduced into the existing forest structure with a minimum of soil disturbance. They protect, anchor and shade the soil, and feed it with their litter, much as the original forest did. They make only small demands on the nutrient supply of the soil. Once established, even weeding below the trees is reduced to a minimum by the shade provided.

Most important, perhaps, of all: tree crops live for decades and give the farmer a lasting return for his labour, a capital asset, and something to hand on to his children. All this contrasts with the hard work and poor returns of shifting cultivation, the impoverishment of the soil it involves, the fact that most of the land is unproductive, and the lack of any permanent reward given the farmer for his efforts.

The worst form of soil mining is the clearing of original forest for only short and rapidly declining yields of bananas, plantains and other food crops. Where these are grown to shade cocoa, then they are a temporary stage prior to the establishment of a semi-permanent tree crop. The ultimate aim should be to plant all the better-drained soils with tree crops, and to use the ill-drained bottom areas for rice, preferably swamp rice. Swamp rice can be grown continually, two crops a year, without soil erosion or impoverishment, and yields can be high. The final stage of this system would be the relative reduction of some of the present forest food crops and the production instead of large quantities of rice, coffee, rubber, palm and coconut oil, copra, and other minor tree crops. This is the system evolved in the densely peopled hot wet lands of Asia: it is difficult to envisage a system better adapted to local conditions, since it combines the continuous utilisation of all or nearly all the available land with a method of preserving the productivity of the soil and of stabilising the present forest zone climatic conditions which are in danger of being upset if the number of trees is reduced too far.

Applying this system to the basin itself, one can envisage most of the Tertiary and coastal sands area planted to coconuts and improved oil palm, and the remaining well-drained soils of the basin devoted to limited areas of cocoa and extensive areas of rubber, oil palm, coffee and minor tree crops, including timber plantations. Throughout the basin, low-lying areas suited to rice are extensive. Small quantities of chewing cane, maize, cassava, plantain, cocoyam and vegetables might be grown, mainly for local use. The income from the exports of rice, rubber, coffee, oil and copra should be sufficient to ensure a higher standard of living than at present prevails, including a more balanced diet, and should add considerably to the exports of the country as a whole. Moreover, the soils would then be under an agricultural system which, with careful management, could be exptected to continue successfully into the future, and not be subject to soil impoverishment and the dangers of indiscriminate forest destruction without permanent benefit. Thus the productivity of the soils of the basin would remain to be handed on to coming generations.

Mineral resources and mining

The area is not important for its minerals. There has been a little scattered digging for gold (now abandoned), bauxite occurs on the Afao hills, and both limestone and oil have formed the object of investigations in Western Nzima. These are dealt with briefly below. Apart from this, there is a little quarrying of granite for road material near Samreboi.

Gold is found scattered in stream beds and alluvial deposits in a number of places near Enchi, but native digging and washing has almost ceased. A mine was sunk at Tokosea but has been abandoned.

Bauxite on the Afao hills forms a continuation of the deposit mined by the British Aluminium Company at Awaso, but that actually within the basin has not yet been used.

Limestone occurs in Western Nzima near Nauli, where it forms part of the Apollonian beds which extend for great depths below a superficial covering of Tertiary sand deposits. The limestone is exposed at one or two points along the Nauli Scarp. Investigations by the Geological Survey Department in 1956 showed that the deposits were not large or accessible enough to supply a local cement industry.

Oil has long been known to exist in Western Nzima since it seeps out at the surface in several places. Several earlier attempts at drilling in the Bonyere–Half Assini area ended in failure. In 1956 an agreement was reached with the Gulf Oil Company who employed the Sante Fe drilling company to put down a drill along the sea shore at Kobnaswaso, 4 miles west of Bonyere, which cut through mixed Tertiary deposits to over 10,000 feet, but tapped no oil. Three more shallower drillings have since been completed, also unsuccessfully.

Cultural Features of the Region

Social

Tribes and languages

THE WHOLE of the basin forms part of the Western Region, i.e of the western part of the area formerly known as the Colony.

Two groups of languages occur in the region. The main one is the Sefwi–Broussa–Nzima group which occupies most of this south-west corner of Ghana and extends westwards into the French Ivory Coast, the frontier here cutting across tribal divisions. The second group, spoken in the Sefwi-Bekwai–Asankrangwa area, consists of Ashanti and related dialects and thus forms part of the Akan group of languages spoken in most of central and southern Ghana.

The Sefwi, Broussa and Nzima languages are similar to each other, but the schools in the Sefwi and Broussa areas teach in Ashanti, while in Nzima textbooks printed in Nzima are used and Ashanti is less well understood by the local people.

These language groups are closely related to tribal groups. Sefwi–Bekwai is populated by Sefwis with a strong Ashanti admixture. Enchi is inhabited by the Broussas, Asankrangwa by the Wassaws, and the rest of the basin south of the river Nini by the Nzimas.

Population

The distribution of population is very uneven, there being very large areas which are still virtually uninhabited.

The main population centres are associated with the three main roads which serve the area. These centres of population are old established and the pattern was similar long before roads were built to serve these areas. The coming of the roads has however caused some intensification of the original pattern through the depopulation of the thinly-peopled areas away from the main centres.

These main areas of population concentration are:—

(1) *The Sefwi-Bekwai area.*—Sefwi-Bekwai itself is just outside the basin but numerous villages along the road to Wiawso and on either side of it, as well as villages such as Adobewura and Adiembra along the Suraw valley, make up an area of moderate population density which the 1948 census suggests includes about 3,000 inhabitants (Efwhia 334, Adobewura I and II 240, Ashiem 230).

(2) *The Asankrangwa area.*—This area, particularly the Asankrangwa, Bremang, Mosiaso, Sang area north of the main road has a moderately dense population, and there is some expansion further northwards along the Tano. The villages of Kwaben and Agona connect this area with area 1. This is an area of relatively long-established settlement, now closely farmed. Asankrangwa itself had a population of 2,026 in 1948 (though this was 200 less than in 1931). Moseaso had 506, Kwaben 472 and Agona 504. Taking into account all the scattered smaller villages it is unlikely that the total population exceeds 10,000.

(3) *The Enchi–Yankoman–Yakasi area* has also a moderate population density but is surrounded by much larger tracts of unused lands. It extends southwards beyond Boinso, thus including a string of villages as far south as Jemma and Asemkrom. It is connected with area 2 by the main road which also has minor villages along it, but clearing is very limited throughout the area. The Aowin Native Authority area which includes all the villages as far south as the Tano had a population of 10,441 in 1948 of which Enchi accounted for 2,064, Yakasi 1,034, Yankoman 438, Jemma 571, Asemkrom 486, Boinso 364 and Seewum 356. Subtracting about 1,000 for that northern part of the area outside the Tano Basin this area has a total population of approximately 9,500.

(4) *The Samreboi area.*—The town of Samreboi has grown up since 1948 due to the choice of this site for the headquarters of Messrs. African Timber and Plywood Limited, who employ directly about

2,000 people. Prior to this only a handful of small villages existed here. Including the immigrant farming population who have come in to serve the timber workers, the population of the area is probably about 6,000. It is surrounded by large areas, including forest reserves, almost without settlements.

(5) *The coastal areas of Nzima.*—This is the most densely-populated part of the basin, separated from the areas described above by an extensive forest area which is almost uninhabited. There is a line of old established towns along the coast itself, including Esiama, Beyin, Atuabo, Bonyere and Half Assini. A second group of villages is strung out along the road inland and is separated from the first group by the marshy Lake Amansuri area. This inland group includes Tikobo I and II, Nuba, Mpataba, Aiyinasi and Awiebo. These villages are smaller than the coastal towns and the population is less dense than those areas immediately behind the coast but because of the greater availability of new land this inland area will probably become increasingly important in the future, partly at the expense of the coastal settlements.

In 1948, Eastern Nzima had a population of 17,582 and Western Nzima 41,332, the principal centres of population being Beyin (2,324), Bonyere (1,998), Half Assini (2,733), Tikobo I and II (939 and 1,091), Esiama (2,522), Kikam (1,231) and Atuabo (1,833).

The Lower Tano Basin as a whole therefore had a total population in 1948 approximately as follows:—

Northern tip	3,000
Asankrangwa area	10,000
Enchi area (Aowin N.A.)	9,500
Samreboi area	6,000
Western Nzima	41,300
Eastern Nzima	17,600
Total	87,400

Of this total, the great majority are in the south of the basin in the coastal areas of Nzima. Since this census was made the total population has undoubtedly increased, though some individual centres (e.g. Boinso, Jemma and Asemkrom in the centre of the basin) have probably declined somewhat. The areas of densest population are in Western Nzima. For the basin as a whole the overall density in 1948 was about 31 to the square mile but this figure is very misleading since large areas are almost unpopulated: the Enchi area, for example had an overall density of only 8 per square mile while in the centre of the basin there are large areas where the density does not reach even 1 per square mile.

Houses and settlements

House type depends on the local supply of building materials. Throughout most of the region, where building clay is available, houses are of swish. In the sandy coastal areas, where there is no good clay, huts and compounds are made of raphia palm ribs. Many coastal towns, such as Beyin, Bonyere and Half Assini consist mostly of these palm rib buildings. Throughout the region however, more permanent buildings of concrete blocks are being put up by those who can afford them.

The mud or swish huts and compounds are of two types. The first type is made of solid swish without any framework of wood to give support: in this case the walls are very thick and massive and the house is built by completing the walls in layers about 2 feet thick, each of which has to dry out thoroughly before the next layer is added, so that the house may take several seasons to complete. This is to minimise the effect of cracking, though cracks do occur and may be filled in. This massive swish type of building is used in particular for the large Ashanti type compounds which measure 60 x 80 feet.

The second type of building, very common in the smaller villages, consists of a framework made of poles and sticks, lashed together and plastered over with mud, both inside and out. This is the usual method for small huts.

Roofs used to be of raphia thatch, which is cool and pleasant in appearance, but which needs renewing every two to three years. Thatch roofs are also inflammable and harbour insects. They are being replaced, especially in the towns, by iron or aluminium sheets which are hot and ugly, though they last for many years without attention. The better houses have wooden doors, and shutters for windows. A good swish compound may well last 50 or even 100 years if on good foundations, especially if faced with cement.

In most areas the normal building unit is the compound which consists of a series of rooms forming a rectangle and facing inwards to a central courtyard. This is used by an extended family group, part of the compound being reserved for cooking. The care that goes into the construction of houses varies considerably, some villages being neat and well laid out, with carefully smoothed mud walls, neat thatch roofs and very occasional flower plots in front. Other villages are careless in layout and general construction with a good percentage of unfinished or collapsing houses and poorly surfaced streets perhaps gullied by erosion.

Most villages are grouped around a broad central street sometimes planted with a shade tree or two. In the larger villages other roads run parallel to the main one in a geometrical layout. At one end of the village there is usually a grass field and the school.

In practice, villages (like the individual people) are quite mobile and may be moved from their original site to take up new positions along a lorry road where communications are better and produce can be sold to passing traffic or sent to market towns. On many roads small villages occur 1–3 miles apart, with larger centres every 10 or 20 miles along the road, but there are still many small farming villages accessible only by footpath or canoe. On the central stretches of the Tano, particularly below Samreboi, small hunting and fishing hamlets are frequent, often consisting of only a hut or two (Ahn, 1955*e*). In the lower stretches of the river there are several larger cocoa growing villages.

Community facilities

Schools are in the hands of the churches, mostly Methodist and Catholic. Standard 7 education is available at all the larger towns but nowhere in the basin can any higher education be obtained: for this pupils have to go outside the area.

A hospital has been built at Asankrangwa, largely by voluntary local labour. A hospital at Axim serves the Nzima area. These are supplemented by several local dispensaries, and there is also a good hospital run by Messrs. African Timber and Plywood at their Samreboi headquarters which takes in outside patients.

An agricultural experimental station at Aiyinasi is engaged on coconut and oil palm fertiliser work and the provision of seedlings and stock to local farmers. This station forms the subject of a separate report (Ahn, 1957).

Communications

Earlier this century, when communications were by bush paths and hammock trails, the general trend of trade and movement was north-south. Half Assini, Axim and other coastal towns were connected by paths northwards to Tanoso, Jemma and Abenia in the centre of the basin, and from here porters could carry goods still further north to Enchi, Asankrangwa and the Sefwi area. Printed cloths, gunpowder, kerosene, matches, hardware and other imported goods were head-loaded inland, while cocoa, rubber, incense (a resin from *Daniellia similis*) and other forest products were carried to the coast. At this time Tanoso was an important trading centre with a European-run store: today the town has disappeared and the site is almost deserted.

This spectacular change was due partly to the decline of Half Assini and Axim as ports, but mostly to the cutting off of their hinterland by the construction of new roads which tapped the area from the east and so brought it within the orbit of Takoradi, Tarkwa and other towns outside the region. Thus, the road built from Tarkwa through Bawdia junction to Asankrangwa and Enchi led to the decline of the bush paths between these towns and the coast. Similarly, the road from Dunkwa to Sefwi-Bekwai, Sefwi-Wiawso and Jabeso had the same effect on bush paths extending north to these towns.

The position today is that the basin is served by two main roads from the east which orientate it towards Tarkwa and Takoradi, but which leave two areas, one in the centre of the basin and one in the north, which are still without modern communications and which remain very thinly populated. The basin falls therefore into the following zones:

(*a*) The extreme northern tip near Sefwi-Bekwai. This is served by the Dunkwa-Sefwi-Wiawso road, and by minor feeder roads, e.g. to Adobewura, Adiembra, Ashiem, etc.

(*b*) The Asankrangwa–Enchi area. The main road to Enchi from the east has minor roads feeding it which lead to Bremang, Samreboi, Boinso, Seewum, Yakasi and Yankoman. There are also a number of timber roads in the Samreboi area. In addition, the road from Kwaben and Agona has now been extended to Asankrangwa, connecting the area more directly with (*a*) above.

(*c*) A remote area without roads north and west of Enchi. This is little-populated and is served by bush paths, e.g. the path through the village of Kramokrom north to the Sefwi area.

(*d*) A central area, south of Samreboi and Boinso, and extending south to Nzima which is also without roads and is very thinly populated. A number of bush paths serve such villages as Jemma, Asemkrom, and Abenia: canoes use the Tano as a waterway in the central reach while, lower down the river, villages such as Cocoatown and Elubo enjoy launch communications with Alenda wharf.

(*e*) The Nzima area, where communications are again quite good and the population is the densest in the basin. A main east-west road completed in 1948 connects Half Assini with Axim and the east, and minor roads feed this main one. The beach is also used as a road at low tide.

The effect of road construction has been to concentrate the population in the areas the road was built to serve, and to further depopulate the remoter areas as people move towards the road. In the extensive areas in the centre and north of the basin where there are no roads at all, population has declined, moving to towns such as Samreboi. Some very old bush paths are still in use by the few remaining inhabitants, but many villages have disappeared completely or shrunk in size during the last thirty years (Ahn, 1955*e*).

Condition of the roads: All the roads in the area are unsurfaced earth roads. During the dry season they are hard and uneven, becoming corrugated and pot-holed, and large clouds of dust are produced. During the wet season, the scraping of the surface by specially equipped tractors is easier and there is less dust, but occasional flooding blocks the roads and after heavy rains they become soft and slippery. Flooding is particularly bad in Nzima during late May and June when rainfall is at its heaviest. Storms often bring down trees which block the road. This is at its worst at the beginning of the rains in the so-called tornado season. Generally speaking the major roads are kept in good condition. Minor roads such as that from Enchi to Boinso are often so narrow as to be dangerous and are not kept in such good repair. Timber roads and tracks are frequently abandoned after use.

Roads are normally surfaced from borrow pits dug into the gravel horizons of upland soils. For foundations, stony soils and the pebble beds associated with the larger rivers can be used, while solid granite is quarried on the Samreboi-Prestea road. Adequate drying out and hardening of the road during the dry season is essential: this necessitates good ditches kept clear of obstruction and the felling of all large trees shading the road (Ahn, 1955*c*). Road gravel is in good supply in the Birrimian areas of the basin, but is less plentiful in the granite areas. The normal gravel horizons of upland soils are absent in the Tertiary sands area, but stream gravel is used instead. Areas of coastal sands have little suitable road material.

Future development of communications

New main roads: Long term official plans for the area include the improvement of existing main roads and the construction of entirely new roads in the extreme west of the area connecting Mpataba with Enchi and Enchi with Jabeso in the Sefwi area further north. These roads look impressive on the map but traverse almost unpopulated country, so that it is doubtful if they would be much used for some time to come. It is also questionable whether in view of the hilly country they are to traverse and the high cost of construction, they will in fact be built for many years. The only justification for this expense would be that they should stimulate farming in the areas they traverse. As regards the southern Enchi-Mpataba section it is very doubtful if they would have this effect since the soils are not suited to cocoa and give only poor returns for food crops. Nearby, at Samreboi, numerous roads constructed by Messrs. African Timber and Plywood Ltd. would enable farmers to begin large clearings next to the road, but few farmers have moved in and those who have, have found that the soils are not capable of giving as profitable returns as elsewhere. With so much untouched land near the road in the Samreboi area, little is to be gained by building a road through a very similar area on the other side of the river. There was in fact a road from Boinso south to the Tano, a road which would form part of the new road were it ever constructed, but this road has now been abandoned. The position is not that agricultural development is held up by lack of roads but rather that, in this central area, agricultural development has not yet made full use of existing roads.

The Enchi–Jabeso section would be far more difficult to build than the Boinso–Mpataba section just discussed, since the relief here is very hilly and the distance greater. In this case, however, the area has greater agricultural potentialities and includes occasional small areas of very productive soils, e.g. at Tanokrom.

Feeder roads. Feeder roads linking farming areas where the population is already well established to existing main roads are constantly being built and form a relatively inexpensive way of increasing food production. In the north, between Sefwi-Bekwai and Wiawso, further feeder roads to villages such as Paboasi, Akoti and Echuabo would stimulate food farming, and there is a need for further roads in parts of Nzima. In the centre of the basin there is less need because there is less pressure on the existing roads. An exception to this would be the Asimpa area along the Tano north of Asankrangwa where an extension northwards from Bremang would be well used.

The Tano as a waterway. Except for a low-water period between January and April, the Tano is navigable by small launches from the Juen Lagoon at its mouth as far north as Tanoso. There are several launches which ply regularly on this stretch, carrying cocoa from Elubo and Cocoatown to Alenda Wharf where it is loaded onto lorries. During the low-water season transport is confined to canoes, while north of Tanoso there is also a certain amount of canoe traffic, as for example on the Abenia-Samreboi stretch. Here, however, the riverside population is extremely small and navigation is interrupted by several rapids which are exposed at different levels of water.

In the past, when Tanoso was a rubber growing and timber exporting centre, timber was floated down river and assembled into large rafts at Tanoso which were then taken apart in the lagoon for the logs to be transported across the spit to Half Assini by a small railway. Nowadays the timber travels by road and rail to Takoradi and apart from the launches in the southern section the river is almost unused.

Recently, following the improvement of the Alenda Wharf-Tikobo road with the help of a Cocoa Marketing Board grant, attention has been directed to the possibilities of improving this waterway in order to stimulate development. In 1958 work was begun on a £100,000 scheme for improving landing facilities at Alenda Wharf and building cocoa storage sheds and offices. An assessment of the soil potential of the area, however, suggests that little future development on the Ghana side is likely since the cocoa soils on which the present prosperity of such riverside villages as Elubo and Cocoatown depends are confined to a narrow area on the immediate banks of the Tano. Most of these alluvial soils have been used already and inferior soils further away from the river have, when tried, failed to support cocoa and give disappointing yields of food crops. Existing launch transport seems sufficient for present requirements and it would be misleading to suggest that development is held up by lack of transport facilities. It follows therefore that additional investment on improving the waterway would be justified only if it were carried out in conjunction with a scheme for organised agricultural development of the area served by the river, and this would probably be confined to rubber growing. There is, however, plenty of land equally suitable for rubber in more accessible areas.

From the practical point of view, it seems probable that rocks and rapids could easily be blasted sufficiently to give an uninterrupted passage for launches during the wetter parts of the year as far as Samreboi, if not beyond. If this were done the question of using the Tano to float down timber from the Samreboi area might well arise again, especially if railway costs and delays were to increase. The basic problem here is that of offshore loading at Half-Assini, though this has recently been carried out successfully at Axim.

Economic

Major forms of land-use

Land-use in the basin includes hunting, collecting and fishing, the cutting of timber, and crop and animal husbandry: there is now no mining.

It has already been estimated (page 15) that 74 per cent of the basin is still under original forest which is thought never to have been cleared for agriculture. The remainder, apart from the small amount which is built-over land or used for roads, consists of land under current cultivation (including land under permanent tree crops) and land which has been cultivated in the past and has now been abandoned to recuperate, i.e. land which is now left as fallow.

The proportion of original forest to farm land and farm fallow is used to define the land-use categories shown on the land-use map (Map 2, at back cover). These categories are as follows, and correspond with the vegetation categories listed above (pp.14–15).

1. *Forest reserves:* In reserved areas farming is not allowed and even hunting and collecting may be forbidden. On the other hand a limited amount of timber felling is permitted if cut according to a fixed working plan, as approved by the Forestry Department, which allows the removal of a percentage of trees above certain size classes.

2. *Unused or little-used forest:* In this category there is either no farming at all or only a little shifting cultivation which affects less than 10 per cent of the total area, leaving at least 90 per cent under the original forest, though some of this has been cut over by timber extractors.

3. *Incipient land rotation.* Here shifting cultivation is more extensive and may affect up to half the area, but at least 50 per cent of the land in this category is still under original high forest or forest broken only by selective timber extraction.

4. *Land rotation cultivation:* In this category, farmland and farm fallow under regrowth vegetation forms between 50 and 90 per cent of the total, so that the original forest left covers 10–50 per cent of the total area.

5. *Intensively cultivated areas:* In these areas, land rotation cultivation is relatively intensive and over the years farmers have cleared at least 90 per cent of the original forest, which remains only on unsuitable sites such as exceptionally steep or inaccessible hill slopes. Such areas form a mosaic of current cultivation, permanent tree crops, and the regrowth vegetation stages of forb regrowth, thicket and secondary forest. The greater the pressure on the land, the shorter is the fallow period, so that, among the regrowth vegetation, secondary forest diminishes in proportion to the younger regrowth types.

Categories 3, 4 and 5 are subdivided according to whether the main tree crop is cocoa or coconuts. It will be noticed that the main divisions used here are similar to those used to classify vegetation on the vegetation map which are also subdivided according to the proportion of original forest which remains in each category. It should be emphasised that in both cases boundaries are very approximate and that since each unit is a patchwork of little farms, regrowth vegetation and original forest differing only according to the relative proportion of each, these categories are artificial divisions which in practice often merge into each other somewhat gradually. Their distribution is obviously closely related to population densities, since most of the people in the area are farmers.

As new clearings are made the pattern shown on the accompanying maps will be modified. The rate at which the forest is being cut down for farms is obviously of the greatest importance for the future of Ghana. Various estimates have been made as to how long the unreserved forests will last. These estimates attempt to assess the current rate of clearing in the forest area as a whole and then divide the total unreserved forest by the area cut annually in order to calculate how long it will be before there is none left. Such estimates are too generalised to be accurate since they ignore the fact that most of the present cutting is confined to certain favourable areas. It cannot be assumed that, once these better areas are used up, areas less favourable to agriculture will be cleared at the same high rate.

In certain forest areas where cocoa has been found to do well, the news of the fertility of the area rapidly attracts large numbers of farmers from outside who quickly obtain concessions from local chiefs and fell the forest. The Bia Basin is rapidly being opened up in this way, as is the Aboum area west of Sankori, Ahafo, for example (Ahn, in preparation). In areas such as these, clearing may be rapid enough to outrun the activities of timber extractors who, as a result, find their concessions being depleted by farmers before they have time to use them. In the Lower Tano Basin, on the other hand, cocoa and food farmers have, for the most part, reported only very disappointing results so that there is no similar seeking after land and the rate of clearing remains very low. In the Samreboi area in particular, farmers are not even following in the paths of timber operators, making use of the roads and tracks they provide, so that large areas of original forest border the roads, yet nobody wishes to use them. The greater part of the unreserved forest in the basin is therefore being attacked at a very low rate indeed and, since the returns for clearing on the acid soils of the central area of the basin are so low, it seems unlikely that this low rate of clearing will be increased for several decades to come. Most of the clearing that is taking place is in the extreme-north and south of the basin, particularly in the Tertiary sands area where it is realised that the soils will support coconut and oil palms, and along the Tano where a narrow band of yellow alluvial soils is suited to cocoa production.

Collecting, hunting and fishing

In an area where there is still a large percentage of forest, hunting and collecting are naturally important. In the coastal areas where the population is denser and there is less forest, the sea replaces the forest as an extra source of food. Both sea and forest supply protein foods normally deficient in diets consisting mainly of starchy food such as maize, yam, cocoyam, plantains and cassava.

Collecting includes the gathering of chewing sticks and various medicinal leaves, barks, and roots from the forest, and the collecting of snails, mushrooms and such items as the larvae of Hercules beetles for food. In certain districts large quantities of forest snails are collected at the beginning of the main wet season and are sold either alive, or smoked on sticks. Wild oil palms supply oil, palm kernels, palm wine and locally distilled gin. Building materials, particularly raphia leaves and ribs and small-sized trunks for hut frameworks, are also important, as is the finding of firewood. In the past various fruits, leaves and insects formed a larger part of the diet than they do now. Even today, however, the knowledge possessed by some people of local trees and their medicinal properties is surprisingly extensive.

Hunting is important throughout the basin. There are a number of professional full-time hunters as well as a much larger number of farmers who occasionally use a shotgun or set traps in addition to their normal work. Wire snares and various baited traps are set, especially for the smaller rodents, but the bulk of the supply is shot by hunters working at night with acetylene lamps fixed to their heads.

Wild animals form an important article of the diet throughout the area, being relatively scarce in the towns and larger villages but more abundant in the smaller forest villages which may export smoked meat to the larger settlements.

Bush meat includes a very great variety of animals of all sizes, there being no forest mammal which is not good to eat. The commonest, providing the greater part of the meat supply, are (*a*) duikers and antelopes (*b*) monkeys and (*c*) small rodents.

Duikers are of several kinds, all providing excellent meat. The commonest duiker is Maxwells brown duiker (otwe)[5], while the black duiker (ewi) and the bay duiker (odabo) are also frequently killed. Of these the largest may reach the size of a local sheep. In contrast the smallest antelope in the forest, and possibly in the world, is the tiny royal antelope (adowa), particularly prized for its meat, which owes its name to the fact that in local folk legend it is the king of the forest. The bush buck (owansan) and other less common duikers are also present within the basin.

In some areas monkeys are even more important as meat suppliers. Of these there is a large variety, the most frequently shot being the black monkey. These are so common in some parts as to do great damage to food and cocoa farms.

Of the small rodents which are commonly eaten, the giant forest rat (okusie) is the most important, but the cutting grass or cane rat (akrantee), the brush-tailed porcupine (apese), the quilled porcupine (kotoko) and even the northern ground squirrel (amoakua) and other forest squirrels (opuro and apetibi) are much sought after.

Ant eaters or pangolins, whose meat is excellent, are also hunted: these include the small tree. climbing tricusped variety (apra) and the big ground pangolin (same local name) as big as a pig. There are also mongoose (ahwia), tree bears (owia), wild hogs (kokote), palm civets (abrebee) and bush cows (otrom). Crocodiles, tortoises and turtles provide further additions to the diet. Elephants and leopards are present in the basin but are killed only rarely. Birds are not important sources of food, though hawks (akroma) and the allied hornbill (akyinkyina) are good eating.

Fishing includes fresh-water fishing in the Tano and the Juen lagoon, and sea fishing off the coast.

In the Tano the most important fish are various smooth skinned and dark coloured mud fish of somewhat fearsome appearance known under the general local name of adwene. These include

[5] Names in brackets are the usual local Ashanti-Twi names.

opitire (*Clarias* species), the larger kontro, and esene, the biggest of all, which may attain the size of a small crocodile. Oyoyo, the spiny eel (*Mastacembelus nigromarginatus*) is also taken and there is a very wide variety of normal river fish, too numerous to list here. River prawns (*Palaemon* species) and freshwater crabs (*Potamon* species) are common.

River fish are caught in a number of ingenious ways: the commonest is to use wickerwork traps with one-way entrances baited with cassava which has been roasted over a fire, but there are also various spring traps using a bent branch, and palisades are built across smaller rivers or along the banks of the larger ones to catch fish as the flood waters subside. Fish, like meat, is smoked over wood fires before being sent away for sale: the smaller fish are smoked whole, the larger cut into sections first.

Fishing in the sea and in the Juen lagoon is either from canoes or from the beach. In both cases nets are used, some of which are made locally. The usual practice is for a number of men to form a company to work together pulling in the big nets up onto the beach. The fish are sold to women waiting to buy and the money divided between the company and the owner of the net. A large variety of sea fish of all sizes is caught in the nets. Of those not immediately consumed the larger are smoked, and the very small ones merely dried in the sun.

Fishing is important at Axim and at all the coastal towns, though it is markedly seasonal. Some of the fishermen are immigrant Fantes, as at the small village of Ahobre, near Half Assini. Newtown wharf, on the lagoon, exports dried small fish by the drum. Some research is being done by Government into the possibility of using trawlers. If the sea bottom is suitable, yields could no doubt be increased considerably.

Both hunting and fishing are traditionally the work of the man, whose role is that of meat provider, while his wife or wives produce the farm food which goes with it. Collecting of wild products is done by both sexes. Nowadays men who cannot provide meat are expected to provide money to buy it with, but the idea that food farming, as distinct from the production of cash crops, is only women's work dies hard.

Forestry

The 2,042 square miles of original forest in the basin represent a very large timber reserve, nearly all of which now forms concessions to various extractors. The most important of these is African Timber and Plywood (a subsidiary of the United Africa Company) which has a very big centre and sawmill at Samreboi, where the river Samre joins the Tano. This firm has concessions covering most of the area north of the Ankasa River forest reserve and has recently taken over a smaller firm, African Veneers and Mahogany (A.V.M.E.) at Soroso, east of Asankrangwa, whose concessions cover an area to the north-east of the A.T.P. concessions.

The other important concession is that made to Messrs. Mengels (W. Africa) Limited, whose area is approximately that part of the southern half of the basin between the main coastal road and the river Nini. Their concession includes rights to limited felling in the Ankasa River forest reserve. A road has been made from Mpataba, on the coastal road, north-westwards into the forest area and logs carried from here to Axim where they were floated out to ships standing off-shore.

The timber felled in the north of the basin is sent by road to the railway at Prestea, and is thence railed to Takoradi for shipment. A road 43 miles long has been constructed from Samreboi to Prestea.

The principal commercial species extracted vary according to the forest association, which in turn is influenced by soil and climate. In the south of the basin, heavier woods such as kusia (*Nauclea diderichii*) and kaku (*Mimusops heckelii*) become commoner than in the north, while nyankom (*Tarrietia utilis*) is confined completely to the rain forest and is not found north of the latitude of Samreboi. The following list[6] shows the first annual coupe which was to be extracted by Messrs. Mengels (W.A.) Limited, from 6·775 square miles in the south-west of the Ankasa River forest reserve:—

Odum (*Chlorophora excelsa*)	36
Edinam (*Entandrophragma macrophyllum*)	36
Guarea (*Guarea cedrata*)	44
Mahogany (*Khaya ivorensis*)	435

[6] Figures kindly supplied by the Conservator of Forests in charge, Western Division, Takoradi.

Walnut (*Lovoa klaineana*)	3
Kaku (*Mimusops heckelii*)	115
Kusia (*Nauclea diderrichii*)	283
Nyankom (*Tarrietia utilis*)	512
Emeri (*Terminalia ivorensis*)	45
Subaha (*Mitragyna ciliata*)	116

Messrs. African Timber and Plywood, working from Samreboi, fell a similar range of trees from their southern concessions, but also supplement these with more northerly timbers. About 5m. cubic feet are felled annually by this firm, and of this total about 60 per cent consists of only three species, mahogany (*Khaya ivorensis*), wawa (*Triplochiton scleroxylon*) and nyankom (*Tarrietia utilis*), the last of which is found in a particularly well marked belt just south of Samreboi. Most of the rest of the total is made up of the following species, listed in order of importance: kusia (*Nauclea diderichii*), makore (*Mimusops heckelii*), sapele (*Entandrophragma cylindricum*), guarea (*Guarea cedrata* and *G. thompsonii*), edinam (*Entandrophragma macrophylla*), walnut (*Lovoa klaineana*), odum (*Chlorophora excelsa*) and emeri (*Terminalia ivorensis*). Trees felled in very minor quantities include omu (*Entandrophragma candollei*), abura (*Mitragyna stipulosa*), dahoma (*Piptadenia africana*), danta (*Cistanthera papaverifera*), avodire (*Turraenthus vignei*), African rosewood (*Copaifera salikounda*), osol (*Symphonia gabonensis*), denya (*Cylicodiscus gabonensis*) and feyuo (*Distemonanthus benthamianus*). In addition a number of trees are being cut in trial quantities or being investigated: these include *Canarium schweinfurthii*, *Celtis mildbraedii*, *Pterygota macrocarpa*, *Brachystegia leonensis*, *Sterculia rhinopetala* and *Ceiba pentandra*. Since some of these are present in very large quantities indeed within the basin, their acceptance in the timber trade would greatly increase the reserves of marketable timber available.

The present total export overseas from the basin is probably of the order of 30,000 tons of logs per year, plus a relatively small amount of sawn timber. Of this total, at least 80 per cent comes from Messrs. African Timber and Plywood, Samreboi.

Crop husbandry

The term shifting cultivation implies that the farming group itself moves about continually seeking new areas to clear for a season or two and then abandon. For farming by a relatively fixed population who leave land fallow but eventually use it again when its turn comes, the term land rotation cultivation is more appropriate. In this sense, farming within the basin is basically of the land rotation type, since annual or semi-perennial crops are grown for a year or two on a site which is sooner or later left in fallow for a variable period and then used again. This system has been modified however by the introduction of tree crops with a life of thirty or even fifty years. This introduction of semi-permanent crops has changed the whole concept of land ownership, too, since a cocoa farm is now a capital asset which can be given as security for a loan, bought or sold, whereas formerly cultivated land soon went back to bush and had no lasting value as a source of income.

All the farms are owned by Africans and nearly all of them are small and irregular in shape. In most cases ownership is acquired simply by clearing the forest and establishing a farm, though if the would-be farmer is not a local man he will have to buy the land from the owners, usually the local stool, or agree to give up a share (usually one-third) of the value of cash crops produced. Once acquired and cleared the land may be handed down to other members of the family, or, in the case of tree crops, it may be sold. Although the buying and selling of cocoa farms is not uncommon, it is very rare for an Nzima man to sell his coconut plantation. This he regards as a permanent family asset to be handed on to his descendants, and he would rather raise a loan on the strength of its future yields than sell it out-right. Throughout the area inheritance is matrilineal and a man's property, unless he arranges otherwise, will go to a sister's son.

The clearing of virgin land is an arduous and expensive task requiring the felling of many small trees and a smaller number of very large ones. In Nzima land is measured in " poles " i.e., the distance between telegraph poles and the charge for clearing a square pole is £3, though this excludes the cost of felling the large trees. An approximate estimate for normal forest would be that it takes 50 man-days clearing per acre. At 4s. per day this is equivalent to £10 an acre. In practice, extra tree fellers might be engaged for the bigger trees and these cost say 9s. each to fell.

Clearing is done throughout the main dry season, but particularly at the beginning so as to leave longer for the material cleared to dry. The undergrowth is cut down first and then most of the larger trees are felled. At the end of the dry season the cut-down trunks, branches and leafage should be dry enough to burn and as much as possible is then usually got rid of by setting it on fire, though in some areas burning is omitted and planting takes place between the refuse. The ash left on burning supplies potash and other nutrients to the soil, but a proportion of these is quickly washed away before it can be taken up by the crops introduced. After the burning there will still be a number of large trees left standing for shade, and numerous trunks, stumps and piles of half-burnt wood scattered over the ground. The ground cleared is therefore still far too obstructed by tree roots and remnants for any machinery to be used. To clear the ground completely would be quite a different task requiring bull-dozers or other heavy machinery. The usual partial forest clearing allows only hoes and cutlasses to be used in breaking up the soil prior to planting.

The cleared patches vary in size and shape and in the number of big trees left standing. If it is desired to plant cocoa, leafy food crops such as plantain and cocoyam are planted to give extra shade and get a quick return from the ground, while the cocoa seedlings are planted between them. Planting begins with the first rains, that is in March to May, depending on the area. Food patches planted to a single crop are rarely seen, except in the cases of rice and of certain cassava farms where pure stands of cassava are grown. For other crops the usual practice is to have a mixture of plantains interplanted with cocoyams, pepper, and other vegetables such as garden eggs, okro, tomatoes, onions and perhaps gourds or beans, with one part of the patch set aside for maize. Mixed cropping has the big advantage of giving some cover throughout the season.

The length of farm fallow and the proportion of fallow land to cultivated land varies within rather wide limits, depending on distance from the town or village and the road, and the proportion of unused forest in the area still available for new clearing. There are certain small areas near the coastal towns of Nzima which are continuously cropped with groundnuts, gourds, vegetables, pineapples and cassava: one informant stated that a certain small patch near Esiama, for example, had been continuously cropped with groundnuts and vegetables since he was a boy, 40 years ago. Such cases are exceptional, but in the coastal areas as a whole the proportion of cultivated land to fallow is increasing steadily as areas of thicket and even of food farms are being planted to coconuts, which unlike cocoa do not require new land to be successful. Near the larger towns and villages of the rest of the basin the ratio of fallow to farmed land is probably 1 to 3 or 4, so that the average fallow duration may be six or twelve years following two to three years of cultivation, but further away from these settlements farms once abandoned may not be cultivated again for twenty years or more so that they are allowed to revert to a well developed secondary forest.

The more important food crops are dealt with in turn below.

Plantains (*Musa sapientum var. paradisiaca*) are the staple and best liked food of the forest areas of Ghana and large quantities go by road to the towns. In the Lower Tano Basin however there is no surplus for export outside the region, and some are even imported from Ahafo. In some districts farmers excuse their poor production of plantains by claiming that strong winds blow them down. They do best in the north of the basin, but generally speaking the yellower more acid soils of this region appear less well suited to plantains than the soils of Ashanti. It may also be that farming standards are lower. As a result the price in most areas is quite high, though the total quantities produced are considerable.

Plantains are planted from suckers which grow at the base of the mother plant. They are detached with a cutlass, cut down to a height of about 12–18 inches and kept for several days to allow them to dry and also to begin to sprout. They are then planted in holes, 12 inches deep and dug with a hoe, which are spaced somewhat irregularly at about 10 feet apart. Planting is usually done between February and June, during the major rains. The fruit sets in about twelve months and is ready for harvesting fifteen months after planting, when the plant is cut down, though the adjacent suckers will be left. On a good soil these will mature at intervals up to four years after the original planting, but on poorer soils only the first one or two suckers may yield, so that the period a plantain continues to produce provides a convenient guide to the fertility of any particular soil.

In the north of the basin near Sefwi-Bekwai plantains are usually planted in newly cleared forest patches intended for cocoa. The soils here are mostly the relatively fertile ochrosols, and suckers continue to yield for at least three years. The crop is planted on all except particularly poorly drained sites.

In the Asankrangwa area to the south of this (area 2*a* in Fig. 6) the soils are mixed oxysols and ochrosols and the plants decline after the second year, while the size of a bunch of fruits is also reduced. In the Enchi area (2*b*) condition and yields are similar, though north of Enchi they are slightly better. South of these areas however (areas 3*a* and *b*) there is a rapid deterioration, and only the first year's harvest is satisfactory. At Boinso, for example, bananas are grown instead and cooked green. In the remaining southern part of the basin (area 4) yields are also low and confined to the first year after planting, but throughout these poorer areas of acid soils somewhat better yields are obtained on areas of a riverside alluvium (Kwaben series).

A number of local varieties of plantain are distinguished. By far the commonest is *apantu*, the normal large variety. *Apim* is a small, thin variety, usually eaten boiled and not pounded for fufu, while *nyiretia* is a relatively rare short small variety about the size of bananas.

Bananas (*Musa sapientum*) are botanically the same species as plantains but produce smaller fruits containing sugar instead of starch. They seem to be less exacting in their requirements, often growing where plantains do not. Nearly all the bananas in the basin now grow wild and little attention is given even to weeding them.

Cocoyams seem, like plantain, to do well in the same areas as cocoa. They are thus at their best in the north of the basin, i.e. in the Sefwi-Bekwai ochrosol area, becoming progressively poorer southwards. They do moderately well in the Enchi area and in alluvial soils of the major rivers but in the centre and south of the basin they are very seldom seen. This suggests that they are sensitive to soil acidity and do poorly in oxysol areas.

Generally speaking, cocoyams like a soft, easily worked soil and do not grow well in gravelly upland soils where there is less room for the tubers to develop. For this reason, the soft drift soils of the Upper Tano Basin are well suited to the crop. The sandy soils of Nzima have a suitable texture but they are too acid and have too low a nutrient status.

Cocoyams can be planted from suckers but the usual method is to dig up the central rhizome (not the tubers) of an old plant and to cut it into pieces. Each section, which must have two or three eyes from which germination takes place, is placed in a shallow hole. Spacing is irregular and much closer than for plantain, with which the cocoyam is nearly always mixed, and the two crops are planted at the same time. Cocoyam can be harvested after about twelve months but is usually left for sixteen or seventeen months to become fully mature, though this depends on demand. In some areas farmers complained of an insect which attacks the stems, so that the leaves turn yellow and the plant dies.

Unlike cassava, cocoyam can be kept for six to eight weeks after lifting. In addition to the tubers, the leaves provide a widely used and nutritious spinach.

The usual cocoyam grown today is *Xanthosoma sagittifolia* and this is said to have been introduced into the country by the Basel Mission in 1843. An older and probably indigenous variety, *Colocasia esculentum*, is occasionally seen; the tubers are softer and are said to be preferred by old people.

Cassava (*Manihot utilissima*) is a staple food throughout the area and is produced in larger quantities than any other crop. It is a shrubby quasi-perennial but is almost always grown as an annual. In the south, where plantains and cocoyams do less well than in the north, cassava becomes relatively more important. Cassava does not tolerate poor drainage but will grow on any well drained soil except the very poorest, though better soils give higher yields. The plant is also tolerant of acid conditions. On the better soils, as in the cocoa growing areas, cassava is grown in succession to other more valuable crops such as cocoyam and plantain which have already partly exhausted the soil, or it may be planted in previously cultivated soils left to develop a thicket cover and then cleared for cassava. In less fertile areas, as in the south of the basin, it is often planted on ground newly cleared of forest, though in the coastal areas it is often grown repeatedly on the same poor sandy soils with the result that the yields are very low.

Apart from the fact that cassava grows almost anywhere, it has the great advantage of yielding food relatively quickly; it matures in nine months and can be eaten at five to six months already. It is thus valuable to farmers clearing in new areas. The tubers, if not required immediately, can be cut into pieces and dried, or grated and roasted to form gari which can be stored or sent away for sale. Unless treated in this way the tubers keep only two to three days after lifting, and only about a week if buried again. Starch is sometimes extracted from the tubers, and the leaves can also be eaten.

Cassava is grown from pieces of the stem which are cut into sections about 10 inches long containing three to four nodes. These are stuck at an angle into the ground, with about half of the cutting buried. In Nzima a slightly different method is used, the whole stem being buried horizontally below a few inches of earth. The cuttings are planted about 3–4 feet apart, sometimes slight mounds being roughly heaped up with a hoe or cutlass. Cassava is more easily propagated than the previous crops discussed since a single bundle of stems, easily carried to a new farm, can cover a considerable area. Planting is done at any time during the rains.

There are many minor varieties of cassava, distinguished by their bitterness and prussic acid content, by the size, shape and colour of the tubers and leaves, and the height of the plant. The two main varieties recognised in the basin are the red and the less common and less bitter white; the colour refers to the thick inner skin of the tuber. Cassava mosaic, a disease which reduces yields, is fairly common, especially in the south of the basin.

It is very difficult to assess yields, which probably vary between considerable limits, perhaps becoming as low sometimes as between 500 and 2,000 lb. per acre. Cassava is often sold in the ground per 100 plants or per given area of farm.

Maize (*Zea mays*) is found throughout the basin, but it forms only a minor food crop. It is available for only part of the year at the end of each rainy season, when much of it is eaten as sweet corn before it is fully ripe, and there is little stored for the rest of the year. There are two crops a year, of which the first one maturing in May–July is the more important in most of the basin, though in Nzima more maize is planted for the second crop, maturing November–December, possibly because of the very heavy May–July rainfall here. In the wet climate of the basin there is always a danger from rust. It is important to plant the maize as early as possible in the season, since late planted maize suffers the most.

Two or three well-dried seeds are planted together in shallow holes or in slight mounds 2–3 feet apart. Maize is often planted by itself, but may also be mixed with other crops, especially rice. Maize grows on almost any site, including poorly drained ones, though yields are probably best where the drainage is moderately good. Yields might be greatly increased by the introduction of improved strains such as those developed in the Belgian Congo (Kellogg, 1954).

Rice (*Oryza sativa*) is more important than maize, though less widely distributed. It is usually grown by itself, but may be also grown mixed with maize, generally on low, flattish, and poorly drained areas near streams. Rice is simply scattered broadcast at the beginning of the rains and harvested about four months later during the short August dry spell. Only the ears are cut off, and the plants are left to produce a second crop, yielding less than half the first, later in the year. Birds may do serious damage to the crop if not constantly scared away.

The valley bottoms near Agona, Kwaben, Asankrangwa and Dunkwa are widely used for rice, and this area now forms the main rice producing centre of the basin from which rice is sent to Takoradi. There are five rice mills in this area, and another at Tokosue, on the Enchi–Boinso road, which handles the rice of the Seewum–Boinso area. Considerable quantities were formerly grown in the damper bottom soils of Nzima on the borders of the marshy Lake Amansuri area (Robb, 1929), but this has now all but disappeared, possibly due to a greater preoccupation with coconuts. The rice mill erected by the Division of Agriculture at Esiama has had to be closed down.

Rice is of several varieties, sown mixed together: these are *abogyese*, with long barley-like awns, and *mansah* and *boafo* in which the awns are short or absent. Of these, boafo bends to the ground when ripe and has to be harvested quickly, i.e. with a helper or " boafo ". Yields vary: two bags per acre, though low, is not unusual, and a bag, weighing two cwt., sells for about £7.

Sugarcane (*Saccharum officinarum*) is grown only in relatively small quantities and is a soft variety used for chewing. It grows moderately well on damp valley bottom soils liable to occasional flooding, but not on soils water-logged for long periods. It is grown from sections of stem about 12 inches long, planted 4–5 feet apart, and is usually harvested after about one to one and a half years.

Groundnuts (*Arachis hypogaea*) are confined to the sandy soils near the coast (areas 4*a* and 4*d*, Fig. 6) whose light texture is ideal for the crop. After an initial slight hoeing of the ground, individual nuts are dropped into small holes made with a stick or cutlass which are a foot or less apart, so that the plants later completely carpet the ground. The nuts are planted in March and October and are ready for harvesting about three months later in each case, though they may be left in the ground a few weeks longer. No yield figures are available.

Pineapples (*Ananas sativus*) like acid soils and grow well in most of the basin, though they form a minor crop. In Nzima (Fig. 6, 4*a* and *d*) they are particularly plentiful. Both slips and suckers are used for planting and these are planted in March, April and May. Two main varieties are found, the short rounded yellow-fleshed type, and a longer, thinner variety, red outside but very pale inside.

Vegetable crops, such as red pepper (*Capsicum frutescens*), garden eggs (*Solanum incanum*), tomatoes (*Lycopersicon esculentum*), okro (*Hibiscus esculentus*) and shallots (*Allium sativum*), are grown by women, often among the other crops, but are mostly low in quality and in rather poor supply throughout the basin so that prices are higher than in Ashanti, for example. Beans are seen only occasionally and gourds (*Lagenaria sicerana*) are grown near the coast. Red peppers are of several varieties, some of them wild. Most of these vegetables are grown from seed in beds and transplanted out at the beginning of the rains in April and May.

Yams (*Dioscorea rotundata*) are not grown within the basin, as these prefer a drier climate, but the water or winged yam (*Dioscorea alata*) is seen very occasionally, grown in the usual yam mounds. In the Nzima area a small wild yam (*Dioscorea bulbifera*) is collected.

Tree crops have already been mentioned as introducing a new element into cultivation practices and land tenure. Nevertheless a great advantage of both cocoa and coconuts, the two major permanent crops, is that they fit in so well in the early stages with normal food farming. A farmer merely slips in a number of cocoa or coconut seedlings, which have germinated in a separate nursery, between his food crops on the farm. He obtains his normal yield of food crops, which shades the seedlings at the same time: after two or three years the cocoa or coconuts are left by themselves and only need occasional weeding: in five or six years the trees begin to yield.

The only major difference between this and normal food crop planting is that in the case of cocoa newly-cleared original forest is usually necessary for successful results. In the case of coconuts, however, this is not the case and this had led to large numbers of old food farms, cultivated for many years in the past, being turned over to coconuts.

Cocoa (*Theobroma cacao*) needs a moderately fertile soil to do well, since its nutrient demands are fairly high. It is, however, tolerant of poor drainage and will survive even annual flooding, so that it can grow on a range of sites. It is a forest shade tree and needs shade in the early stages of its growth. Its distribution in the Lower Tano Basin suggests that it is not suited to upland soils with a surface reaction more acid than pH 5·0 and to rainfalls higher than about 70 inches per annum, though it is grown successfully on the alluvial soils associated with the river Tano and other smaller streams even though these soils are as acid as associated upland ones unsuited to cocoa.

The most important enemies of the cocoa farmer are swollen shoot disease, capsid attack and black pod, in that order. The Enchi and Asankrangwa areas are now being surveyed for swollen shoot, which is already extensive, and many affected trees have been cut out. Capsid attacks many cocoa trees, both old and young, and usually causes their decline and death, though recently introduced insecticides applied by portable sprayers are being used with encouraging results. Control of capsid would probably have the further advantage of allowing the shade trees to be thinned, a measure formerly thought to encourage capsid attack. Black pod is less serious since it affects only the pods, which are spoilt, not the tree: the fungus which causes black pod thrives best in damp conditions so that it is most prevalent in riverside farms.

With so many possible factors limiting yield and affecting the condition of the tree it is difficult to separate the influence of the soil. In many cases poor farms may be due to disease or to careless cultivation rather than environmental factors. Where cocoa is obviously thriving, however, then it can be assumed that all necessary conditions have been met, including that of soil fertility, and in this way much can be learnt about the soil from the field without recourse to laboratory analysis.

The majority of cocoa farms are small, of a few acres only, and these are weeded by the farmer himself and his family. Owners of large and more prosperous farms usually employ labourers to do the weeding and there are cases where the owner gives the farm to a caretaker who divides the profits with him. The main crop is taken in November and December, with a minor mid-season crop in July–August. Dried beans are made up into 60 lb. loads and sold to various brokers. Cocoa is old-established in the area, some trees being 50 years old. Formerly the produce had to be head-loaded very considerable distances. Nowadays relatively little of the cocoa is far from a road of some sort, while that near the Tano is transported by canoe or launch.

Yields are very difficult to assess, but many of the poor to moderate cocoa farms in the Asankrangwa area give low yields of as little as two loads per acre. The income from one load an acre barely covers weeding costs and then the cocoa may be left to become overgrown. Yields on the better alluvial soils exceed these figures, and may reach five loads per acre, which is still not a high figure.

Coconut palms (*Cocos nucifera*) of the type now planted are of more recent introduction than cocoa, but have spread very quickly in the coastal areas to which they are suited. They do not require a fertile soil and are well adapted to the deep sandy soils of Nzima. They have the advantages over cocoa of yielding all the year round and therefore giving a more regular income, and of being less troubled by disease, which has not yet appeared in Nzima, though the present high concentration of palms would supply good conditions for the spread of any new disease that might break out in the future. They are also hardier and easier to plant and grow. Moreover they are not entirely an export crop but one which provides local food and oil, as well as by-products such as husks for fuel. They can be grown even on poor sands behind the beaches which would support little else. In less than thirty years they have profoundly modified the economy of Nzima and will no doubt continue to spread inland in the future. Exports of copra have steadily increased and provide the main source of cash income for the area.[7]

The spacing advised by the Division of Agriculture is 25 by 30 feet or 27 feet triangular, which gives about sixty palms to the acre. Many local plantations are closer than this, and too crowded, so that yields are reduced. A good palm should give 60 nuts per year, though many of the palms in Nzima are in only poor to moderate condition and probably yield only about half of this. In the early years of the Division of Agriculture's plantation at Atuabo it was found (Fishlock, 1930) that the average yield of two plots was 3,738 nuts per acre per year, which gave 13 cwts. 14 lb. of copra per acre. The current price of nuts is 12s. a 100 and at this rate an acre of inferior thirty nuts-a-year trees would produce £10 16s., while trees in good condition would give a gross return of double this. It requires about 5,500 nuts for a ton of copra which sells (1958) for £45, while the flesh of 200 nuts, if grated and boiled, produces one kerosene tin (4 gallons) of coconut oil sold for £2 or 1s. 6d. a pint bottle.

The nuts are germinated in damp areas and then planted out at any time during the wet season, though most of the clearing is done in November–February. The trees need occasional weeding, but are sometimes planted amid other food crops or interplanted with groundnuts. They begin to yield in 5–7 years. The nuts fall off the tree when they are ripe and merely have to be collected, so that once a plantation is established, overheads are low. Most of the palms in Nzima are near the sea: in Puerto Rico (Roberts, 1942) it is thought that yields get less away from the sea and on land above 300 feet, though almost all the Tertiary sands of Nzima are below this height.

None of the mature coconut plantations in Nzima are interplanted with other crops: elsewhere in the tropics pigeon peas, beans, sweet potatoes, cassava and other crops are planted between palms of all ages (Roberts, 1942). If grass or forage crops could be grown between the palms and used for sheep or cattle, the palms would benefit from the organic manure. The nuts themselves form excellent animal feeding stuff, as does the residue after oil extraction. In many parts of the tropics, pigs are fattened on the nuts when the world price is low. The coconut palm provides quite durable lumber, while in Ceylon it is tapped for the palm wine from which arrack is prepared.

Oil palm (*Elaeis guineensis*) grows wild throughout the basin, but this section is concerned only with cultivated oil palm. At the moment this is still unimportant despite the fact that it is an ideal crop for the Tertiary sand areas of Nzima where the soils are deep and uniform and the rainfall high. Apart from two or three small locally owned plantations there has been no planting of oil palm by farmers. This is mainly because coconuts are preferred, oil palm being less popular because the palm has to be climbed in order to pick the fruit. There are other practical considerations limiting its immediate development: these are the shortage of seedlings of improved varieties available, the general difficulty of germinating all oil palm seeds, the disease known as " blast " which sometimes decimates seedlings, and the lack and expense of modern oil extracting equipment to handle the fruits

[7] Recent estimates of the total acreage under palms in Nzima and of copra production are given below, page 125.

and kernels. On the other hand there is little doubt that the financial return per acre would be higher for oil palm than for coconut, particularly with the new improved varieties now being introduced.

Minor tree crops include coffee (*Coffea* spp.), citrus (*Citrus* spp.), and rubber (*Hevea braziliensis*). Coffee needs, above all, a well drained upland site and does well on certain highly concretionary upland soils in the north of the basin, though it is very inextensive as yet. Citrus fruits appear to do sufficiently well in Nzima to justify larger scale trials being made on them. A few small plantations of para rubber occur on alluvial soils as, for example, at Boinso. Some of these are now abandoned but all appear in good condition and there is little doubt that the basin is climatically well suited to the rubber tree.

Agricultural exports from the region

Food crops: Some rice is exported from Asankrangwa to Takoradi and a small amount of coconut oil and dried fish is exported from Nzima. On the other hand many areas import food, especially plantains from Ashanti.

Cash crops exported consist almost entirely of cocoa and copra. Figs. 9, 13 and 23 show the distribution of cocoa farms in the Sefwi–Bekwai, Asankrangwa and Enchi areas, based on individual farm surveys made by the Cocoa Survey Branch of the Division of Agriculture. It is difficult to estimate accurately the tonnage of cocoa produced within the basin. The only figures available are those showing tonnage purchased by the Cocoa Marketing Board. The following purchases were made during the 1955–56 main crop season :—

Summary of whole of Ghana	*Tons*
Ashanti	117,316
Eastern Province	46,087
Western Province	28,517
Trans-Volta Togoland	26,097
	218,017
Centres listed within the Basin	
Sefwi-Bekwai Area	
Sefwi-Bekwai	933
Appiakrom	15
Agona	44
Odumasi	3
Paboasi	3
Sayerano	84
	1,082
Enchi Area	
Enchi	471
Yakasi	79
Yankomam	6
Akyimfu	3
Jemma	21
Boinso	14
Seewum	1
Asemkrom	14
Omappe	7
	616

Asankrangwa Area	Tons
Asankrangwa	72
Asankra Dunkwa	2
Samreboi	7
Moseaso	29
Anyinam	4
Bremang	33
Efiena	2
	149
Nzima Area	
Axim	107
A. B. Bokaso	9
Esiama	5
Elubo	81
Ebowu	26
Mpataba	3
Samanya	12
Tikobo	9
Teko Bokaso	1
	253
Total for Basin	2,100

This shows a 1955–56 total for the basin of 2,100 tons, or just under 1 per cent of the Ghana total. It is probable that not all the tonnage shown for Sefwi-Bekwai and Axim comes from the basin itself: on the other hand the figures for the Asankrangwa area seem rather low and some cocoa may have been sent out of the region to appear in the tables under another buying centre elsewhere. In any case a certain amount has to be added for the minor mid-season crop to obtain the annual total. With a price to the farmer of £4 per 60 lb. load, i.e., about £150 a ton, the 2,100 tons produced in 1955–56 brought a gross return of £315,000 to the farmers of the region, though the world value of the product in 1955 was about double this. This £315,000 is equivalent to £4 per head of population throughout the area, though obviously the money is distributed very unevenly.

Animal husbandry

Animal husbandry in the area is typical of the forest regions of Ghana in as much as sheep, goats and chickens are kept but little attention is given to their feeding or management. These animals are mostly left to fend for themselves, finding what food they can in and around the compound.

Chickens are very widespread, but small and generally neglected. They scratch around for themselves during the day and may be shut up in a hen house or coop during the night. Occasionally the owner will give them a little maize or scraps, but the usual idea is that chickens do not need feeding. The birds are small, grow slowly and lay very little, possibly 30–40 eggs a year and less if the eggs are left to hatch. They are tough and adapted to local conditions, but are periodically decimated by epidemics of Newcastle disease. There has been little attempt to improve the breed. English birds and eggs are sold at Aiyinasi Agricultural Station but they are less resistant than local strains and require to be well fed if they are to do well. As yet there are very few chicken keepers who are willing to do this.

Goats and, to a lesser extent, sheep are also found in the villages. Along the coast goats are common but sheep are rarely seen. The short stocky local goats are tough animals able to live on a variety of local food and vegetation. Their meat is good. They are not used for milk. The sheep are local coarse-haired varieties and wander about the compounds gleaning scraps. Even in areas where food is plentiful little thought has been given to feeding and fattening these animals, which are therefore generally in poor condition.

There are a few semi-wild local white pigs at Ahobre, near Half-Assini, which forage among the coconut plantations. At Esiama and along the coast there are local dwarf shorthorn cattle, small and rounded, of good appearance. These grow very slowly, however, and the grass patches on which they feed are of poor quality. They are not numerically important and usually a labourer from Northern Ghana rather than a local man looks after them.

The improvement of animal stock is basic to agriculture. At the moment stock is of poor quality, there is no interest in feeding and no use is made of the animal manure. It would be quite unjustified to imagine that European-type mixed farming could ever be important here, but at the same time animals could be made to play a far greater part in the economy. To do this, local grasses liked by the cattle would have to be planted, possibly between the coconuts, and food crops grown for the fattening of sheep, goats, pigs, and chickens. Stock improvement might best be achieved by crossing with local breeds rather than by introduction of unaclimatised foreign ones, though breeds from other parts of the tropics (e.g. Zebu cattle crosses developed in America) offer additional possibilities. The local diet is short in protein: obviously more eggs and meat would help to balance it. The biggest change needed is the alteration of the farmers attitude to animals, for at the moment he regards them as wild products which happen to live in and around his house, but which need no attention of his, instead of a system by which he can change large quantities of low value food into high value proteins. In Europe a chicken is a machine for changing maize and other chicken food into eggs: here it is a product of nature more akin to the forest animals.

To a large extent animals compete with human beings for food. Is there any local food surplus available for stock rearing? Prices are high enough, especially in the coastal towns, to suggest there is not. The problem of improving animal husbandry here is largely the basic one of growing more food. There are still, however, such large areas of unused forest within easy access of the main roads that large scale food farms, especially cassava farms, could certainly be started with a view to fattening stock. When oil is expressed from coconuts the residue forms a valuable animal food, and to sell the oil and use the residue in this way might be more profitable than exporting copra. To feed animals well, however, can be expensive if care is not taken. The profitable method probably lies in organising a farm's production specially for chicken or stock feeding, growing a sufficient variety of crops (included pulses and oil palm) to provide all the animals' needs. A regular supply of meat, eggs or birds could be marketed without difficulty in large towns such as Sekondi-Takoradi.

Manufactures

The only manufacturing activities within the basin are small scale home activities concerned primarily with the preparation of agricultural products or with building. There are no factory manufactures.

The preparation and processing of local products includes the extraction of oil from palm fruits and coconuts by boiling, the roasting of gari, the preparation of very small quantities of rubber at Boinso, the distilling of illicit gin, the husking of rice and so on. Concrete blocks for building are made from local sand and imported cement where wanted. Timber is sawn in large quantities at Samreboi and at some local sawmills in Nzima.

PART II

A general account of the Soils, Vegetation and Land-use of each soil association within the basin

INTRODUCTION

SCOPE OF PART II

PART II of this report consists of a systematic but, as far as possible, non-technical description of the soil associations found in the Lower Tano Basin. It is intended for those who require a general account of a particular area. The soil associations are placed in five major groups according to their geology and each group is prefixed by a very brief introduction to the associations it includes. The soils, vegetation and present and future land-use of each association are then described in turn. The soil descriptions in particular have been kept very short since more detailed and technical descriptions and analyses, if required, can be found in Part III of this report. Vegetation is also discussed only briefly in Part II, but more technically in Part III. Current land-use, on the other hand, is given in some detail since it is not dealt with elsewhese.

HOW TO USE THIS SECTION

This section should be used in conjunction with the soil map which will show what association is found in any particular place. Assume, for example, that more information is required on the soils of a farm near Sefwi-Bekwai. The soil map shows this belongs to the Nzima association, a description of which begins on page 59. Assume further that a pit or hole on the farm is dug, revealing a yellow-brown gravelly upland soil. The soil descriptions will enable the reader to identify this as Nzima or Atonsu series, depending on whether or not there is a hard indurated layer below the gravel horizon. General information on this series and on other series in the same association is given in this section, together with notes on land-use. This can be supplemented, if required, by consulting the detailed soil descriptions and analyses of Part III, while general information on geology, climate, vegetation and on the economic activities of the area can be found in Part I.

In some cases interest will not be in a particular farm but in the overall development of relatively large areas. In this case, several associations might be involved, and reference will have to be made to each association in turn.

MEANING OF TERMS USED

The normal unit used is the *soil series*. This term is a practical one denoting a type of soil which, in the opinion of the Soil Survey Officer concerned, is sufficiently distinct to be separated from all other series. Theoretically, a soil series consists of soils which have a similar profile and are derived from similar parent materials under similar conditions of climate, vegetation, relief and drainage. In practice, the series are defined and distinguished from each other by the colour, texture and arrangement of horizons, by the content of stones and gravel, by drainage, reaction, site, and parent rock.

A single soil series can sometimes be subdivided. A *subseries* is distinguished from the normal series by a minor difference (such as a slightly different texture or a greater content of stones) of sufficient practical importance to warrant making a subdivision. Such characteristics are permanent: a *soil phase* on the other hand is distinguished by some more ephemeral quality such as the loss of a topsoil due to bad farming or simply by the fact that the original vegetation is replaced by a regrowth type. It is implied that a soil phase, if left undisturbed, would ultimately return to normal.

For convenience, soil series are grouped into larger units known as *soil associations*. A soil association consists of a number of series related to each other in a fixed way, so that there is a regular succession of particular soil series found one after the other from the hill summits to the valley bottoms. In its simplest form the normal forest soil association consists of (*a*) gravelly sedentary[8] soils on the higher parts (*b*) non-gravelly yellow colluvial clays on lower slopes and (*c*) a variety of alluvial sands and clays in the valley bottoms. This basic pattern is discussed further in Part I, pages 20–30, and typical examples are shown diagrammatically in Figs. 8 and 24. The presence of summit soils containing ironpan and of old alluvial river terraces often further diversifies this pattern.

The normal association thus consists of soils of different types—sedentary, colluvial and alluvial—all of which have developed over related parent material. In some areas the geology is more varied and different parent rocks, each giving rise to a distinct association, are found side by side. In such areas each separate association cannot be mapped separately on the scale used in this report and such areas become *soil complexes* in which two or more normal associations are found together. For ease of reference, however, all these units are usually referred to simply as an association named after the most important upland soil(s).

VARIATIONS BETWEEN SOILS OF A SINGLE SERIES

Soil productivity is discussed in general in Part I (pages 22–32) and the nutrient status of most individual series is described more fully in Part III. Since it is also discussed for each series and association in this part of the report, it is necessary to stress first what range of variation might be found within soils of an individual series and the reasons for this variation.

All the analyses given with this report emphasise the fact that the humous topsoil, i.e. the first 2–7 inches of the soil, has a higher content of plant nutrients and organic matter than the lower layers. The humus of this layer has a far higher base-retention capacity than the sub-soil clays and is thought to be particularly important in regard to phosphorus availability. The thickness and state of preservation of this important humous layer vary from place to place according to the vegetation or the care, or lack of care, with which the soil is cultivated. Thus, a soil under original forest will usually contain more organic matter and bases than one under regrowth vegetation, while a carelessly farmed soil, particularly one on a steeply sloping hillside, may have part or all of the topsoil washed away. It follows therefore that individual examples of the same series may in practice differ quite considerably in their productivity.

A more important but less obvious factor affecting productivity is the reaction of the soil. Since acidity increases as the bases in the soil are washed out, acidity is merely a convenient way of measuring the extent to which the bases have been removed. This is discussed more fully in Part I, pages 24–27, but it is worth emphasising that although many soils have been divided into separate series according to whether they are ochrosols (with a topsoil acidity of less than pH 5·5) or oxysols (with a topsoil of greater acidity than pH 5·0) there is still a considerable range within these limits. Thus an Nzima series may have a topsoil pH of anything between 5·5, and nearly 7·0, and this in turn represents considerable differences in the content of bases. This is therefore a second factor responsible for differences in productivity between individual examples of the same series.

Conversely, series which have a similar acidity may not differ from each other very much in respect of their nutrient status. In the very high rainfall areas of the south of the basin, all the upland soils are leached and acid and do not differ much in their content of bases, which is low throughout this area. The major differences between series here are differences of texture, drainage, ease of working and accessibility. These factors are also discussed above, in Part I (pages 19–20).

CULTURAL PRACTICES

Cultural practices, including the time of planting of crops and the spacing employed, are fairly uniform throughout the basin. For this reason they are not described for each soil association but are dealt with generally in Part I, pages 43–50.

LAND-USE RECOMMENDATIONS

The soil surveyor's task is to examine, classify and describe soils and their associated vegetation, and also to give as accurate a picture as possible of current land-use. This basic information is essential

[8] These terms are defined in Part I, pages 20-22.

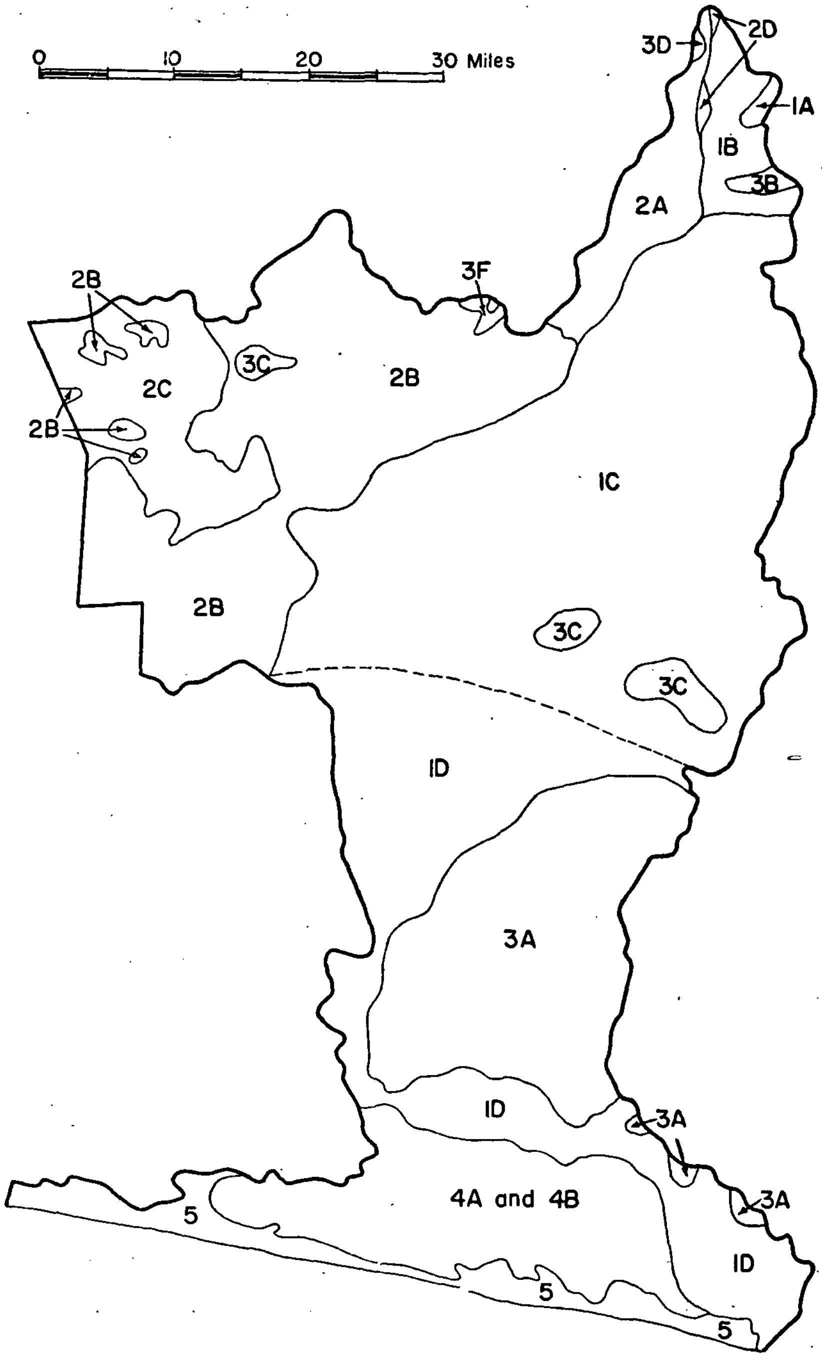


Fig. 7. Simplified soil map. (For explanation, *see* text.)

for the planning of future land-use and for the carrying out of experimental agriculture designed to test the potentialities of individual soils. At the same time the soil surveyor's detailed firsthand knowledge of the area and his observations on the condition of crops associated with each soil series enable him to give tentative observations on the best way of using each series which may well serve, together with the analyses available, as a useful preliminary guide. These suggestions are included under each separate association, in the sections on land-use.

ARRANGEMENT OF PART II

The nineteen soil associations recognised in the basin are listed in Table 7 and they are discussed in Part II in the order shown in the table. Fig. 7, a simplified soil map, shows the location of these associations. The five major groupings into which these associations are divided are each prefixed by a general introduction. On the main soil map the major areas of alluvial soils have also been indicated, though in Table 7 and in the text they have been included under the associations to which they belong.

TABLE 7

SOIL ASSOCIATIONS WITHIN THE LOWER TANO BASIN

	Area in square miles	*Area in acres*	*% of total*
1. SOILS DEVELOPED OVER LOWER BIRRIMIAN ROCKS			
1A. The Yenahin association	4	2,560	0·14
1B. The Nzima association	46	29,440	1·66
1C. The Nzima-Boi association	835	534,400	30·18
1D. The Boi association	439	280,960	15·86
Total, Group One	1,234	847,360	47·84
2. SOILS DEVELOPED OVER UPPER BIRRIMIAN ROCKS			
2A. The Atukrom association	73	46,720	2·64
2B. The Yakasi-Shi association	405	259,200	14·63
2C. The Yakasi association	161	103,040	5·82
2D. The Sefwi association	3	1,920	0·11
2E. 2C. and 1C. mixed	50	32,000	1·81
Total, Group Two	692	442,880	25·01
3. SOILS DEVELOPED OVER GRANITES AND ASSOCIATED ROCKS			
3A. The Ankasa association	330	211,200	11·96
3B. The Nsaba association	7	4,480	0·25
3C. The Ninisu association (mixed with some 1C.)	27	17,280	0·97
3D The Adujansu association	2	1,280	0·07
3E. The Yoyo association	9	5,760	0·32
3F. The Pepri association	6	3,840	0·21
Total, Group Three	381	243,840	13·79

	Area in square miles	Area in acres	% of total
4. SOILS DEVELOPED OVER TERTIARY SANDS			
4A. The Tikobo association	205	131,200	7·41
4B. Swampy areas associated with 4A. ..	74	47,360	2·67
Total, Group Four	279	178,560	10·08
5. SOILS DEVELOPED OVER COASTAL (QUATERNARY) SANDS.			
5. The Fredericksburg association	91	58,240	3·29
In addition major areas of alluvial soils, included within the above associations, have also been indicated on the soil map.			
Total, All Groups	2,767	1,770,880	100·00

SOILS DEVELOPED OVER LOWER BIRRIMIAN ROCKS (GROUP 1)

LOWER BIRRIMIAN phyllites and associated rocks (Part 1, page 7) are more extensive in the basin than any other geological group, covering nearly half of the total area. They usually form fairly simple and uniform soil expanses in which the pattern of soil series is repeated with little change. The soils consist of a regular succession of yellow to orange-brown gravelly sedentary upland soils, yellow-brown colluvial clays of lower slopes, and varied alluvial soils of the valley bottoms. The wide range of rainfall over the same parent material has however made it necessary to distinguish the very acid soils of the wetter south from the less acid soils of the north, while a third central zone includes soils of both groups in about equal quantities.

In certain areas of suitable geomorphology there are also minor areas of other soils which complicate this simple basic pattern. These are (*a*) relatively old soils which have developed an indurated layer or a layer of ironpan below the gravelly subsoil, such as Atonsu and Nsuta series, and (*b*) soils developed in river terrace material, i.e. alluvial material at a higher level than present floodplain deposits.

Major areas of river alluvium and associated terrace soils have been shown separately on the main soil map. These are described here, but are also found throughout the basin, irrespective of geology.

In the extreme north-east of the basin, near Sefwi-Bekwai, occurs a very small but distinct and well-defined association, the Yenahin association, consisting of soils developed over bauxitic pan and associated drift material which caps and mantles the underlying phyllite: this association is confined to the high and steeply sloping Afao hills.

The remaining associations cover the greater part of the basin and are outwardly somewhat similar to each other since they differ more in the acidity and nutrient status of their soils than in their morphology. The most northerly of these is the Nzima association, very extensive in the Ghana forest area but limited in the Lower Tano Basin to the northern tip. In the south of the basin is the acid equivalent of this, the Boi association (*see* Fig. 8), while the intervening area consists of a mixture of soils of both associations and forms the Nzima-Boi association.

1A. THE YENAHIN ASSOCIATION

This small but well defined association occupies the steep slopes and narrow flat summits of the bauxite-capped Afao hills, north-west of Sefwi-Bekwai. Only about 4 square miles are included within the basin but immediately outside the basin west of Awaso, where the hills are more extensive and the flat summits broader, bauxite is mined by the British Aluminium Company.

Soils

On the summits relatively shallow soils over massive bauxite are found. These are *Yenahin series*, a shallow soil consisting of up to 12 inches of red or brown light clay with frequent concretions and bauxitic pan fragments, overlying solid bauxite. On the slopes the soils consist of red or brown drift soils, *Yoyo* and *Bobo series*, in which 1–4 feet of red or brown light clay containing occasional bauxite boulders overlies weathered bedrock, and of *Bosum series*, a highly concretionary and bouldery soil developed in material derived from the break-up of a bauxitic pan sheet.

The soils on the summits overlie solid pan, usually at 6–12 inches below the surface, and because of this have little agricultural value. Both internal drainage and root penetration are held up by the pan. The soils are also acid. In view of this and their inaccessible summit position it is very doubtful whether they could be used economically for agriculture. The slope soils, though not quite so inhospitable as those on the summits, suffer from their very steeply sloping site and thus their liability to accelerated erosion. They are also acid and of very low natural fertility.

Vegetation and land-use

The vegetation of the association is poor forest of the *Celtis-Triplochiton* type, mostly original, though there is some regrowth on the summit due to clearing for former camps. The forest has a comparative absence of climbers and has an open look, being poor in large trees and generally low in height. Most of the trees are pole sized understorey species whose small size reflects the poor soil and lack of root room, particularly on the summit. Any clearing of the slopes would result in accelerated erosion and the area is best left uncultivated as at present.

1B. THE NZIMA ASSOCIATION

This is the normal forest association developed over Lower Birrimian formations. Similar soils are very extensive elsewhere in the forest zone, but within the Lower Tano Basin the association is confined to 46 square miles in the north, near Sefwi-Bekwai, an area which represents less than 2 per cent of the basin.

The most extensive and important soils are Nzima and Atonsu series, two gravelly upland soils which together cover most of the hills, and Kakum series, a yellow-brown alluvial soil of valley bottoms.

The parent rock is usually phyllite with very subordinate amounts of greywacke, mudstone, and schist. These parent rocks give rise to silty clay soils, most of which contain varying amounts of quartz gravel and stones, derived from numerous quartz veins in the parent rock.

The climate of the northern Sefwi-Bekwai area where this association is found is much the same as that for Sefwi-Wiawso, just outside the basin, for which rainfall figures are given in Table 2. The total rainfall is of the order of 60 inches per year.

The area consists of rolling hills at a general level of about 550 feet above sea level, with occasional steep high hills in the north of the area adjoining the Bibiani range, which reach 1,200–1,300 feet. The whole of the area drains to the river Suraw, a Tano tributary which has a fairly broad valley and well developed alluvial deposits which form the most productive soils of the association. The natural vegetation is forest of the *Celtis-Triplochiton* association, though most of the unreserved areas have been cleared of their original vegetation and are now under cocoa, current cultivation, or regrowth vegetation.

From the soil and land-use point of view, the area falls into three sections, as follows:

1. *Steep high hills, up to 1,300 feet high, on which the soils are mainly Kobeda series, Atonsu series, and shallow eroded examples of Nzima series.*
2. *Broad gently rolling hilly areas with summits at about 550 feet, on which the commonest soils are Atonsu and Nzima series, with minor areas of Birim and Kokofu series on middle and lower slopes. This section of the area is the most extensive.*
3. *Alluvial deposits of valley bottoms and lower slopes where the commonest series is Kakum series, though low-level terrace soils and some poorly drained valley bottom clays (Densu and Oda series) are also found. Where these are extensive they have been shown separately on the soil map.*

Soils

Nzima series

Nzima series is the most extensive soil of the association, being found on all types of upland sites. Below a grey-brown humous topsoil 5–7 inches thick the subsoil is orange-brown to dull yellow-brown in colour and contains large quantities of gravel (i.e., of ironstone concretions, quartz gravel, ferruginised rock fragments and quartz stones) which are concentrated in the first 3 feet. Below this the gravel is less frequent and at about 5 feet the subsoil merges into the weathered substratum, usually light clay or loam, which is mottled and contains traces of decomposing rock. Soft but recognisable phyllite is usually found at 12–15 feet, though on steep sites the whole profile may be much shallower.

This series is usually well drained. To some extent slight variations between the drainage of individual examples are reflected in the colour, which varies from yellow-brown to orange-brown.

Similar, but red-brown, soils (Bekwai series) are found further north, but within the Lower Tano Basin these are almost absent because of the heavier rainfall and shorter dry season. For the same reasons, Nzima series within the basin is not likely to dry out dangerously in a normal dry season, even though it has a fairly high silt and gravel content and is not quite as retentive of moisture as more clay soils.

Nzima series is fairly easy to cultivate with local hand tools since normal weeding and hoeing are confined to the topsoil and only occasionally, as when small holes are dug to plant plantain, is the gravel zone disturbed. Particularly stony examples or eroded phases which have lost their topsoil form occasional exceptions to this.

Nzima series is, by local standards, a moderately fertile soil which in some areas has supported good cocoa for twenty to thirty years and which is also widely and successfully used for a considerable range of food crops, particularly plantain and cocoyam. It is a representative forest ochrosol and, as such, has higher reserves of bases than the wide-spread oxysols of the basin to the south. Nevertheless, the Nzima soils of the Sefwi-Bekwai area are found towards the southern limit of the main Nzima area and for this reason they contain a greater proportion of relatively less fertile examples whose acidity approaches the lower limit for ochrosols.

A proportion of Nzima series are slightly indurated in the subsoil: when this induration is well developed the soil becomes Atonsu series.

Atonsu series

Atonsu series is distinguished from Nzima series mainly by the presence of a hard mottled layer, dug only with difficulty, which is found immediately below the gravel horizon. A typical Atonsu series would have a much shallower topsoil than Nzima series, grey-brown and humous, and 2–3 inches thick. Below this, the gravel horizon is very well developed, consisting of abundant ironstone concretions with lesser amounts of gravel and stones. At about 4 feet there is a fairly sharp transition into the indurated layer which may continue for another 5 or 6 feet before merging into the soft weathered substratum below.

Atonsu series occurs on flatter sites than is usual for Nzima, such as flat hill summits. The two series grade into each other and together cover most of the upland areas.

Atonsu series is more gravelly than Nzima, and this, together with the thinner topsoil, gives it a distinctly lower nutrient reserve. Root development is impeded by the indurated layer, which also makes the soil less well drained during wet periods and increases the likelihood of the gravel layer drying out during the dry season. Because the nutrient status of this soil is lower than that of Nzima series and the drainage is less satisfactory, it gives lower food crop yields and rarely supports good cocoa.

Atonsu series is the soil usually dug for road pits and, since it is extensive, this association is well supplied with road gravel.

Nsuta series

Nsuta series is very inextensive in this association, and is confined toc ertain flattish hill summits. It can be regarded as a more extreme and shallow version of Atonsu series: the topsoil is usually thin

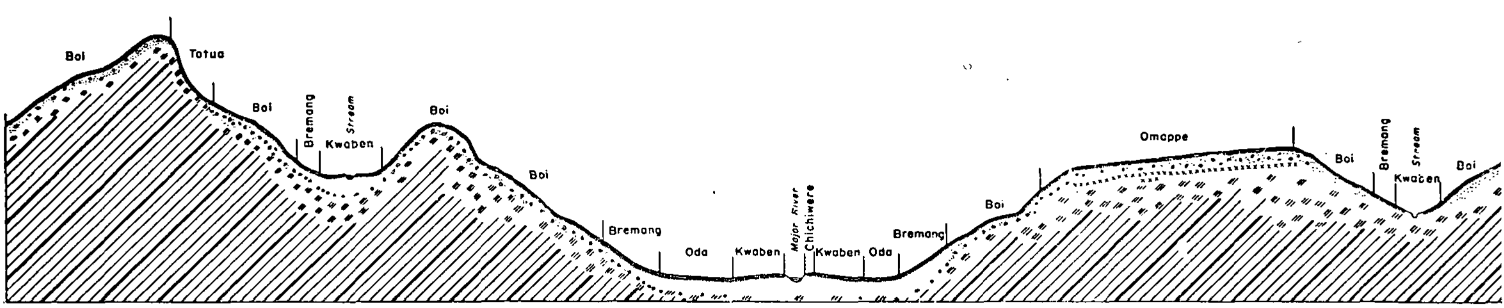


Fig. 8. Major acid soils developed over phyllite (the Boi association).

and gravelly and the highly concretionary red or brown subsoil overlies, at about 3 feet, massive ironpan which is too hard to be penetrated by roots or by normal digging equipment.

The drainage may be rapid in the upper gravel layer but is usually completely impeded below this by the pan, so that after heavy rains the soil may be temporarily waterlogged. Its power of retaining moisture is, however, inadequate and it is liable to dry out completely during the dry season.

The nutrient reserves are poor because most of the soil consists of gravel, with very little fine earth between, and this is underlain by the ironpan which also provides nothing for the plant. The topsoil is often thin and gravelly too, so that the total amounts of plant food available are very low.

Roots cannot usually penetrate the ironpan, so are limited to the upper 3 feet or less. The agricultural value of this soil—fortunately very limited in extent—is therefore so inferior that it is not usually worth the effort of clearing and cultivation. It is quite unsuited to tree crops and at best can only support shallow rooted annuals. Even with these, yields are unsatisfactory and the soil has soon to be abandoned. It is better to leave this soil under the natural vegetation.

Kobeda series

Kobeda series is an immature soil found on very steep slopes where normal profile development is prevented. It consists of a grey-brown humous topsoil directly overlying a weathered substratum containing large amounts of decomposing phyllite.

Drainage is rapid because of the steep site and great care is needed in cultivating this series as the topsoil is quickly washed away when exposed after clearing. There is no gravel subsoil so that immediately below the topsoil, plant roots reach decomposing rock (which in Nzima series they might not encounter at all because it is 12–15 feet down and out of reach except to certain tree crops). This allows them access to nutrients liberated in this zone, and if the topsoil is not too thin or eroded this can be a moderately productive soil for both tree crops and annuals.

Amuni series

Amuni series is found on very steep sites similar to those on which Kobeda develops, but it is a deeper soil than Kobeda. A thin grey-brown humous topsoil overlies a considerable depth of very uniform, brown to red-brown, light clay easily recognised by its softness and ease of digging and the absence of any included gravel. At 10–15 feet, occasionally more, this merges into decomposing phyllite.

This series is inextensive and suffers from the disadvantages of its steep and usually inaccessible site, including the danger of erosion, but is easy to work and field observations suggest it is moderately fertile. Its physical properties make it very suitable for root crops.

Kokofu series

Kokofu series is a colluvial soil found on lower slopes below the sedentary upland soils already discussed but above the alluvial soils of the valley bottoms. It is not extensive and is sometimes absent from the catena altogether. It consists of a greyish brown humous topsoil overlying 2–4 feet of yellow-brown light clay which has been derived from soils further up the slope. This colluvial material has little or no included gravel or stones, but might be separated by a slight gravel or stone layer from the underlying weathered substratum of soft decomposing phyllite.

The soil is well drained, but retains its moisture well during dry seasons. Because it is soft, easily worked and free of stones it is physically very suitable for root crops. There is no downward limit to root penetration, and weathered rock and the nutrients released there are often near enough the surface to be reached by roots. The nutrient status of the soil is usually quite good, being rather similar to Nzima series. Care in checking erosion is necessary but the main disadvantage of this soil is its limited extent and irregular distribution.

Sang series

Sang series is similar to Kokofu series except that below the yellow-brown subsoil a mottled and indurated layer has developed. This layer begins at 2–5 feet below the surface. The series is inextensive and relatively unimportant. Agriculturally it is similar to Kokofu series, except that both drainage and root development are impeded by the indurated layer.

Kakum series

Kakum series is the most extensive of the alluvial soils and one of the most important series in the association. It is not confined to this association but is widespread in the forest zone irrespective of geology. In most of the Lower Tano Basin however it is replaced by its more acid counterpart, Kwaben series.

Kakum series is developed in fine river-borne silty clay alluvium and is found along river banks and in low-lying areas beyond the banks. Along minor streams it may form only a narrow band a few yards wide, but next to the major rivers it widens out to become fairly extensive.

Kakum series consists of a greyish-brown humous topsoil overlying several feet of yellow-brown silty light clay. This is usually characterised by a few small yellow and grey stains and mottles which become more noticeable with depth. Occasional quartz gravel horizons may occur, but the normal soil is free of coarse material, and is soft and easy to work. As in all alluvial soils, the subsoil overlies, at depths of 5–10 feet or more, non-transported material below, which, in the case of Kakum series: within the Nzima association, is usually loam of decomposing phyllite.

The soil is within the floodplain of the river and so is liable to occasional flooding at times of very high water, as is suggested by the slightly stained and mottled subsoil, and this flooding may add fine alluvium and possibly nutrients in solution to the soil. For most Kakums, however, drainage is adequate during nearly all of the year, hence the yellow-brown colour which distinguishes the series from badly drained soils which are grey in colour.

This series is relatively fertile, often at least as productive as the better upland soils associated with it. It usually supports good cocoa, which is tolerant of occasional periods of poor drainage, but is not well drained enough for coffee. Food crops yields are also satisfactory. Much of the cocoa in the Sefwi-Bekwai area is on this series.

Chichiwere series

Chichiwere series is developed over alluvial sands found along river banks, and is small in extent and irregular in occurrence. A grey-brown loamy topsoil overlies several feet of pale yellow-brown sand or loamy sand, often very fine. The soil is well drained, though not retentive of moisture during dry spells. The texture is light and the series is very easy to work, but the transported sand is low in nutrients and this, together with its liability to dry out, limits its agricultural possibilities. Coconut palms grow relatively well on this series, which is also sometimes used for nurseries and for vegetable crops and pineapples.

Oda and Densu series

Both Oda and Densu series are poorly drained grey alluvial clays of valley bottoms found in association with Kakum series. Oda series is the usual grey clay of flat ill-drained sites and consists of a grey-brown humous topsoil overlying grey light clay, often mottled with depth. Occasional sand or gravel horizons may occur within the profile. Densu series is far less common: it consists of a grey-brown often highly humous topsoil overlying heavy plastic grey clay. This series in particular is heavy to work. Both series are subject to frequent waterlogging and they remain moist during dry spells. Natural fertility is rather low, though some examples have a well developed humous topsoil, and the normal vegetation of these series is swamp forest or regrowth vegetation. Poorly drained sites such as these are suited to such crops as rice and chewing cane.

Terrace soils: Birim, Awaham and Boppa series

In some areas, the normal soil catena includes soils developed over old river terraces which are now above the present floodplain of the river. These are mostly silty light clays of the Kakum type, often containing pebble beds, which are now very well drained. They are older than alluvial soils of the present floodplain so that soil forming process have been working on them much longer and they may have developed an indurated layer or even a few small concretions. They are thus intermediate in characteristics between alluvial and sedentary soils. Although most extensive on lower slopes, these soils are also found at anything up to 100 feet above the present stream or river level.

Birim series is the normal deep soil developed over the old alluvium of terrace deposits. A greyish brown topsoil overlies 5–15 or more feet of yellow-brown to orange-brown light clay. Pebble beds are either absent or present only below the first 30 inches: if present near enough to the surface to interfere with cultivation the soil becomes Awaham series. The pebble beds themselves or the layer immediately below them may be mottled and somewhat indurated.

This series is usually fairly easy to work and has the advantage of a flattish site. Its nutrient status varies considerably according to its acidity: the less acid examples with a topsoil pH value above 5·5 are comparable to Kakum series, while more acid examples are classified as Samreboi series (page 79) and are similar in nutrient status to Kwaben series. Some of the higher and older examples may be more comparable with such sedentary soils as Nzima and Boi series.

This series, like all the alluvial soils discussed here, is not confined to this association but is widespread in the basin, hence the range of degree of acidity and therefore of nutrient status found. Generally speaking, however, this series is of greater value than associated upland sedentary soils. Its main disadvantages are its limited extent and irregular occurrence.

Awaham series resembles Birim series except that pebble beds are found near enough to the surface to interfere with cultivation. The pebbles may also reduce the fine earth fraction and so the nutrient status: apart from this the two soils are similar.

Boppa series is very uncommon and is merely a grey ill-drained version of Awaham series found on flattish lower slopes. It is best considered as a pebbly version of Oda series, since its uses and limitations are similar.

Vegetation

The natural vegetation of this association is semi-deciduous forest of the *Celtis-Triplochiton* type in which the two commonest trees are *Celtis mildraedii* (esa) and *Triplochiton scleroxylon* (wawa), though the total number of different species is very large. This forest association is described in general in Part I, pages 15–16 while individual species characteristic of it are given in Part III, pages 241–242.

On the steep high hills where shallow or indurated soils are common the forest is relatively poor and pole-like and it is these areas of poor and inaccessible forest which usually still remain intact, the better and more accessible parts having been cleared for cultivation. The main areas of remaining original forest on this association are within or adjoining the Tano-Suraw, Afao Hills and Suhuma forest reserves, and on the hills south of Akoti. Near the roads and more densely settled areas there is little or no original forest left, there being a mosaic here of current cultivation, cocoa, and regrowth vegetation types, i.e. forb regrowth, thicket and secondary forest. Further away in the remoter areas and approaching the forest reserves the proportion of original forest increases, as is shown on the vegetation map. Swamp forest and swamp regrowth vegetation occur in poorly drained localities.

Land-use

The present pattern of land-use

The area occupied by this association is relatively densely populated. Cocoa is old established and widespread (Fig. 9), and food farming is extensive enough to allow of exports to towns outside the area. Intensity of cultivation is closely related both to lines of communications and accessibility, and to soil fertility (Ahn, 1955*a*).

The main land-use feature of the area is a belt of relatively dense population and close cultivation extending east-west on either side of the Sefwi-Bekwai–Wiawso road. This belt cuts across soil and relief divisions. A second equally closely cultivated area along the Suraw valley, on the other hand, is clearly related to the alluvial deposits of the Suraw which local farmers recognise as being better than the general run of upland soils in this area, including most of the Upper Birrimian upland soils to the west. This alluvial belt is particularly well marked south of Sefwi-Bekwai where a minor road connects this town with Nyetina, Adobewura I and Adobewura II, villages whose inhabitants have planted extensive areas of good cocoa on broad expanses of Kakum and some Birim series on either side of the river. North of the main road the valley is narrower, but is still fairly closely cultivated, curving north to Adiembra, Odumasi and Surawno, though in this area road communications are less good.

Outside these two main belts of relatively intensive cultivation are steeper and more inaccessible areas where there has been less clearing. Cocoa may be grown as a cash crop in such areas but food supplies cannot be exported and only sufficient for local needs is planted.

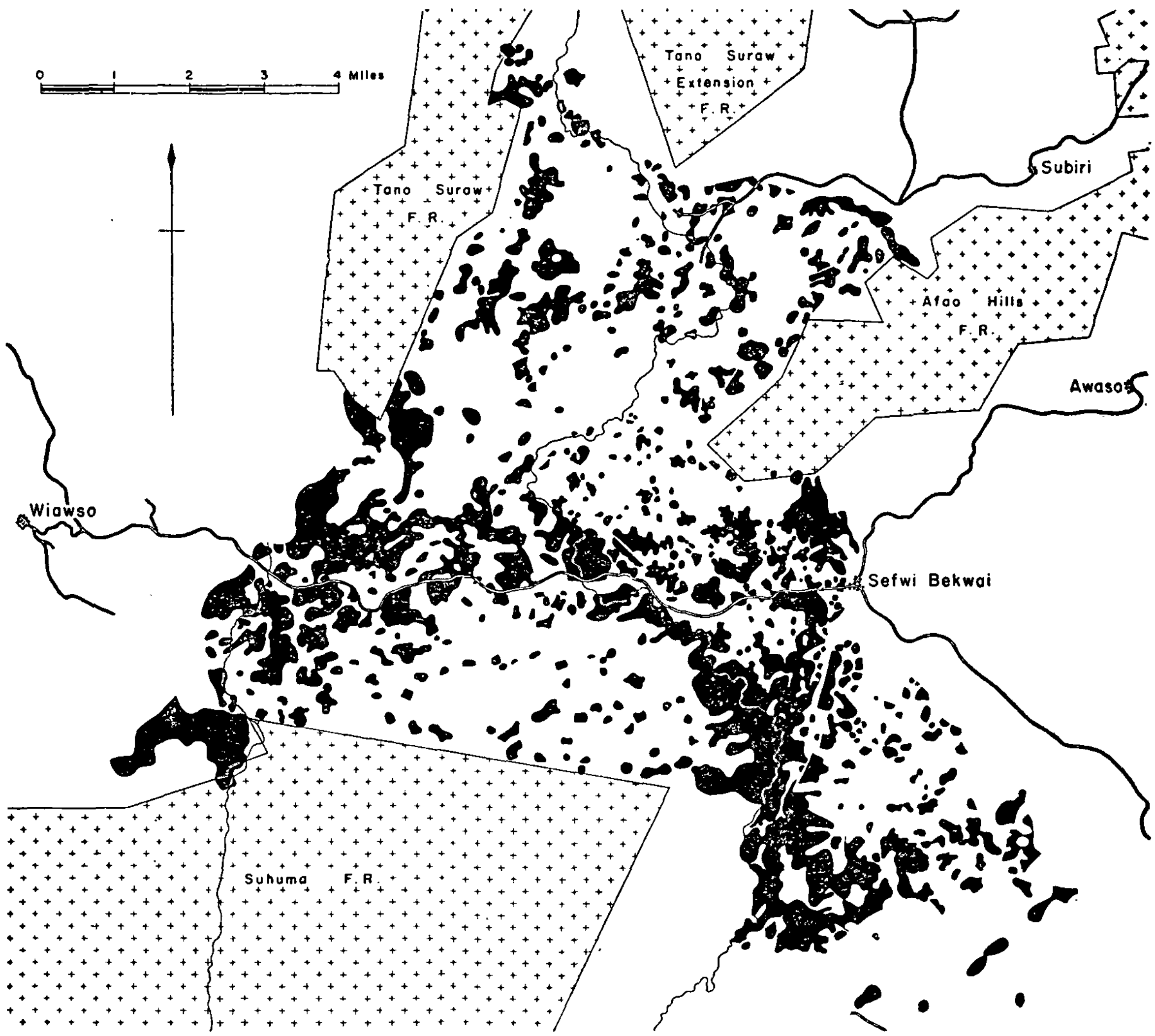


Fig. 9. Distribution of cocoa farms in the Sefwi-Bekwai area. (Based on field sheets of the Cocoa Survey Branch.)

The largest villages on the main road in the central belt are Surawno and Dansukrom. This area is closely farmed and cultivation is expanding south towards the Suhuma forest reserve. Cocoa, mostly over fifteen years old, is widely planted both in the Suraw valley and on the Nzima series of nearby hills. Near the road itself most of the fallow is at the forb regrowth and thicket stages, indicating relatively short fallow periods. The area has the advantage of main road communications, and food, especially plantains, is sent to Sefwi-Bekwai and even to Tarkwa, Kumasi, Samreboi and Takoradi.

In the extreme north of the area Akoti and Surawno are still relatively remote, Surawno alone being connected by a very poor road to the Sefwi-Anwhiawso area outside the basin. The higher ground is within forest reserves and agriculture is confined to lower slopes. Cocoa farming is expanding, some of it in the hands of immigrant Krobos. Most of the cocoa is young, that in the valleys being in the best condition. Food crops are grown for local use only.

The Surawno-Adiembra area to the south of this is one of older established cocoa farms, which are extensive on the alluvial soils. Some coffee has been introduced recently and this does best on gravelly well drained upland soils. Adiembra is connected by road to Sefwi-Bekwai.

To the south of Sefwi-Bekwai the Chirano-Nyetina-Adobewura cocoa belt along the Suraw already referred to is probably the most prosperous part of the area. It is surrounded by less closely farmed upland areas which are distinctly less productive.

Future land-use

Unlike most of the Lower Tano Basin, the area occupied by this association has already been relatively closely cultivated and most of the unused areas are hilly or inaccessible. The most valuable soils are the alluvial soils of the Suraw, many of which are under cocoa. On the upland soils the future trend will probably be towards coffee production. This grows well on highly concretionary soils, even on sites where cocoa has previously failed.

Many crops can be grown on a variety of sites, but the general pattern of land-use best suited to local soils can be summarised as follows:—

Poorly drained lowland soils are best used for permanent rice production with minor quantities of sugarcane for local chewing only. Maize is tolerant of damp conditions and can sometimes be seen mixed with rice. The series usually found on these sites are Oda and Densu series.

Moderately well drained alluvial soils such as Kakum series are best planted to cocoa, which is tolerant of moist conditions and even occasional flooding, though black pod control is necessary on damp sites such as these.

Well drained alluvial soils include soils developed over recent alluvium and older terrace alluvium. On the lower sites, Chichiwere series is a poor but well drained alluvial sand suitable for pineapples and cassava. Well drained higher level terrace soils (Birim and Awaham series) are best used for cocoa and mixed food crops, including cocoyams, and vegetables.

Colluvial soils (Kokofu series) are easy to work and suited to root crops such as cocoyam and cassava, while, of the tree crops, cocoa grows better than coffee.

Upland sedentary soils where highly concretionary and well drained are best used for coffee. Only those with a cover of original forest and a well developed topsoil are likely to give satisfactory results with cocoa. Plantains and cocoyam give satisfactory yields for two to four years after clearing, while older and more exhausted soils are better used for cassava and pineapples before being left in fallow to recuperate. Of the two commonest upland soils, Nzima and Atonsu series, Nzima is distinctly the more productive, though there are considerable local variations. Although most of the upland cocoa is on Nzima series, Atonsu series has occasionally been seen supporting both coffee and cocoa. Nsuta series, on the other hand, is always of low productivity and can only be used for shallow rooted annuals.

1C. THE NZIMA-BOI ASSOCIATION

The Nzima-Boi association covers 835 square miles, or 30 per cent of the basin, so that it is the largest association within it. It consists simply of a mixture of the Nzima association found to the north of it and the more acid but outwardly similar Boi association to the south. It therefore forms a transitional zone between these two associations in which the ochrosols of the first are found side by side with the oxysols of the second. The individual soil series which it includes are described under their respective associations, to which the reader is referred, where the agricultural possibilities of the soils are also assessed. This section, therefore, is concerned mainly with current land-use and possible future development of the area.

To the north and south the association merges gradually into the two associations of which it is composed. These boundaries cannot be fixed accurately since there is a slow transition from one area to the other and not a sudden change, so that they have been shown on the soil map by a broken line. To the west the association merges into associations developed over Upper Birrimian rocks but here again the boundary is imprecise because the geology is somewhat mixed. In some cases Lower Birrimian rocks are found in the valleys and Upper Birrimian rocks on the hills, while the Upper Birrimian formations themselves contain some phyllite.

It should be emphasised that outwardly this complex association does not differ from a normal association such as the Nzima association to the north, since the two associations of which it is composed consist of soils separated because of their acidity and these cannot be distinguished unless their pH value is tested. Differences in acidity and in the content of bases which this represents, however, are in some respects more important than the more obvious physical differences between different series of the same association.

Relief.—The eastern watershed, dividing the area from the Ankobra basin, follows a range of irregular hills running approximately due north-south. The general height of these hills is about 500 feet above sea level with occasional isolated peaks at about 850 feet. The topography here is often steep and deeply dissected. It has been described in more detail in a separate report on the Mamiri group of forest reserves which lie on or near this watershed (Ahn, 1958*a*).

Between this eastern watershed and the Tano to the west is a rolling area dissected by a well developed and closely spaced pattern of rivers flowing westwards which have left a series of summits at about 450 feet separated by valleys some 100–150 feet lower. There are also numerous residual steep-sided but often flat-topped hills which rise to 600 feet or more and form remnants of a higher surface (*see* Part 1, page 10, and Plate 8*c*).

The valley of the Tano is irregular in width, broadening out in some places to form extensive alluvial flats, as at Mosiaso, but becoming steep-sided and narrow in many places where it crosses areas of resistant hills. At the point where the river is crossed by the main Enchi-Asankrangwa road the valley is particularly narrow and gorgelike.

To the west of the river are very extensive areas of high dissected hills reaching over 1,000 feet, where road building or timber extraction would be difficult and gradients are often very steep. The highest hills are to the west of the Tano-Anwia forest reserve and here the area merges with the still higher Upper Birrimian area further west.

In the south-west the relief is more subdued. The Boin has a broad valley, with well marked alluvial deposits, separated from the Tano by the hilly Tano-Nimri area.

Climate.—The rainfall of this area is probably about 60–65 inches per annum, reaching a little over 65 inches towards its southern boundary.

Soils

The soils of this intergrade area are very similar in appearance and distribution to those of the adjoining phyllite areas, being a mixture of the Nzima association to the north and the Boi association to the south. Oxysols and ochrosols (usually those near the lower acidity limit of these soils) are found side by side. An area of brown sedentary soils, for example, would be mapped as a mixture of Nzima series and of Boi series, its corresponding oxysol. In some areas of a few hundred acres most of the soils may belong to one or other of the two groups, oxysols or ochrosols, but in the whole area the evidence available suggests that the two groups are represented in approximately equal amounts. The reaction of the topsoil varies over very short distances, perhaps over a few yards, so that it is not possible to map oxysols and ochrosols separately. In general, the topsoil pH of upland soils is between pH 4·6 and 6·0, with occasional examples outside this range.

The Nzima association is described above, pages 59–65, and the Boi association on pages 75–86. Reference should be made to these sections.

The major upland soil is either Nzima or Boi series. On flatter upland areas these merge into soils with an indurated layer in the subsoil, i.e. into Atonsu series and into Omappe series, its corresponding oxysol. On particularly steep sites Kobeda and Amuni series are locally common, together with their more acid counterparts, Totua and Ebowu series. Soils over ironpan (Nsuta and Sutri series) and yellow colluvial soils of lower slopes (Kokofu and Bremang series) are relatively minor in extent.

The lowland soils are often a little more acid than upland soils, the topsoil usually being in the range 4·6–5·8. For this reason Kwaben series, the normal yellow-brown alluvial soil is more common than the less acid Kakum series. These series are found on most of the better drained valley bottom, lower slope and river bank sites. On the river bank sites a yellow-brown sandy soil, Chichiwere series,

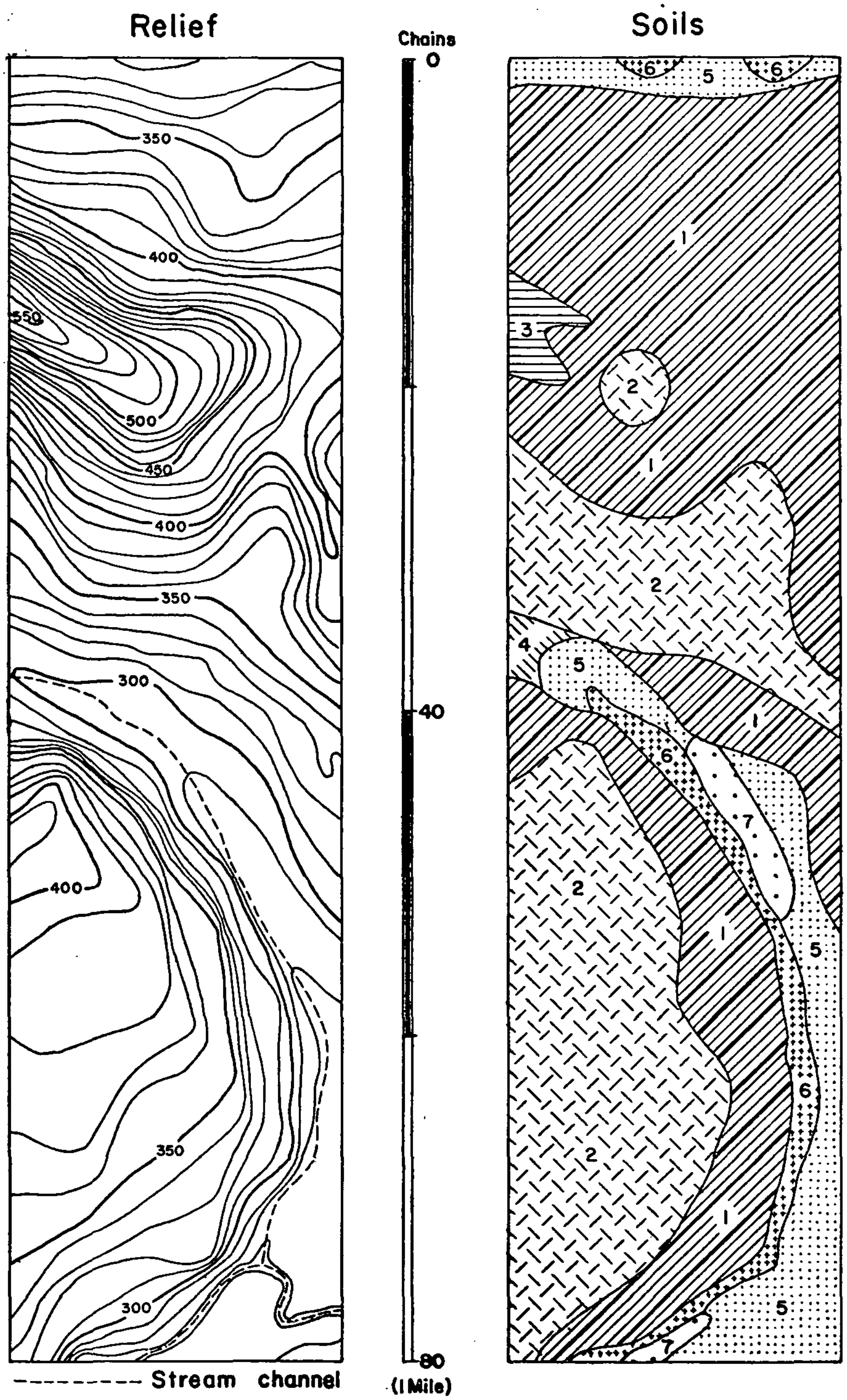


Fig. 10. The Nzima-Boi association: relief and soil maps of Sample strip 1 near Asankrangwa. Contour heights are in feet.

1. Boi and Nzima series.
2. Omappe and Atonsu series.
3. Kobeda series.
4. Bremang series.
5. Kwaben series.
6. Oda series.
7. Chichiwere series.

is found occasionally while in ill-drained bottom sites the grey Oda series is usually found. The heavier Densu series is relatively uncommon. On river terraces now above the level of contemporary alluvium, well drained terrace soils are found (page 62 and page 79).

Detailed sample strips on the association

Five sample strips were recorded on the association. The soil and relief maps of two of them are reproduced with this report (Figs. 10 and 11) and these are thought to show soil patterns typical of the area.

Sample strip 1 (Fig. 10) near Asankrangwa[9] includes a steep high hill rising to 550 feet on which shallow sedentary soils (Nzima and Boi series) and immature soils (Kobeda series) were recorded. Extensive flattish areas of the strip at 350–400 feet were found to have soils with indurated subsoils (Atonsu and Omappe series), the soil on the remaining upland areas being Nzima and Boi series, by far the most extensive series of the association, with very minor areas of colluvial soils (Bremang series).

In the valleys, Kwaben series is the most extensive alluvial soil, with subordinate areas of Oda and Chichiwere series. Topsoil reaction on this strip averages about 5·5, with a range of 4·5 to 6·8.

The vegetation and land-use map of this strip (Fig. 12) shows that the small areas of very steep slopes have not been cultivated and still support broken forest, but that the greater part of the area is under fallow of various ages and now supports regrowth vegetation, mostly thicket two to six years old. Amid the regrowth are small patches of current cultivation for food crops (mostly plantain) and small cocoa farms. The cocoa trees are mostly old-aged (over twenty years) in poor to moderate condition: yields are thought to be low, possibly as little as one to two loads of 60 lb. per acre. Some cocoa has been abandoned and is now found among the thicket regrowth. This map, together with that of Sample strip 2 (Fig. 12) shows the mosaic of small farms and more extensive fallow areas thought to be typical of the closely farmed area near Asankrangwa (*see* vegetation and land-use maps for the basin).

Sample strip 2, 1½ miles north-west of Asankrangwa, has similar soils to those recorded on Sample strip 1 except that adjoining the river Totua in the south considerable areas of terrace soils (Birim and Samreboi series) were recorded. Valley bottom soils here are successfully used for rice cultivation. Nearly all the upland soils are Nzima and Boi series, the indurated soils so extensive on Sample strip 1 being absent. Here there are a few cocoa farms over thirty years old thought to yield two to three bags per acre, while the great bulk of the strip is under regrowth vegetation, mostly about six years old.

Sample strips 3 (*Fig.* 11) *and* 4 were sited to represent hilly areas of this association, as yet little cultivated, to the south of Asankrangwa. In both cases immature soils (Kobeda and Totua series) and shallow gravelly soils (shallow examples of Nzima and Boi series) occupy most of the upland areas, with areas of deeper non-gravelly soils (Amuni and Ebowu series) on steeply sloping higher ground. Vegetation in both cases was, at the time of the survey (1955), mostly unfarmed broken forest.

Sample strip 19 adjoining the Totua shelter belt forest reserve, near Agona, includes extensive areas, up to ¼ mile across, of Kwaben series associated with the river Totua. Most of the upland soils are Boi series. The soils of this strip are relatively acid: the average topsoil reaction of upland soils is thought to be about pH 4·6, while that of lowland soils is similar. Most of the strip is still under the original forest, cut over for timber but not cleared for farming. Rice is grown nearby in valley bottom areas similar to those on the strip.

Each of the above sample strips is described in more detail in an interim report on the Asankrangwa area (Ahn. 1955*b*).

Vegetation

This association occupies an area where the vegetation is usually described as transitional between the *Celtis Triplochiton* type of forest to the north and the true ever-green rain forest, characterised by *Cynometra*, *Tarrietia* and *Lophira* to the south. In general character, however, the vegetation resembles the *Celtis-Triplochiton* forest of the Nzima association discussed above more than the wetter rain forest, since both *Celtis* and *Triplochiton* are found as far south as Samreboi. This general latitude also marks the usual northern limit of *Tarrietia* and *Cynometra*, though there are some *Cynometra* in the Tano-Anwia area. Vegetation is discussed more fully in Part III.

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[9] The location of all sample strips is shown on the traverse map (Map 1, in the end pocket).

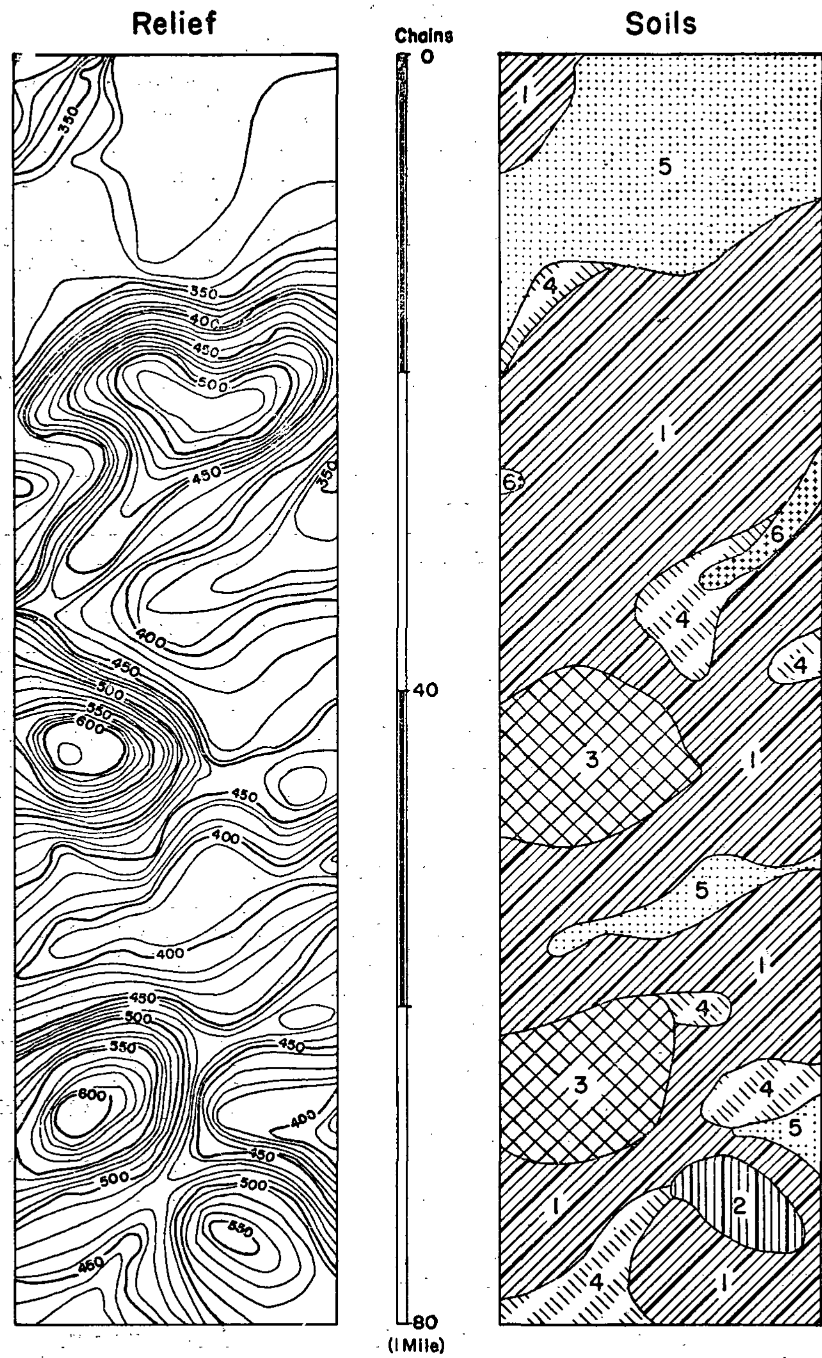


Fig. 11. The Nzima-Boi association: relief and soil maps of Sample strip 3 near Amuni. **Contour** heights are in feet.

1. Boi and Nzima series, often shallow.
2. Totua series.
3. Ebowu and Amuni series.
4. Bremang and Kokofu series.
5. Kwabeng series.
6. Oda series.

6

Land-use

The present pattern of land-use

This is an area where lowland soils are frequently more fertile than upland ones, and this is reflected in the land-use pattern. Cocoa on alluvial soils is moderately good whereas cocoa on sedentary upland soils is often poor. As a result there is more cocoa on the lowland soils (*see* Fig. 13), and in newer areas these are the first soils to be cleared. Of the food crops, rice, grown on low damp sites, is the only one exported outside the area.

Upland soils appear to be generally of low productivity, though it is necessary to distinguish between ochrosols of the Nzima association and their corresponding but more infertile oxysol equivalents of the Boi association. Youthful soils such as Kobeda, the easily worked Amuni series and their acid equivalents are often more fertile than leached deep gravelly soils such as Boi and Omappe series, but they suffer from being on steep sites and from their inaccessibility.

Most of the association is still under original forest, much of it reserved. The Asankrangwa area, on the other hand, situated approximately in the centre of the association, is an area of relatively old settlement and close cultivation in which most of the original forest has long been cleared. In addition there has been considerable though less extensive clearing along the main Enchi-Asankrangwa road, and in the Seewum-Kwau area in the west, the Agona area in the north and the Amuni-Anakum area in the south west. More recently there has been some expansion of farming in the immediate environs of Samreboi. These areas are discussed in turn below. Further details are available in interim reports on the area (Ahn, 1955*b* and 1955*d*).

The Asankrangwa area includes, in addition to Asankrangwa itself, Dunkwa to the west and a large number of smaller towns and villages to the north, including Mosiaso, Bremang, Da, Efiena and Kwaben. Of this area, the central Asankrangwa-Bremang-Kwaben triangle is the oldest cultivated and now forms a mosaic of food farms, occasional old cocoa farms, forb regrowth, thicket and secondary forest fallow (Fig. 12). Soils here are mostly Atonsu and Nzima series and their acid equivalents, less inherently fertile than the alluvial soils near the Tano.

Key to Fig. 12 (next page)

1. Cocoa, mostly old-aged, in poor to moderate condition.
2*a*. Relics of abandoned cocoa amid a thicket regrowth 3-5 years old.
2*b*. Relics of abandoned cocoa amid a secondary forest growth 7-12 years old.
3*a*. Fallow farm land supporting forb regrowth vegetation about 1 year old.
3*b*. Fallow farm land supporting forb regrowth vegetation about 2 years old.
4*a*, 4*b*, 4*c*. Fallow farmland supporting thicket regrowth. 4*a* is about 3 years old, 4*b* about 4 years, while 4*c* is mature thicket, with some young secondary forest trees, 5 to 6 years old.
4*d*. Fallow swampland supporting swamp thicket vegetation 5 years old.
5*a*, 5*b*, 5*c*. Fallow farmland, abandoned 7-12 years ago, now supporting a secondary forest regrowth. 5*a* is 7-8 years old. 5*b* 9-10 years, 5*c* 11-12 years.
6. Unfarmed land, never cleared for cultivation, usually on steeply sloping sites. Vegetation is rather poor original forest of the *Celtis-Triplochiton* association with frequent *Celtis, Triplochiton* and *Terminalia* spp.
7. Newly cleared land not yet planted to crops.
8. Current cultivation, subdivided as follows:—
    - 8*a:* Plantains 1-2 years old.
    - 8*b:* Plantains about 1 year old mixed with cocoyams of the same age.
    - 8*c:* Mixed yams, cocoyams, and plantains, newly planted.
    - 8*d:* Cassava, 1 year old.
    - 8*e:* Cassava, 1 year old, mixed with plantain of the same age.
    - 8*f:* Pineapples, 1 year old.
    - 8*g:* Pineapples, 2 years old, mixed with sugarcane of the same age.
    - 8*h:* Rice, newly planted.
    - 8*i:* Maize, newly planted.
9 Village site (built-over land).

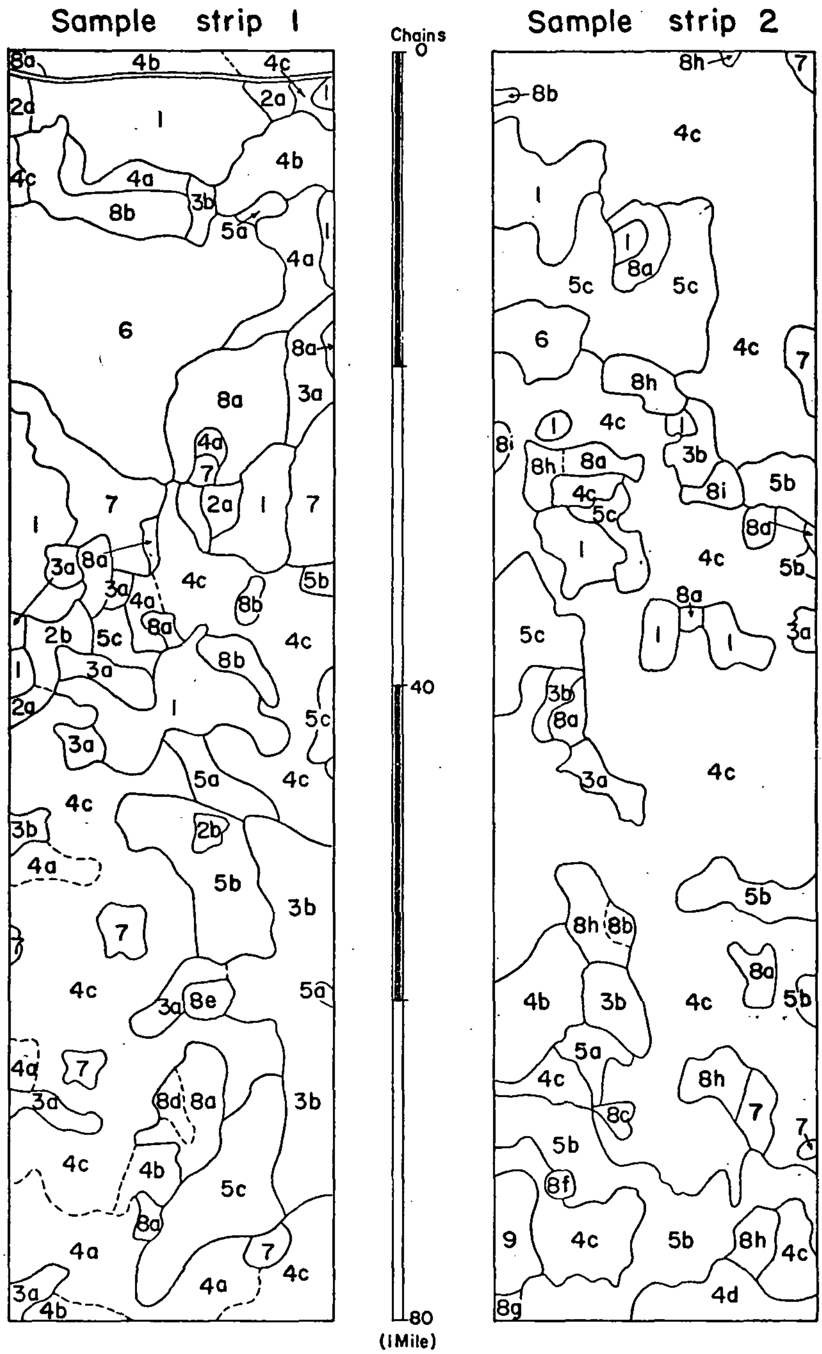


Fig. 12. The Nzima-Boi association: land-use and vegetation maps of Sample strips 1 and 2, both near Asankrangwa. (Recorded March-April, 1955.)

For key, see previous page.

Cultivation has spread from this central triangle to include Mosiaso, Dunkwa, Da and Efiena and this closely cultivated area is now bounded by the main road to the south and the Tano to the west, while to the north and east cultivation is rapidly approaching the Suhuma and Totua Shelterbelt forest reserves. Within this area there is little original forest, hence farmers are moving north to the land between the Suhuma reserve and the Tano. It is noteworthy that all the expansion is northwards and that there is little clearing south of the main road despite the fact that new land can be found within a mile or two of Asankrangwa in this direction.

Fig. 13, showing the present distribution of cocoa farms, was compiled from individual large-scale survey sheets drawn by the Division of Agriculture in connection with the campaign for the cutting out of swollen shoot. There are relatively few farms in the older central area, but extensive cocoa farms, some thirty years old, occur all along the Tano, mostly on Kakum and Kwaben series. The old cocoa in the centre rarely gives more than very low yields, two loads per acre probably being a normal figure. Such a return barely covers weeding costs. In addition, considerable areas here have failed or been abandoned, and new cocoa planted on fallow ground in this area has also been unsuccessful. Most of the cocoa is nearer the river, and on the better soils five loads per acre may not be uncommon. In the extreme north between the Tano and the Suhuma forest reserve, cocoa is expanding, with a few old farms and larger areas of young ones.

Farming standards vary somewhat within the area, being best near Dunkwa and in the newly planted areas around Asimpa. Elsewhere agriculture has suffered from a neglect reflected in high local food prices, this neglect being due partly to alternative employment being available at the Tarkwa mines and with numerous local timber companies. Foodstuffs, particularly plantain, are in short supply. Vegetables are scarce and expensive. Cocoyams do not do well. Maize is plentiful when in season, but the main food crop apart from cassava is undoubtedly rice. There are three rice mills at Asankrangwa and two at Bremang, and considerable quantities of rice are sent south to Takoradi. It is grown throughout the area in broad moist valley bottoms and along the Tano. Two 224 lb. bags of milled rice per acre might be taken as a minimum yield. The main harvest is in August, but a minor second crop from the same plants is taken in November.

The Agona area north of the Totua shelterbelt is similar to the Kwaben area, and has scattered cocoa, mostly old-aged, with rice in the valley bottoms. This area is now connected by a poor road to Asankrangwa, to which it sends plantains.

The Amuni-Anakum area in the south-west is another relatively long-settled area, though inextensive. There is very little cocoa here, but some growing of food crops to supply local timber workers.

Samreboi was, until 1947, an unimportant village. Now it is the headquarters of the largest timber company in Ghana (African Timber and Plywood) with a considerable European population and a payroll of over 2,000. As a result farming in the immediate vicinity has been stimulated, and most of the food is local, though some of it (especially plantain) comes by lorry from Ashanti. Rice and cassava are again the principal crops, cocoyam and yam being very scarce. The main centre of food growing is Amoku, just north of Samreboi, and there is some successful cocoa along the Tano in the area. Many of the farmers are immigrant Fantes. Samreboi itself is situated on an extensive area of terrace soils.

Further away from Samreboi, along the roads to Prestea and to Asankrangwa for example, there is remarkably little agriculture and farmers have made little or no use of timber roads.

The Seewum-Kwau area in the west of the area is relatively poor. Cocoa on the uplands is not very successful, though alluvial cocoa is often good and extends along the Boin southwards as far as Tanoso. Food supplies are inadequate and the area is static or declining.

Areas of original forest.—The bulk of this association, including very extensive tracts south of Asankrangwa and north and west of the Tano-Anwia forest reserves, is still unused for agriculture. The latter areas in particular are very steep and hilly, as well as remote, and the yields are not such as to encourage farmers. In the Samreboi area, in particular, opportunities provided by timber roads have not been taken up simply because cocoa and food crops on the upland soils give discouraging results.

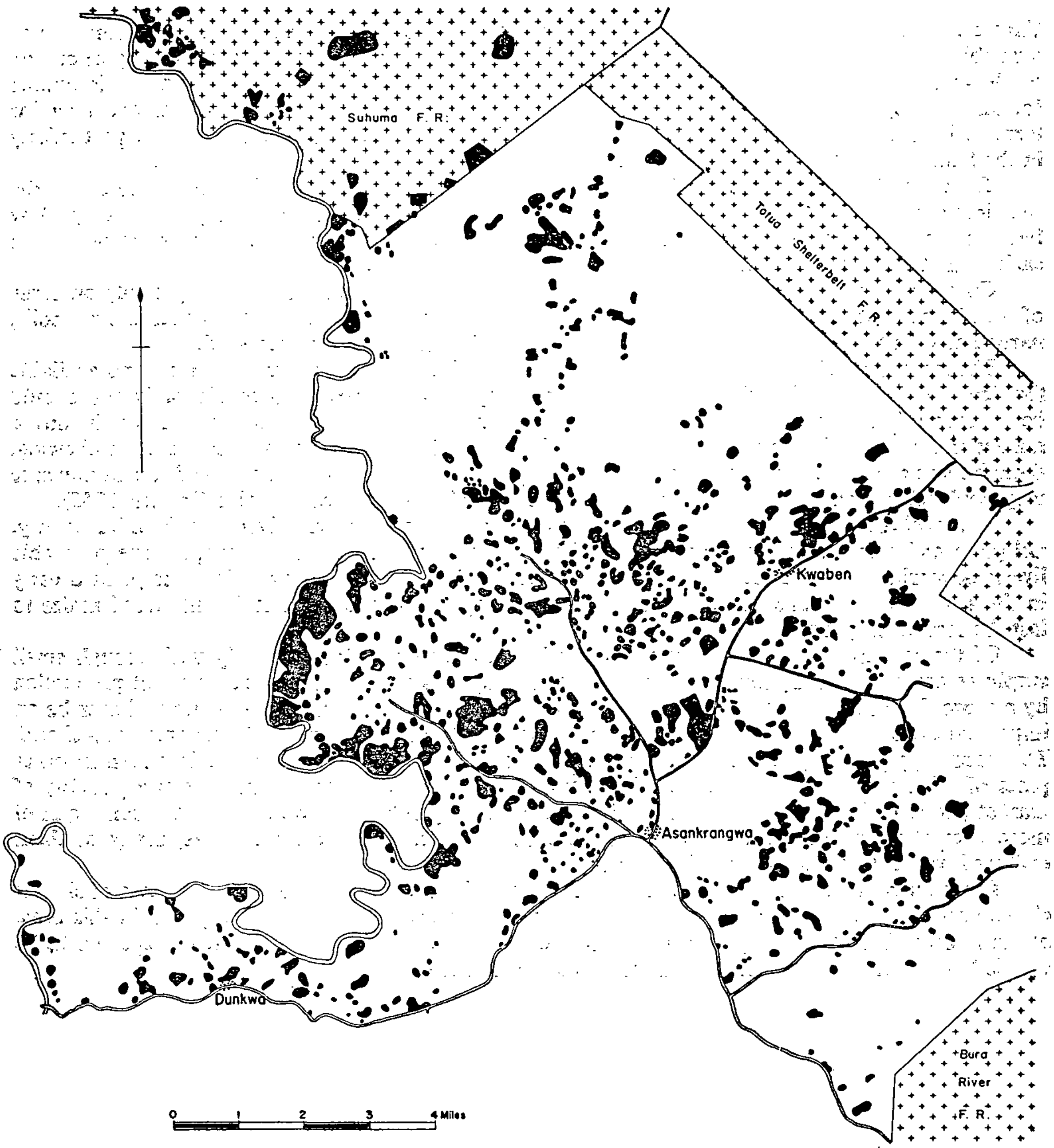


Fig. 13. Distribution of cocoa farms in the Asankrangwa area. (Based on field sheets of the Cocoa Survey Branch.)

Future land-use

Future agricultural expansion will probably not be rapid in view of the alternative employment available locally in timber firms and, further afield, in mines, and because there are no particularly fertile soils to attract farmers from outside. There is plenty of untouched forest and this is offered for sale cheaply to immigrants if they want it, but cocoa prospects are in general poor and very few farmers have taken advantage of the availability of this land even though some of it, particularly in the Samreboi area, is near to or even adjoining good roads.

The expansion that does take place will probably be on existing lines, with a tendency to use the remaining areas of alluvium along the Tano first, while there will probably be a very slow but continuous expansion away from the existing overfarmed area round Asankrangwa to new areas such as that along the road to Atasi near the Mamiri forest reserve.

Cocoa is worth growing on Kakum and Kwaben series, on terrace soils, and possibly on some of the Kobeda and Amuni series, but not elsewhere. On very well drained upland concretionary soils, particularly on the better examples of Nzima series, coffee should prove successful.

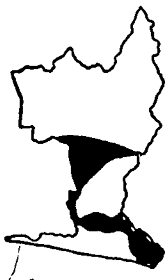
The most successful crop in the area is rice and there is still plenty of damp bottom land available for rice cultivation, so that the production of this crop could be expanded considerably and should be encouraged. Pineapples also grow well, but the development of this crop depends on finding a regular market outside the area. Small areas of bottom soils are suitable for sugarcane for chewing, though there are no extensive areas available for large-scale production for sugar and it is in any case very doubtful if such an enterprise would be economic unless subsidised (*see* also Charter, 1955).

The local diet would be considerably improved if more attention was given to animal husbandry. Oil palm and cassava both grow well throughout the area and on these two crops alone profitable livestock rearing can be undertaken. Maize also does well in most years provided it is planted early in the season, and production of this crop could be expanded to provide sufficient stored maize to last the rest of the year.

Of the remaining food crops, plantains and cocoyams do only moderately well, though small surpluses are produced by farms in the newer areas and it is possible to increase present production by a more determined expansion to unused lands. It is not likely however that there will ever be an important export of these crops to the larger towns as there is now from the forest areas of Ashanti. The poor supply of vegetables in the area contrasts with the abundance and variety seen in other parts of Ghana and suggests that farming standards suffer from a lack of interest and possibly of markets, so that the future development of the area also depends on such factors as the coming in of more energetic farmers from elsewhere and the competition of other forest areas, many of them endowed with better soils, for outside markets.

The successful results achieved by the rubber plantation at Dunkwa-on-Ofin, in an area of similar climate outside the basin, suggest that commercial rubber could be successfully grown in this area, as could oil palm, particularly with improved varieties, even though yields might be expected to be a little lower than those of heavier rainfall areas to the south.

1D. THE BOI ASSOCIATION



The Boi association covers 439 square miles in the south of the basin, or about 16 per cent of its total area. This association merges to the north with the Nzima-Boi association, while to the south and east it adjoins granite and Tertiary sand soils. The annual rainfall in this area ranges from 70 inches or a little less in the north to over 85 inches in the south where the association comes to the coast east of Esiama. This high rainfall is responsible for the greater acidity of the soils due to the high degree of leaching they have undergone as compared with the outwardly similar but more fertile soils of the Nzima association to the north. The morphology and arrangement of the individual series of the Boi association is almost the same as that of the Nzima-Kakum association, the important difference between the two associations being the degree of acidity, the effects of which are summarised in Part I, pages 22–27.

The Boi association is agriculturally far less valuable than the Nzima association and this is reflected in the lower yields and poorer range of crops grown on it. Cocoa, in particular, can be grown on most of the series in the Nzima association, particularly on Nzima and Kakum series. In the Boi association, however, only one major soil can normally be recommended for cocoa, Kwaben series, the remaining soils, except some of the terrace soils, being too poor to support this crop. Food crop yields, particularly plantain and cocoyam, are also very much reduced on these more acid soils.

Relief.—The area occupied by this association is somewhat lower than Lower Birrimian areas to the north. From a maximum of about 400 feet in the north and along the eastern watershed the ground falls gradually to the Tano in the west and the sea to the south. The whole area is dissected by a close network of river valleys into very numerous small steep hills. In the west, the valley of the Tano broadens out below Cocoatown to include, on the Ghana side, a broad area up to 2 miles wide of the low-lying alluvial soils.

Soils

Boi series

Boi series is found on most of the upland sites and is the most extensive soil in the basin. It is the oxysol counterpart of Nzima series and there is little outward difference between the two. It consists of a grey-brown humous topsoil, slightly thinner than that of Nzima series, overlying a very deep gravelly light clay subsoil in which concretions and quartz gravel are usually plentiful to about 5 feet. The subsoil merges into the weathered substratum of decomposing phyllite at about 7 feet. The whole profile is therefore deeper than the usual Nzima series, and is also paler in colour, being yellow-brown to orange-brown. The normal reaction of the topsoil is about pH 4·6 to 4·8, as compared with 6·0 in Nzima series, but acidity decreases gradually down the profile so that at 5 feet the usual pH value is about 5·0.

Internal drainage is moderately good in the subsoil, becoming slower in the weathered substratum which is usually deeply mottled. Cultivation characteristics are similar to Nzima series, but the nutrient status is distinctly lower due to leaching and deeper weathering. Exchangeable bases, in particular, are only about one-third to half of those contained in a normal forest ochrosol such as Nzima, though differences in organic matter content are relatively slight.

This low nutrient status is reflected in the low yields obtained and the limited range of crops which can be grown on this series. Cocoa, in particular, is not usually successful on Boi series, which is better adapted to Liberica coffee, rubber and oil palm.

Omappe series

Omappe series (the acid equivalent of Atonsu series) is an upland soil distinguished from Boi series by the indurated layer occurring below the subsoil. A thin humous topsoil, often containing concretions, overlies a highly gravelly, yellow-brown light clay subsoil which extends to about 50 inches and then merges into an indurated mottled layer which may extend for several feet below this before merging gradually into the weathered substratum containing traces of decomposing phyllite.

Omappe series is a poor soil, less fertile than Boi series because of a thinner topsoil and a

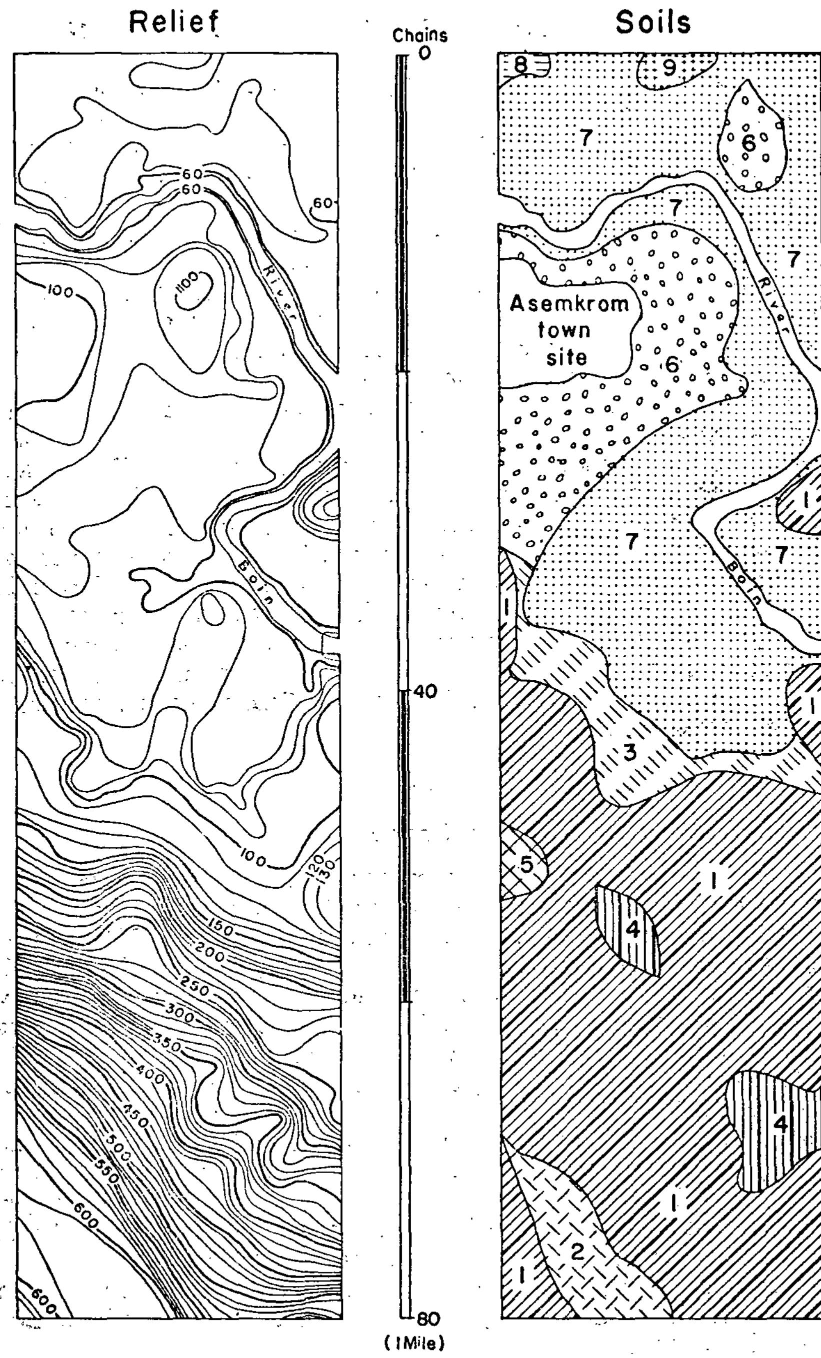


Fig. 14. The Boi association: relief and soil maps of Sample strip 10 at Asemkrom, on the Boin. Contour heights are in feet.

1. Boi series (including many shallow examples).
2. Omappe series.
3. Bremang series.
4. Totua series.
5. Ebowu series.
6. Samreboi series.
7. Kwaben series.
8. Chichiwere series.
9. Oda series.

lower fine earth percentage, while drainage is also unsatisfactory because of the indurated layer in the lower subsoil. This makes the soil quite unsuitable for such crops as coffee which require free drainage. This series is somewhat less extensive in this association than its ochrosol equivalent, Atonsu series, is in the Nzima-Kakum association, as the area is more dissected and has fewer of the flattish upland sites on which this series is usually found. There are, however, many slightly indurated soils which are intermediate between Boi and Omappe series.

Sutri series

Sutri series is the acid equivalent of Nsuta series, a shallow and highly concretionary soil overlying solid ironpan. It is found capping very occasional high hills and has little or no agricultural value.

Totua series

Totua series, the acid equivalent of Kobeda series, is an immature soil found on very steep slopes. A thin and highly acid topsoil overlies directly the weathered substratum of decomposing phyllite. The subsoil is absent. Although Totua has a more acid topsoil than Kobeda series, the soils are similar below this since the weathered substratum of most forest soils is about pH 5·0 irrespective of the acidity of the upper horizons. The topsoil of Totua series is lower in bases than that of Kobeda, but below this there is in both soils an additional though very small supply of nutrients from the rock decomposing relatively near the surface. In most other forest soils this zone is too deep to be reached by plant roots.

The soil is well drained but its main disadvantages are its steep and often inaccessible site, and the consequent liability to erosion and rapid removal of the topsoil when exposed through clearing. With careful handling, however, this soil may prove a little more productive than the deeper upland sedentary soils associated with it.

Ebowu series

Ebowu series is a relatively very inextensive soil found on similar steep sites to Totua series. It closely resembles Amuni series, its less acid equivalent in the Nzima association. A thin grey-brown topsoil overlies a considerable depth of uniform, soft and easily worked brown light clay which has no included gravel. At 10–15 feet this soft subsoil merges into decomposing phyllite. It differs from Amuni series in its lower supply of bases, but has the same ease of working. The disadvantages of its normal very steep site are the same as those outlined for Totua series above.

Bremang series

Bremang series, the acid equivalent of Kokofu series, is a yellow colluvial soil of lower slopes. Below a greyish-brown humous topsoil there is a subsoil consisting of 2–4 feet of yellow-brown colluvial light clay overlying a weathered substratum of decomposing phyllite. The highly acid topsoil—usually with a pH of 4·4 to 4·8—reflects the greater amount of leaching and lower base status of this soil as compared with Kokofu series, though drainage and cultivation characteristics are similar, the soil being easy to work and providing decomposing rock within root depth. As in the case of Kokofu series, the soil is relatively very inextensive, and scattered and irregular in its distribution. Its nutrient status is similar to or slightly better than Boi series, while the absence of stones and gravel suggests its use for root crops. This series is not usually sufficiently well drained for coffee, but is suited to rubber and oil palm.

Kwaben series

Kwaben series, the most productive soil in the association, is an alluvial soil of valley bottoms. Alluvial soils in the Lower Tano Basin are usually acid to the same degree as associated upland soils. Minor alluvial series are not subdivided on grounds of acidity (as are ochrosols and oxysols) but Kakum series, when the topsoil pH is below 5·0, becomes Kwaben series. This distinction is made because of the extent and importance of both of these soils.

Kwaben series is indistinguishable from Kakum in its outward appearance, and consists of a grey-brown humous topsoil about 5 inches thick overlying alluvial yellow-brown silty light clay, slightly stained or mottled orange and grey in the lower parts. The normal topsoil pH of Kwaben

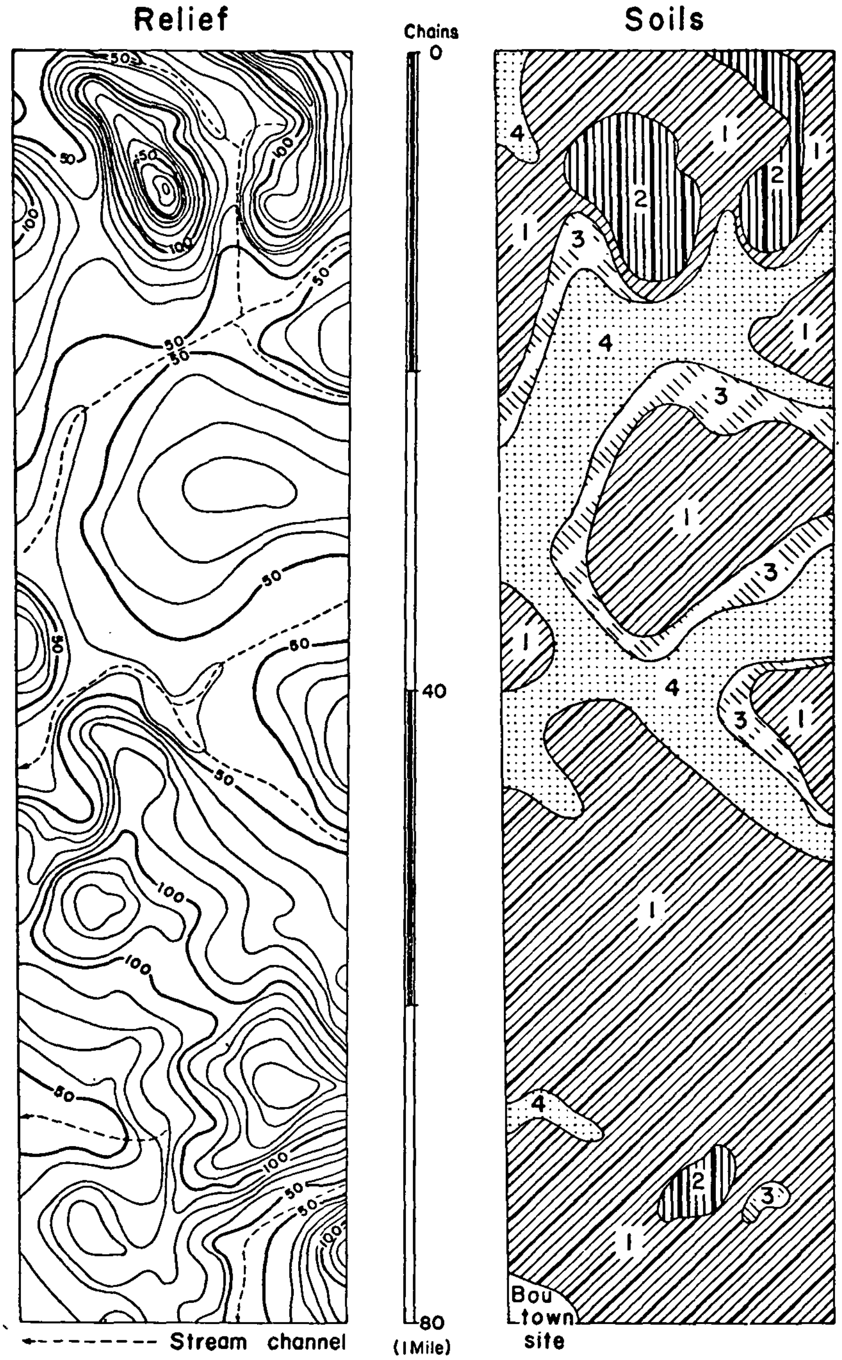


Fig. 15. The Boi association; relief and soil maps of Sample strip 16 at Bou, in Nzima. Contour heights are in feet.

1. Boi series.
2. Totua series.
3. Bremang series.
4. Kwaben series, with subordinate areas of Oda series.

series is 4·4 to 4·8 whereas Kakum series has a topsoil pH of 5·6 to 6·0 or more.

Kwaben series, although just as acid as the remaining soils of the association, is undoubtedly more fertile than these are. Analyses given in Part III of this report suggest that this is due to a higher fine earth fraction and a somewhat higher exchangeable base content, particularly in the horizons below the topsoil. Kwaben series also has an unusually high content of manganese and it is possible that this is connected with the fact that this series is more productive than adjacent sedentary soils. Cocoa is often grown successfully on this soil, and this is the only series in the southern half of the Lower Tano Basin of which this is true. Extensive riverside cocoa at Elubo and Cocoatown is planted on Kwaben series. Food crops, including plantains, also yield satisfactorily on this series, yet do less well on adjoining upland soils. The soil is not suited to plants which require very good drainage (e.g. coffee) but is otherwise suitable for a very wide range of crops, and is flat and easy to work. This soil has the further advantage, particularly important in remote areas, that it is often accessible by canoe or even, as along the lower stretches of the Tano, by launch.

Terrace soils: Samreboi and Amoku series

Older alluvial soils, developed in river terrace material now above areas of contemporary alluvium, are found associated with some of the larger streams and rivers, particularly the Boin and Tano. The normal soil is *Samreboi series*, a uniform well drained yellow-brown alluvial clay in which pebble beds are absent or occur only in the lower subsoil. This series can be regarded as an older, better drained Kwaben series. Where pebble beds occur within the top 30 inches, the soil is *Amoku series.* Samreboi and Amoku series are very similar to the less acid Birim and Awaham series of the Nzima association (page 62), but have a somewhat lower nutrient status. Nevertheless they are often of greater agricultural value than associated upland sedentary soils, being a little more fertile, easy to work and occurring on fairly flat areas. They are, however, limited and irregular in occurrence. They are frequently planted to cocoa, which is usually in relatively good condition.

Remaining alluvial soils

In ill-drained bottom sites *Oda series* is found. This is a pale grey light clay or loam occasionally with sandy horizons. The heavy grey clays *Densu series* are relatively uncommon, as is *Chichiwere series,* a yellow brown sand of river banks. These soils occur throughout the basin and have been described under the Nzima association above (page 59). In general they are of similar acidity to associated upland soils, and of low fertility, with the bulk of the nutrients stored in the humous topsoil. In some ill-drained sites the topsoils are thicker than the average and have higher organic matter contents than upland soils.

Detailed sample strips on the association

Three sample strips were recorded on this association: of these, Strip 10 at Asemkrom on the Boin, and Strip 16, at Bou, in Nzima, showed fairly typical areas of soils in the north and south of the association respectively. Sample strip 15, on the other hand, was sited in order to examine the alluvial soils of the Tano which support relatively good cocoa at Cocoatown and Elubo, and is not typical of the remaining areas of the association.

Sample strip 10 at Asemkrom (Fig. 14) has alluvial soils covering about half of its area. These consist of Kwaben series on low-lying but moderately well drained areas near the river Boin, with similar but older and better drained soils (Samreboi series) developed in a terrace 30–40 feet above the present river. The town of Asemkrom is built on this terrace at a point where it approaches close to the river. Small areas of yellow-brown alluvial sands (Chichiwere series) occur on the river bank and in occasional poorly drained sites grey soils (Oda series) are found. The topsoil pH of all these alluvial soils averages 4·6–4·8.

The remaining half of the strip consists of a very steeply sloping area with gradients up to 1 in 3, rising to a small area of flattish summit at the western end of the strip, at about 610 feet above sea level, which probably represents a remnant of the Aya surface. The soils on the steep slopes are mostly shallow phases of Boi series, with occasional patches of the immature Totua series. On the summit, concretionary soils with an indurated horizon below the gravel layer are found (Omappe series). Topsoil reaction of upland soils is in the range pH 4·0 to 6·0 with an average of about 4·6.

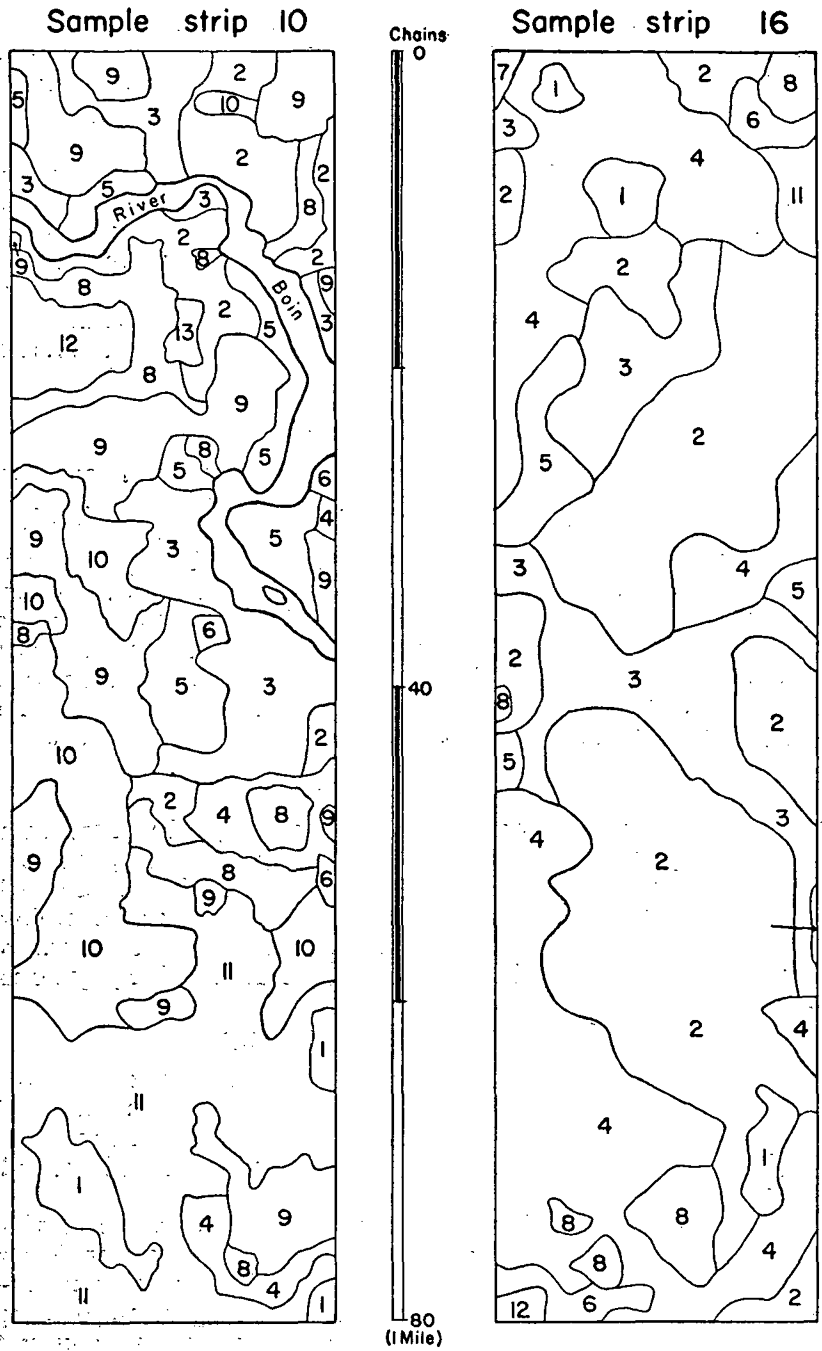


Fig. 16. The Boi association: vegetation maps of Sample strips 10 (at Asemkrom) and 16 (at Bou).

1. Broken forest.
2. Secondary forest.
3. Secondary swamp forest.
4. Thicket.
5. Swamp thicket.
6. Forb regrowth.
7. Swamp forb regrowth.
8. Cultivation.
9. Cocoa.
10. Thicket and cocoa.
11. Secondary forest and coffee.
12. Town site; cemetery.

Most of the summit area appears never to have been farmed (Fig. 16). The very steep slopes are now under regrowth two to ten years old, with occasional mature cocoa farms in poorish condition. More extensive areas of somewhat better cocoa are found on the flattish or gently sloping areas of alluvial soils on both sides of the river. Near the town are small areas of coconuts and food crops, with further small food farms (mostly cassava) on the steep slopes above the town.

Sample strip 16, at Bou (Fig. 15) represents the most southerly extension of the association. The greater part of this strip consists of Boi series found on nearly all upland sites. Colluvial soils of lower slopes are relatively inextensive, and Kwaben series occupies most of the lower areas. The topsoil reaction on the strip averages pH 4·8. Nearly the whole of the strip is under regrowth vegetation, both thicket and secondary forest (Fig. 16).

Sample strips 15*A and* 15*B* were sited at Cocoatown and Elubo on the Tano (Fig. 17). Of these, strip 15A (Fig. 18) was recorded parallel to and almost adjoining the Tano, and shows the extensive areas of Kwaben series, almost all planted to cocoa, along the river. Occasional sandy patches (Chichiwere series) occur on the river banks, while poorly drained areas further away from the river have grey soils (Oda series). The village of Cocoatown itself is built on a somewhat higher area of Boi series at the northern end of the strip.

Strip 15B at Elubo (Fig. 19) was sited across a semi-circular lowland area in a bend of the Tano and reaches the river at both its northern and southern ends. At the southern end, the usual riverside areas of Kwaben and Chichiwere series were recorded. The central area further from the river consists of moderately well drained Kwaben series merging into poorly drained Oda series in the lower parts. At the northern end, Elubo is sited on a higher area of mixed sedentary and terrace soils (Boi and Samreboi series). Most of the areas of Kwaben series support cocoa. Samples from two pits from these strips have been analysed (Part III, page 173): topsoil pH values of the 126 chisel hole samples recorded average about 4·8.

Vegetation

Observations made during the course of the survey suggest that the northern limit of this association corresponds to the northern limit of evergreen rain forest (Part I, pages 15–16), and that the whole of the association falls within the rain forest area. *Tarrietia* is particularly plentiful immediately south of Samreboi, while *Cynometra* is frequent throughout the area. Areas of swamp forest are frequent on poorly drained valley bottom sites. Both the rain forest and the associated swamp forest are discussed more fully in Part III (pages 239–243).

Land-use

The present pattern of land-use

The greater part of this association has never been cleared or disturbed, and still supports original forest.

In the north, Samreboi, discussed above (page 72), occurs at the junction of this association with the Nzima-Boi complex to the north. Along the road from Samreboi south-eastwards to Prestea there has been little permanent settlement, and the few very small villages south of Samreboi are declining in population. West of the Tano, population is concentrated along the Boin valley in the villages of Omappe, Boinso, Jemma and Asemkrom. This area is also declining in population, particularly in the south. A road which once connected Boinso with Tanoso on the Tano is now abandoned. A considerable amount of cocoa is produced from the alluvial soils of the Boin, mostly Kwaben and Birim series, and there are some small rubber plantations here, that at Boinso still being tapped. Agriculture in these areas produces sufficient food for local needs only.

In the west, the isolated Cocoatown-Elubo area along the Tano owes its relative prosperity to the expanses of Kwaben series on which considerable areas of cocoa have been planted.

In the south of the association, areas adjoining the Ankasa River forest reserve have not yet been cultivated. In the extreme south-east of the basin east of Awiebo are a number of main road villages, the chief of which is Ebowu, where food farming and areas of fallow are relatively extensive. There is little cocoa here, but coconut planting has been started. It is doubtful whether these soils will prove as suitable for this crop as the Tertiary sand soils nearby.

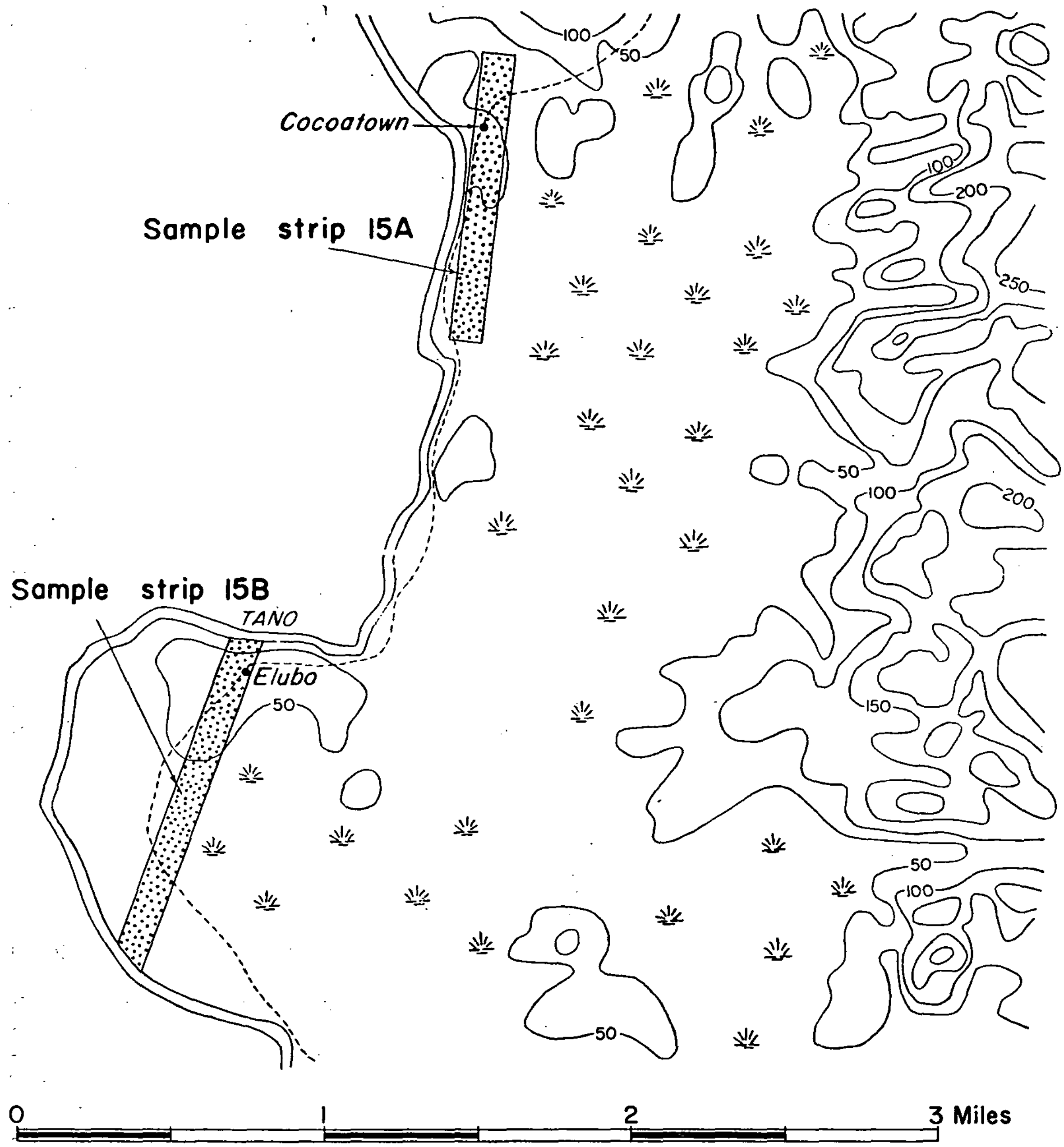


Fig. 17. The Boi association: map showing the location of Sample strips 15A and 15B at Cocoatown and Elubo on the Tano.

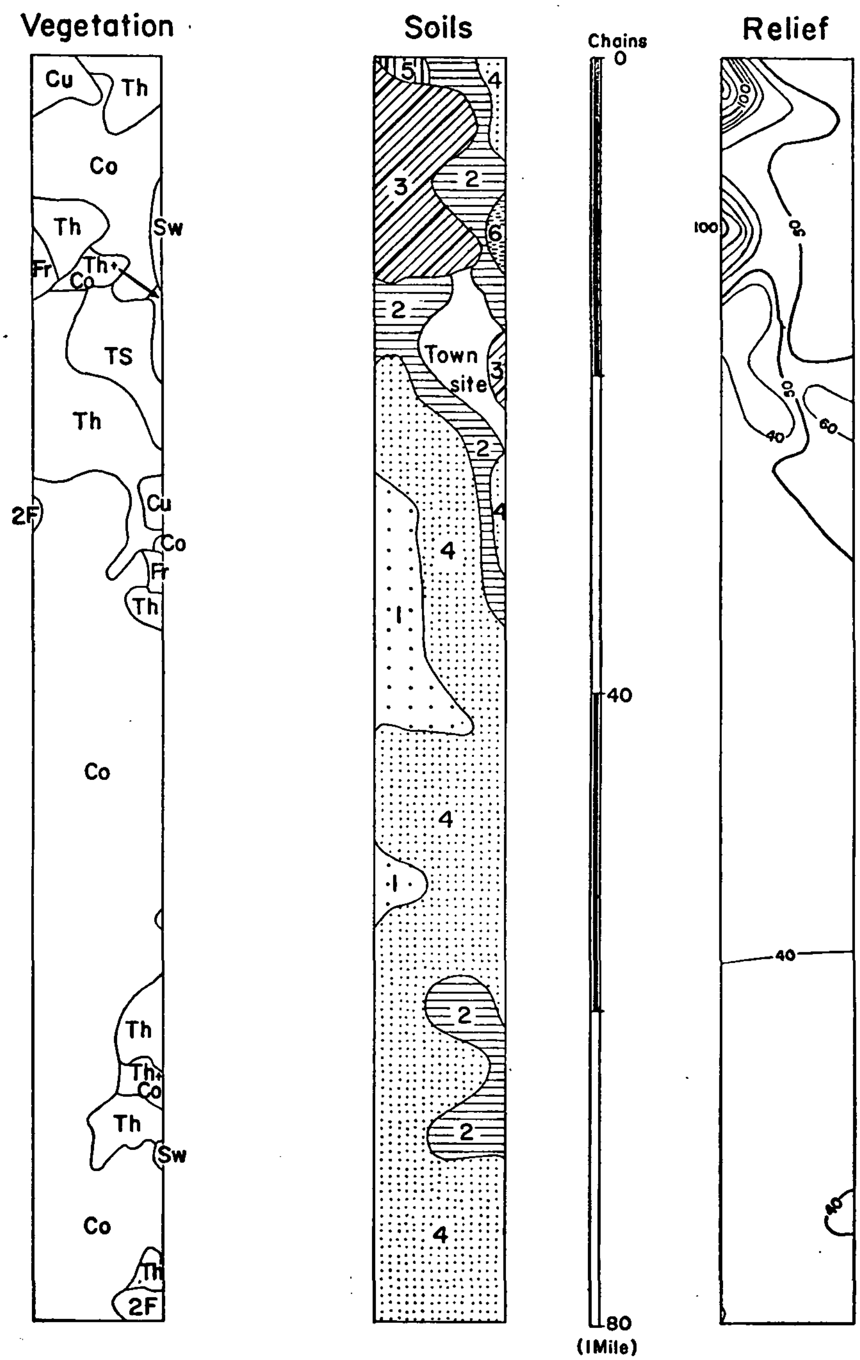


Fig. 18. The Boi association: vegetation, soil and relief maps of Sample strip 15A at Cocoatown, on the Tano. (*See* also the location map, Fig. 17.)

Key to vegetation map

Cu—Land under current cultivation.
Fr—Forb regrowth.
Th—Thicket.
Co—Cocoa (old and healthy).
Th & Co—Thicket with abandoned cocoa in fair condition.
Sw—Secondary swamp forest.
2F—Secondary forest.
TS—Town site (Cocoatown).

Key to soils map

1. Chichiwere series.
2. Densu series.
3. Boi series.
4. Kwaben series.
5. Totua series.
6. Waterlogged.

Contour heights are in feet.

Any plans for the future development of this area must take into account:—

(*a*) the exceedingly low density of population;

(*b*) the lack of communications in most of the area; and

(*c*) the low inherent fertility of its highly leached soils which are not likely to attract new settlers or provide an easy livelihood for them.

The association can be divided into three distinct areas. The largest of these, about two-thirds of the total area, is found north of the Ankasa River forest reserve, and includes parts of the Boin and Tano valleys with their associated alluvial deposits. This area is orientated to the north, the nearest roads being at Boinso and Samreboi. The river alluvial soils are the best and settlements are mostly confined to the riverside sites where the Boin and the Tano allow of canoe navigation and also provide a supply of fish. The intervening hilly areas where the soils are mostly Boi and Omappe series are almost unused as yet and are of low fertility. The road along the Boin from Tanoso to Boinso has been abandoned, as have rubber plantations at Tanoso, although these are in good condition, and the area has declined considerably since the trade which went north and south along the footpaths of this central area ceased when the lorry road was built to Asankrangwa and Enchi. Any future development would probably begin along the river valleys again. A road is planned from Boinso to the Tano and thence south to Mpataba (*see* Part I, Communications), though it is doubtful to what extent this would stimulate settlement and agricultural development here. There are still large reserves of timber in this area which might be made more accessible if a scheme for floating logs down the Tano were reintroduced.

The second area into which this association can be divided is the small Cocoatown-Elubo area between the Ankasa River forest reserve and the Tano to the west. Most of this consists of alluvial soils, shown separately on the soil map. Immediately adjoining the Tano is a belt of Kwaben series, usually about ¼-mile wide, which merges inland into broad lowlying areas of mixed Kwaben, Densu, and Oda series. This area, partly marshy, is formed by the lower valleys of the Nkasamta and the Mungraw and its tributaries and has a total width of up to 2 miles, most of which is within the Tano floodplain. Behind it, hills rise fairly steeply up towards the Ankasa River forest reserve boundary. The best soils are along the Tano and these support areas of riverside cocoa. Most of these soils have now been cultivated and the higher soils inland are less productive. The scope for further development here therefore is very limited. Communication is entirely by launch and canoe downstream to Alenda wharf. Schemes for improving this section of the river are discussed in Part I. Since existing transport facilities are adequate and most of the better soils are already developed, there seems little to be gained by investing money on this waterway.

The third area of this association lies to the south of the other two, between the granite areas of the Ankasa River forest reserve and the Tertiary sands. It forms therefore a long but relatively narrow east-west strip reaching the coast at Kikam. The western end of this strip is either very inaccessible or included within the forest reserve: the eastern end is traversed by the Axim-Half Assini road and therefore forms the most accessible part of the whole association, and that area in which agriculture is most extensive, though even here there is not much cultivation away from the road.

The high rainfall of the association and the very moderate quantities of available nutrients in the soils suggest that the best way of developing the area agriculturally is the planting of tree crops which are adapted to leached, low-base, high rainfall areas and which will at the same time anchor and protect the soil. These soils are particularly fragile in as much as the small supply of stored nutrients accumulated under long periods of forest conditions would be rapidly lost under cultivation and the soil itself would be subjected to physical erosion and topsoil removal. The choice is between (*a*) clearing the ground merely to obtain a mediocre yield of food crops for a year or two, and then abandoning the ground in a poor condition without any further return for the effort of clearing, and (*b*) of planting tree crops which provide an economic return for many years and still leave the soil in relatively good condition. The tree crops best suited to the association are rubber and oil palm: coconut palms would also be profitable, but less so than on the Tertiary sands. In the lowland areas hill rice would be the major crop. This combination of rice and tree crops would ensure that soil erosion was kept to a minimum and is the safest and most profitable way of exploiting acid high rainfall areas such as this.

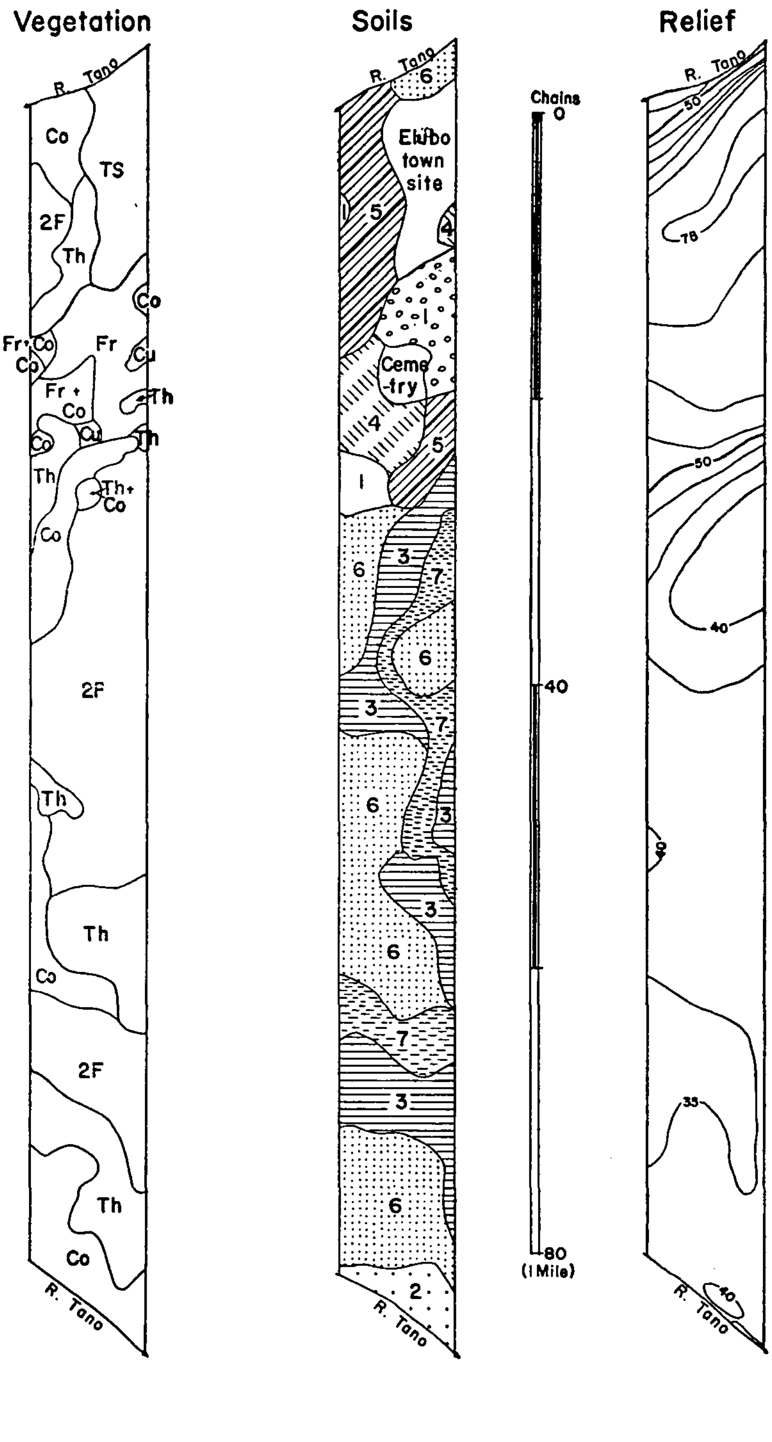


Fig. 19. The Boi association: vegetation, soil and relief maps of Sample strip 15B at Elubo, on the Tano. (*See* also the location map, Fig. 17).

For *key*, *see* next page.

Of the upland soils, Boi series is by far the most extensive. Field observations suggest that yields on this series are very much below those of Nzima series, its ochrosol equivalent. Of the food crops, cocoyams give very disappointing results, while plantains and bananas may give moderate returns on newly cleared ground but decline rapidly after the first year of cultivation. Cassava and maize grow satisfactorily, though they yield less than on less acid soils. Citrus trees may have possibilities on this series, and pineapples, which like acid conditions, do relatively well.

Of the lowland soils, Kwaben is the most important and this has already been described as a soil capable of supporting cocoa as well as a range of food crops. Where this grades into moist areas of Densu and Oda series, rice and chewing cane are more suited to the poorer drainage.

The future land-use development of this area best adapted to soil, climate, and local economic conditions might therefore be on the following lines:

Expansion in the north would begin along the Boin and Tano valleys where remaining areas of Kwaben and Birim series would be planted to cocoa and food crops such as plantain. Poorer drained areas could be devoted to permanent rice, with very minor areas of chewing sugar for local use only. On the upland sites, oil palm plantations could be established. Rubber plantations could be begun on areas of Kwaben and Birim series not planted to cocoa and on relatively flat upland sites not planted to oil palm. Coconuts might be introduced but in this northern area would be mainly for local consumption until it is seen how well they grow.

In the central Elubo-Cocoatown area there is relatively little land left for cocoa expansion, but extensive low areas could be put under rice and hilly areas away from the river planted to oil palm.

In the south, the marshy areas south of the main road again suggest rice cultivation, which was once extensive in this area. The higher areas should be devoted to tree crops, mainly to coconuts, oil palm and possibly citrus. Shifting cultivation for food crops on upland sites should be kept to a minimum. Communications are relatively good in this area and meat and egg production, based particularly on cassava and oil palm, has therefore some possibilities, particularly in relation to the large market in the Sekondi-Takoradi area.

In general, the possibilities of increasing the production of Liberica coffee require investigation: large areas of this have been planted on the French bank of the Tano. On hilly ground, tea might be tried. Piassava collection from the extensive raphia swamps could doubtless become more important. The above observations assume that existing cultivation methods will remain little modified: as soon as fertiliser applications are better understood and more widely used (Part I, page 23), and swamp rice, involving flood control, introduced, then obviously the potential of the area is increased. The advantages of rubber, coffee, and oil palm are that they can be profitable with existing methods even though these may allow of great improvement: the question as to whether land-use changes, such as the introduction of plantations, are also to be introduced is relevant to this, but outside the scope of this report.

Key to Fig. 19 (previous page).

Key to vegetation map

Cu—cultivation (food crops).
Fr—Forb regrowth.
Th—Thicket, mainly with *Macaranga barteri* and *Alchornia cordifolia*.
Co—Cocoa.
Th + Co—Thicket plus abandoned cocoa.
Fr + Co—Forb regrowth with young cocoa.
2F—Secondary forest, mainly with *Ochrocarpus africanus*, *Chrysophyllum laurentii* and *Uapaca sp*.
Ts—Town site (Elubo).

Key to soil map

1. Amoku series.
2. Chichiwere series.
3. Densu series.
4. Bremang series.
5. Boi series.
6. Kwaben series.
7. Waterlogged.

Contour heights are in feet.

SOILS DEVELOPED OVER UPPER BIRRIMIAN ROCKS (GROUP 2)

UPPER BIRRIMIAN rocks are more varied than the relatively uniform phyllites of Lower Birrimian areas and give rise to a greater number of soil series. They consist predominately of volcanic lavas, schists and phyllites, and have minor granite intrusions and areas where other rocks have been formed by heat and pressure changes.

The most complicated Upper Birrimian area within the basin is the Bibiani range which forms the western boundary of the northern tip of the basin. From here the Upper Birrimian hills extend southward, becoming broader and less complicated as they do so.

The usual forest soil catena is developed in this area. On flattish summits, small areas of shallow indurated soils are found. On most upper and middle slopes red and brown sedentary soils occur and these are differentiated according to parent material. On lower slopes and bottoms, colluvial and alluvial soils are formed. Both the indurated soils of the summits and the alluvial soils of valley bottoms are similar to those found in the Lower Birrimian areas. Of the remaining soils, there is also a close correspondence between the two areas: Asikuma is similar in appearance to Nzima series, Ansum to Kokofu, and Piki to Kobeda, the principal difference being the nature of the parent rock. In addition, normal Lower Birrimian soils are also developed where phyllite is found.

Upper Birrimian areas within the basin are higher and more hilly than Lower Birrimian ones. Both north and south of Enchi, hills rise to small remnants of a former peneplain, now at over 1,000 feet above sea level, on which the shallow indurated soils occur. Steep and isolated hills are often composed of more resistant greenstones, while lower areas overlie more easily weathered schists and tuffs. In practice weathering is so deep that it is not possible to distinguish all the different parent rocks.

Two main groups of sedentary soil are found. The first and far more frequent group is usually yellow to orange-brown, deeply weathered, and concretionary (the concretions sometimes being flat and irregular in shape) and generally resembles Nzima series except that (as in most Upper Birrimian soils) there are only small amounts of quartz gravel and stones in the profile. These deep soils are common in all the lower areas of less steep relief. They include Atukrom and Asikuma series and their acid equivalents, Elibo and Yakasi, which are concretionary; these are associated with Atewa series, a non-concretionary sedentary soil; and Piki series, an immature soil found on steep slopes.

The second group of sedentary soils consists of soils which are generally darker in colour, being brown to red-brown. These are less common than the first type, being usually found on very steep high hills, and are developed over more resistant epidiorite and greenstone. Concretions may be relatively few if the slope is steep, and pieces of the parent rock are characteristically scattered throughout the profile. The commonest series in this group is Shi series, which is brown. Wiawso series is its red and better drained equivalent, and Tanokrom series is the corresponding skeletal soil. These soils are usually ochrosols and no acid equivalents have been recorded though they may occur in minor quantities.

A yellow-brown colluvial soil, Ansum series, or its acid equivalent, Disue series, is associated with both these groups of sedentary soils. Alluvial soils in the valley bottoms and occasional terrace soils are similar to those found in the Nzima and Boi associations described above.

This broad general pattern is varied locally by the occurrence of minor patches of distinct soils developed over granite, certain basic rocks rich in hornblende, and over arenaceous rocks in the Bibiani range, while soils developed over phyllites are scattered throughout the area.

Three main associations have been mapped. The first of these, the Atukrom association, includes all the Upper Birrimian area north-east of the Tano, i.e. the Bibiani range and its southward extension into the Suhuma forest reserve, where most of the soils are thought to be ochrosols. The remaining areas north and south of Enchi have been divided into two further associations, the Yakasi-Shi association and the Yakasi association. Of these, the first, covering all the higher and hiller parts, includes a proportion of indurated summit soils and soils developed over resistant greenstone, while the second is one of more gentle relief where most of the soils are more deeply weathered. In both of these areas oxysols and ochrosols are thought to be about equally common. These three associations are described in the sections that follow. A very minor area of soils developed over metamorphosed sands in the Bibiani range (the Sefwi association) is also dealt with here, while soils developed over the granite intrusions in the area are described under Group IV, below.

2A. THE ATUKROM ASSOCIATION

This association is confined to an area of 73 square miles in the north of the basin where it occurs on the relatively steep and narrow Bibiani range which rises to 1,600–1,700 feet, and on its somewhat broader but still deeply dissected southward extension into the Suhuma forest reserve, where numerous hills reach 1,000–1,250 feet above sea level.

The geology of these hill ranges is extremely complicated, consisting mainly of various volcanic rocks which range in composition from basalt to rhyolite and constitute the higher parts of the range. These rocks are often tough and well preserved, the commonest being a range of greenstones which are intermixed with lesser quantities of phyllite. Numerous intrusions of both biotite and hornblende granite, some extensive, are also found, and associated with these are adjacent areas of rocks altered by heat and pressure. According to Hirst (Hirst & Junner, 1946) " few of the rocks in the area have remained unaffected in some degree by . . . metamorphism, in which heat has predominated on the east side of the range itself and pressure on the west ". Clay deposits become phyllites, sandy ones quartzites and quartzitic greywackes, while the same deposits more highly altered (nearer the intrusions, for example) become indurated spotted phyllites, carbonaceous and biotite schists or, in the case of sandy deposits, hornfelses and quartz-biotite schists.

There is therefore a considerable variety of soil parent rocks in the range, and these individual parent rocks would be very difficult to map separately even on a more detailed survey. In practice some soil series are found to develop over a range of parent rocks, and, apart from granite areas and soils of the Sefwi association developed over metamorphosed sandy rocks, both of which form separate associations discussed elsewhere, all the remaining soils belong to the Atukrom association (technically, a soil complex) described here.

Soils

On flattish summits, Atonsu and Nsuta series are found. These are described under the Nzima association (pages 59–63). On the remaining upland sites, three main groups of sedentary soils can be recognised. These, in order of importance, are as follows:

(*a*) *Soils developed over tuffs, schists and other deeply weathered rocks*

Atukrom series—a red concretionary sedentary soil.
Asikuma series—its brown less well drained associate.
Atewa series—a deep red or brown non-concretionary sedentary soil.
Piki series—an immature soil associated with the above.

(*b*) *Soils developed over greenstones, epidiorites and other lavas*

Wiawso series—a red sedentary soil, concretionary and often brashy.
Shi series—its brown associate.
Tanokrom series—a skeletal soil over greenstone or epidiorite.

(*c*) *Soils developed over hornblende schists and basic rocks*

Anum series—a dark brown, plastic, sedentary soil.

The usual colluvial soil associated with these sedentary soils is Ansum series, though very minor areas of Abu series are found associated with Anum series (Group C). Alluvial soils are similar to those in the Nzima association, i.e. Kakum series, the most extensive, with minor areas of Oda, Densu, Chichiwere and very occasional terrace soils.

In addition, minor patches of the Sefwi and the Adujanso associations are found scattered among the soils of this association.

Atukrom series

Atukrom series is a reddish brown, deeply weathered, concretionary sedentary soil found on upper slopes and summits. A thin dark greyish brown humous topsoil overlies a reddish brown concretionary light clay subsoil. The concretions vary in amount and shape: certain Atukroms have abundant flattish irregular concretions, others have only moderate amounts of more regular spherical concretions. Quartz gravel and stones are usually present in only minor amounts. Below the gravel zone the profile merges into a considerable depth of uniform brown light clay or loam of decomposing rock. Those profiles developed over tuff are often rather soft in the weathered substratum and at 15–20 feet there may be a rapid transition to white or nearly white, fine, soft, weathered tuff. Other examples go down to pale mottled material, usually weathered schist, though the parent rock of this series is often difficult to identify with certainty.

This soil is deep and well drained, but moisture retention in the dry season, particularly in the lighter textured examples developed over tuff, is sometimes inadequate, while the topsoil is easily eroded, thus exposing the concretionary subsoil.

The fertility of the series varies considerably according to the thickness and acidity of the topsoil. It is sometimes capable of supporting moderately good cocoa, but is usually better suited to coffee. A wide range of food crops is grown on this soil, though since it is very deep and decomposing rock is well out of range of plant roots this series is distinctly less fertile than such soils as Wiawso and Shi series which contain decomposing rock fragments in the subsoil.

Asikuma series

Asikuma series is the brown, less well drained associate of Atukrom series. Within the basin it is sometimes commoner than Atukrom series, which may be locally absent, so that Asikuma series is found on all types of upland site from summit to lower slope. Its morphology is similar to Atukrom except that the subsoil is pale brown to orange-brown in colour. Drainage is almost as good as Atukrom series, particularly on the higher sites, and the two series are very similar in nutrient status. Both series support moderate cocoa and a wide range of food crops, but care in cultivation is needed to prevent accelerated erosion and removal of the topsoil. Eroded examples, with concretions at the surface, are often seen.

Wiawso series

Wiawso series and its paler drainage associate, Shi series, are found associated with Atukroms and Asikumas. They occur particularly on the steep sides of hills on which boulders and pieces of greenstone and epidiorite outcrop. Wiawso hill, just outside the basin, forms a good example of this where frequent boulders of epidiorite can be seen at the surface. In a typical profile, a thin dark greyish brown humous topsoil overlies a dark reddish brown concretionary light clay subsoil containing frequent brash of decomposing epidiorite and/or greenstone which weathers to a characteristic yellow colour on the outside. Since the site of this series is often rather steep, somewhat eroded examples with little or no topsoil are common. Below the subsoil the profile merges into brown light clay or loam of weathered rock in which pieces and traces of parent material become increasingly plentiful.

This series is easily distinguished from Atukrom and Asikuma by the pieces of partially decomposed rock scattered through the soil, whereas the parent material of Atukrom and Asikuma is soft, deeply weathered and hard to identify even at considerable depths. Wiawso series is very well drained and liable to erosion, but it is one of the most fertile soils in the Upper Birrimian areas, being exceeded only by soils of the Anum type developed over more basic rocks. It supports good cocoa, and is one of the very few soils on which cocoa will grow successfully even if the soil is under thicket or secondary forest prior to clearing. Very stony and concretionary examples may seem inhospitable but are in fact far better than deeply weathered soils, since the weathering rock brash in the profile provides a source of plant nutrients. As a result this soil is not so dependent on the stored nutrients of the topsoil as are most forest soils.

Shi series

Shi series is the brown drainage associate of Wiawso series. It is more common than Wiawso series, from which it is distinguished mainly by its brown to orange-brown subsoil. It is also well drained and the nutrient status and productivity of the two series are similar. This is the normal soil of steep hillsides, where it is associated with the skeletal Tanokrom series.

Atewa series

Atewa series is a deep red or brown sedentary soil distinguished by its considerable depth of uniform, non-concretionary, soft and easily dug light-textured subsoil. It is developed over relatively easily and deeply weathered Upper Birrimian rocks similar to those which give rise to Atukrom and Asikuma series, i.e. over tuffs and schists.

A thin greyish brown humous topsoil overlies a brown to reddish brown uniform light clay to loam subsoil 6–8 feet deep which is usually free or nearly so of included gravel and quartz material. On steep sites the subsoil may be only 3–4 feet thick. This subsoil merges gradually into a loam of soft decomposing rock.

Atewa series is well drained, deep and easily worked though it does not retain moisture well during dry periods and is liable to erosion. It is often found on fairly steep sites, though individual patches of it may be fairly extensive, as, for example, north of Apiakrom and Efwhia on the Sefwi-Bekwai–Sefwi-Wiawso road. Its nutrient status is similar to or slightly better than Atukrom series, but eroded examples and certain older highly weathered examples thought to include residual products from peneplain drifts may be infertile. The soft texture suggests its use for root crops such as cocoyam, while some moderately good cocoa has occasionally been observed on this series.

Piki and Tanokrom series

Piki and Tanokrom series are both immature soils found on very steep sites. Piki series is associated with Atukrom and Asikuma series: it is developed over schists, and weathered schist is found immediately below the greyish brown humous topsoil. Tanokrom series is a similar soil developed over relatively resistant greenstones and epidiorite: these weather slowly, so that the soil is skeletal, and consists of a thin humous topsoil directly overlying a light clay containing fragments of hard, often little weathered parent material. Of these two soils, Tanokrom has a higher nutrient status than Piki because of its parent rock. Both soils are shallow and liable to severe erosion if left unprotected, but Tanokrom series in particular is fertile and both soils are well suited to tree crops, including cocoa, coffee and citrus.

Ansum series

Ansum series is a yellow-brown colluvial soil found associated with all the sedentary soils described above. It consists of a thin greyish brown topsoil overlying a subsoil of yellow-brown fairly porous light clay, usually 2–4 feet thick, which in turn overlies weathered rock below. The junction between the transported subsoil and the weathered substratum below may or may not be marked by a stone-line or gravel layer.

This soil occupies lower slopes between the sedentary soils above and the alluvial soils of the valley bottoms. It is less well drained than associated upland soils, but is easy to work and free of stones. Its physical properties suggest its use for root crops. It occurs somewhat irregularly and is not extensive. Its nutrient status is considerably lower than the better upland soils, such as Shi series, but compares favourably with the less fertile sedentary soils such as Asikuma series.

Anum series

Anum series is a very distinctive but inextensive sedentary soil formed over certain basic rocks rich in hornblende. It is easily recognised by the dark topsoil and dark greyish brown subsoil, the slightly plastic nature of the subsoil clay, and by the neutral or near neutral reaction.

A dark greyish brown crumbly humous topsoil overlies a dull brown to greyish brown slightly plastic and slightly cloddy subsoil containing a moderate amount of ironstone concretions, and some manganese concretions. This merges into an olive-brown weathered substratum containing frequent traces of weathered rock.

This very fertile soil supports excellent cocoa, due to its relatively high base exchange capacity, high nutrient status and near neutral reaction: it is also very retentive of moisture in the dry season. Unfortunately it is very inextensive and is found only in scattered patches. One of these areas occurs south of Efwhia, on the Sefwi-Bekwai–Sefwi-Wiawso road, where it is all planted to mature cocoa in very good condition. Other minor areas occur through the association but the total acreage is very small.

Abu series

Abu series is the colluvial soil associated with Anum series. Like Anum series it is distinguished by its dark-coloured (dull brown to grey brown), slightly plastic, heavy clay subsoil. A dark greyish brown humous clay topsoil overlies a subsoil of 3–5 feet of heavy dull brown to grey brown slightly cloddy and slightly plastic clay. This may contain a little quartz gravel and overlies, more or less abruptly, a zone of weathered rock.

This soil is heavy, retentive of water and only moderately well drained. It has a relatively high nutrient status, a high base exchange capacity, and a near neutral reaction. It supports good cocoa, but like Anum series, is found only in scattered patches and its total area is very small.

Alluvial soils

The alluvial soils of the association are similar to those described for the Nzima association, but are not extensive as there are no broad alluvial valleys. On stream levees, *Kakum series* is found, a useful cocoa soil, while on the poorer drained flats *Oda* and *Densu series* occur. There are extremely minor patches of *Rubi series*, a dark, almost black, heavy clay soil resembling Densu series which is associated with Anum and Abu series, described above.

Terrace soils

Terrace soils such as are described under the Nzima association occur only in very minor quantities where they are associated with some of the larger streams.

Vegetation

The natural vegetation of the association is forest of the *Celtis-Triplochiton* type, large areas of which are still preserved in the two forest reserves which together cover most of the association. These are the Suraw forest reserve, which protects the higher parts of the relatively narrow Bibiani range, to the north, and the much larger Suhuma forest reserve to the south.

Outside the reserves, much of the forest has been cleared for agriculture and now consists of a mosaic of original forest, secondary forest, thicket, forb regrowth, current food crop cultivation and cocoa farms. These areas are discussed in the next section.

Land-use

The present pattern of land-use

The main areas of cultivation within the association are on either side of the main Sefwi-Bekwai–Sefwi-Wiawso road, north and south of Efwhia, Apiakrom and Domiabra. Farming from these main road villages has reached the boundaries of both the Suhuma and Suraw forest reserves, though some areas of original forest remain. To the north of this the lower unreserved foothills of the Bibiani range have been partly cultivated by farmers from Paboasi, Echuabo, and Akoti. In the extreme south of the association, adjoining the Tano, there has been a considerable recent increase in cocoa planting by farmers coming north from the Asankrangwa-Bremang area. These areas are described in turn below (*see also* Ahn, 1955*a*).

The Efwhia-Apiakrom main road area. South of the main road there is a narrow belt of old established cocoa, while many small new farms are being planted between this belt and the forest reserve. There are numerous footpaths in this area and the forest reserve boundary is itself used as one, permitting the extension of new clearing along it. There are several extensive cocoa farms south of Efwhia sited on a patch of Anum soils. These are in excellent condition. Elsewhere the soils are less good (mostly Atonsu, Atukrom and Asikuma series) and in these remaining areas about a quarter of the total acreage is under cocoa, mostly nearer the road, nearly half is broken forest, and the rest is under food crops or fallow.

North of the main road, cocoa is widespread and old established, and food farming is also extensive. From the main road villages cultivation has spread north towards Paboasi. On the middle and lower slopes of the Aboabo valley cocoa is fairly continuous. North-east of this there is a ridge of higher land running NW-SE where the soils are mostly Atewa series: here there is some good cocoa but most of the area is still under forest. Swollen shoot attack has been severe at Apiakrom and throughout most of this area cocoa matures unusually slowly, taking eight to ten years to yield. For this reason farmers are not replanting cut-out areas. On the poorer parts now in thicket, cocoa is reported to have grown well for three years and then to have deteriorated. The local opinion is that cocoa in these upland areas is inferior to that on the alluvial soils of the Suraw valley to the east (*see* the Nzima association, page 59): the main limiting factor may well be the dry season moisture retention capacity of some soils. Despite this, cocoa planting is still expanding, particularly along the footpath north to Paboasi.

Throughout this main road area food is grown for sale outside the region. The principal crops are plantains and cocoyams and these are sent to Wiawso and Sefwi-Bekwai, as well as to towns further afield such as Tarkwa, Samreboi and even Takoradi.

Bibiani range foothills. North of the river Chinsu, the range narrows. Those areas of the association outside the Suraw forest reserve are cultivated to a limited extent by farmers from Paboasi, Echuabo and Akoti. Food crops are grown for local use only, but cocoa farming is expanding. All higher areas are reserved and cultivation is confined to lower slope and valley bottom soils.

South of the Suhuma forest reserve. Between the reserve boundary and the Tano is an area without permanent settlements cultivated by farmers coming from the Asankrangwa-Bremang area to the south. There is some old cocoa here, over thirty years old, and an increasing amount of very young cocoa. The alluvial soils give better results than the sedentary soils.

Future land-use

The unreserved areas of this association not yet cleared and cultivated are limited, and all the more accessible parts will probably be planted to food crops and cocoa within the next five to ten years. No virgin land will then be available, fallow periods will become shorter, and no new cocoa planting will be possible. It is not likely however that pressure on the land will increase greatly here until very extensive tracts of virgin land to the west in the Bia basin have been cleared first. Even now, some farmers have already moved to this area, where cocoa is reported to grow well.

Modifications in land-use on this association once all the original forest is cleared might be expected to include the growing of a greater percentage of the less exacting crops adapted to the decreasing fertility of the soil as fallow periods and nutrient reserves are reduced. Since however, the soils are, in general, moderately productive and nearly all of them are ochrosols which compare favourably with more acid soils further south, this area will continue to be able to export food for a considerable time to come. Current exports are, however, mostly from the newly cleared lands furthest away from the road, and there will undoubtedly be a drop in their quantity as soon as new land is no longer available.

At this stage it is possible that more attention will be given to coffee than at present, since this can be established on land already farmed and is suited to most of the well drained upland soils of the area.

2B. THE YAKASI-SHI ASSOCIATION

This soil complex occupies a very broad upland area of 405 square miles which extends north and south of Enchi in the north-west of the basin and includes very numerous high, steep-sided hills rising to 900–1,250 feet. These are dissected by a well developed and complex drainage system. The major river is the Disue, which divides the complex into a larger area to the north-east, which includes the Yoyo, Santomang and part of the Sui forest reserves, and a smaller, slightly less high area to the south, most of which is included in the Boin river forest reserve.

The central area of the Disue valley and the somewhat lower hills on either side form a separate but similar association, the Yakasi association, in which certain of the higher summit soils present in the Yakasi-Shi association are absent.

Soils

The geology of this area is similar to that of the Bibiani range (the Atukrom association), and consists mainly of volcanic lavas and tuffs with subsidiary amounts of phyllite and schist, while occasional

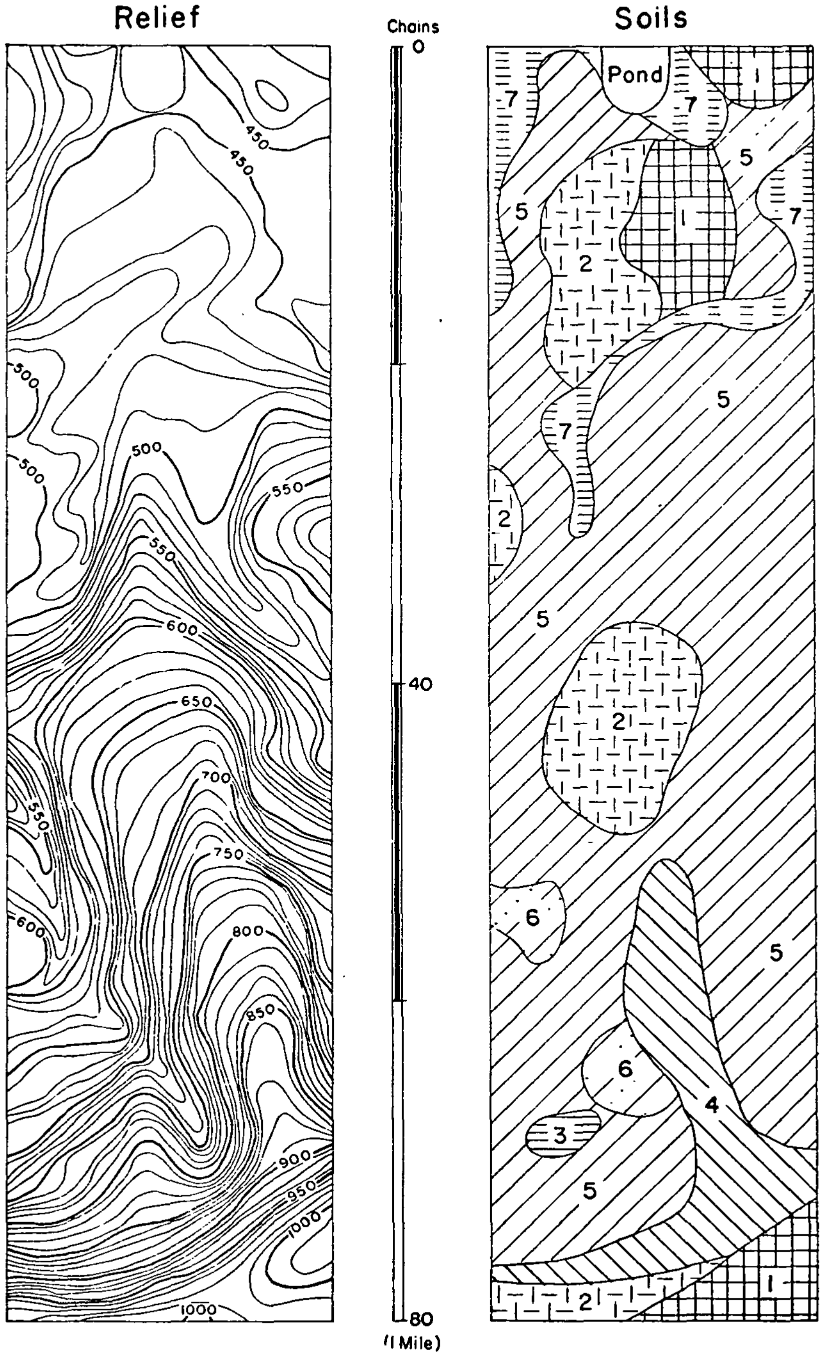


Fig. 20. The Yakasi-Shi association: relief and soil maps of Sample strip 5, South of Enchi. Contour heights are in feet.

1. Nsuta series.
2. Atonsu series.
3. Kobeda series.
4. Red sedentary soils: Atukrom series with subordinate Elibo series.
5. Brown sedentary soils, Asikuma and Yakasi series, with occasional soils developed over phyllite (Nzima and Boi series).
6. Shi series.
7. Alluvial soils (mostly Kakum, Kwaben and Oda series).

small granite intrusions give rise to distinct areas of soils of the Yoyo association, described elsewhere. Major areas of these granite soils have been shown on the soil map but additional small patches occur within the Yakasi-Shi association. Whereas most of the sedentary soils on the Bibiani range are ochrosols, the sedentary soils of this association include about equal quantities of ochrosols and oxysols. with a proportion of intergrades between the two. The ochrosols have been described above (pages 88–91, and 60–61). The oxysol equivalents are given in the following table and described later.

Ochrosol	*Brief description*	*Oxysol*
Atukrom	Red sedentary soil over schists, tuffs, etc.	Elibo
Asikuma	Brown associate of the above	Yakasi
Atewa	Deep, non-gravelly sedentary soil	Enchi
Ansum	Colluvial soil associated with the above	Disue
Wiawso	Red sedentary soil over greenstone, etc.	(not found)
Shi	Brown associate of the above	(not found)
Atonsu	Gravel zone overlying an indurated layer	Omappe
Nsuta	Gravel zone overlying massive iron pan	Sutri.

Broadly speaking this extensive association consists of:

(*a*) *Small areas of indurated soils (Nsuta, Atonsu, Sutri and Omappe series) on the flattish summits of high hills, with further areas of Atonsu and Omappe series on flattish lower parts.*

(*b*) *Limited areas of brashy, often shallow, sedentary soils developed over greenstone and epidiorite (Wiawso and Shi series) found on the steep flanks of the higher hills. These are associated with the corresponding skeletal soil (Tanokrom series) and form the best soils in the area.*

(*c*) *Extensive areas of deep sedentary soils on more gentle slopes and lower hills, developed over a range of more easily weathered rocks, including schists, tuffs and porphyries (Atukrom, Asikuma, Elibo and Yakasi series). The associated skeletal soil (Piki series) is found on the steeper parts and throughout the area occasional phyllite areas give rise to soils similar to those found in adjacent areas of Lower Birrimian geology (Nzima, Boi, Kokofu, Bremang, Kobeda and Totua series) though these are subordinate in extent.*

(*d*) *Locally extensive areas of alluvial soils, of which the most important is Kwaben series, with minor areas of Kakum, Densu, Oda and Chichiwere series (page 62). In certain areas these are associated with terrace soils, mainly Birim series (page 62). Atewa series and Anum series of the Atukrom association to the north are found only in very small amounts.*

Generally speaking, Upper Birrimian sedentary soils are more fertile than corresponding soils of adjacent Lower Birrimian areas, because the volcanic lavas included in the Upper Birrimian are richer in nutrients than the phyllites and greywackes of the Lower Birrimian. The most productive soils are the shallow stony soils of steep high hills. These contain greenstone or epidiorite brash in the profile which decomposes to supply plant nutrients within root depth, but are inextensive and often inaccessible. The very extensive yellow sedentary soils of middle and lower slopes of the more gentle hills are more deeply weathered than the soils of the first group, and are less fertile due to deep leaching and the great depth at which decomposing rock is found. The alluvial soils of valley bottoms, though not so widespread as these leached deep sedentary soils, are somewhat more fertile. These are mostly Kwaben series, with some Kakum and Birim series. These soils may receive mineral nutrients leached out of soils higher up or, in the case of soils associated with the major rivers, from areas a considerable distance upstream.

The ochrosols of the association have been described above, pages 88–91. These are associated with the following more acid soils:

Elibo series

Elibo series, the acid equivalent of Atukrom series, is a deeply weathered, gravelly, sedentary soil of upland areas. The morphology of the profile is very similar to Atukrom series (page 89) but its greater acidity and the higher degree of leaching which it has undergone give it a much lower nutrient status. The soil is well drained, and is less likely to dry out than Atukrom series, but its low nutrient reserves

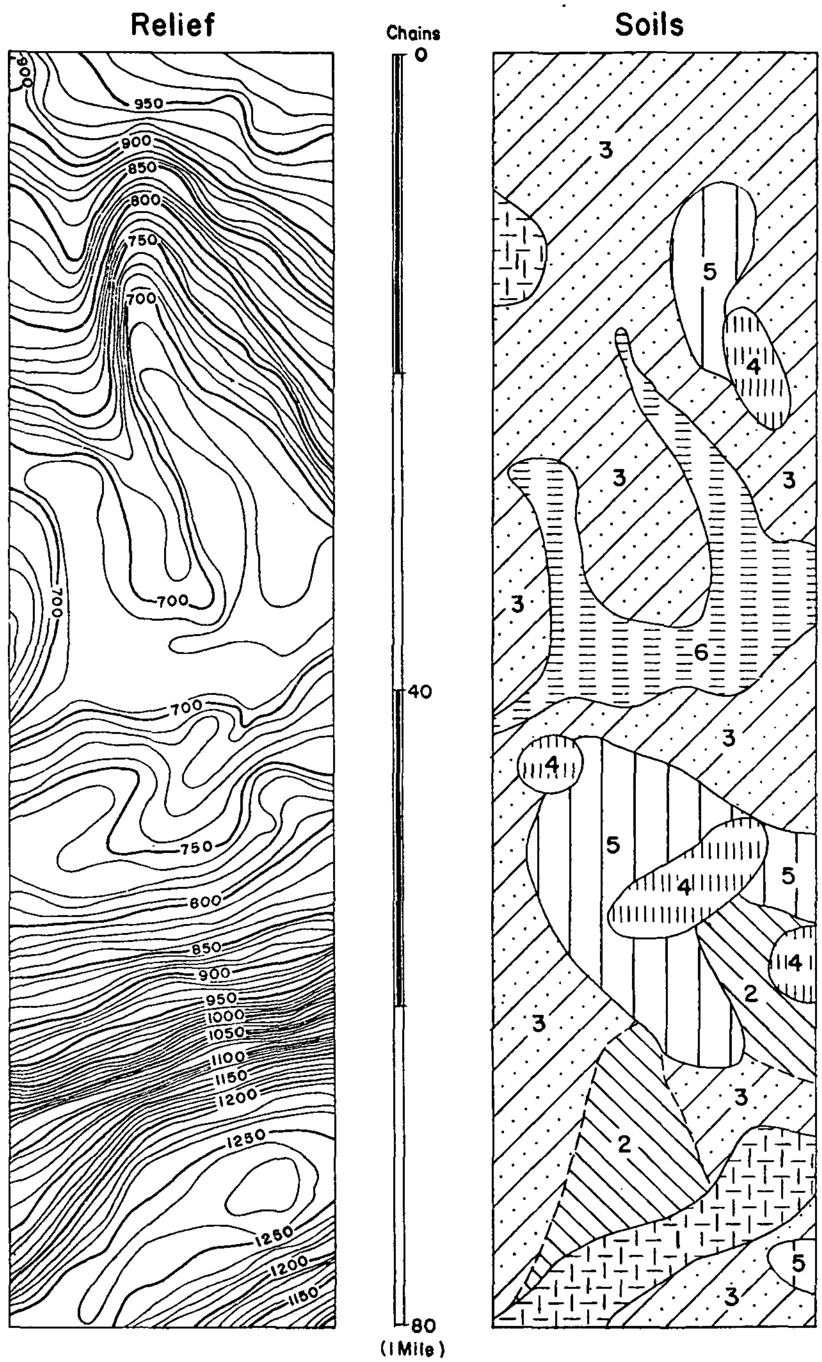


Fig. 21. The Yakasi-Shi association: relief and soils of Sample strip 6 at Tanokrom, 17 miles north of Enchi. Contour heights are in feet.

1. Atonsu series.
2. Wiawso and Atukrom series.
3. Shi and Asikuma series.
4. Tanokrom series.
5. Enchi series (usually shallow) with eroded examples of Atukrom series.
6. Alluvial soils (Kwaben, Kakum and Oda series).

The upland soils include minor areas of their oxysol equivalents.

are likely to be rapidly exhausted so that this series does not support good cocoa and food crop yields are not likely to be as high as on Atukrom series.

Yakasi series

Yakasi series is the paler, less well drained yellow-brown associate of Elibo series, and the acid equivalent of Asikuma series. Yakasi series is very extensive in the association, occupying most of the upland sites. Drainage is usually adequate, but this series has the same low nutrient status as Elibo series, so that it is not normally a cocoa soil and crop yields decline seriously one to two years after clearing.

Enchi series

Enchi series, the acid equivalent of Atewa series, is rare in this association. It is confined to steep upland sites and consists of a thin grey-brown humous topsoil overlying a non concretionary reddish brown to brown light-textured subsoil. The parent material is similar to that of Yakasi and Elibo series, and the nutrient status is either similar or slightly better. This soil is soft and easily worked, but liable to erosion.

Disue series

Disue series, the acid equivalent of Ansum series, is a yellow colluvial clay of lower slopes. It is relatively inextensive and is often absent from the catena. Nutrient status is similar to associated upland soils, but this series has little or no gravel in it and is somewhat less well drained.

Omappe and Sutri series

These soils occur on flattish upland areas. They are described above (pages 75–77).

Detailed sample strips on the association

Two sample strips were recorded on this association: Sample strip 5, south of Enchi and adjoining the Boin River forest reserve, and Sample strip 6, at the village of Tanokrom, 17 miles (by footpath) north of Enchi. Both strips include areas of relatively steep upland soils. Lower areas within the same association resemble Sample strip 7, discussed under the Yakasi association below (page 98).

Sample strip 5 south of Enchi (Fig. 20) includes a relatively gently sloping area in the north. The remaining three-fifths of the strip consists of very steeply sloping dissected slopes rising to a flattish summit area, over 1,000 feet above sea level, a small portion of which is included at the southern end of the strip. The soils on the summit are concretionary and overlie ironpan (Nsuta series). On the steep slopes red and brown sedentary soils (some of them ochrosols, but mostly oxysols) are developed over various schists, phyllites and greenstones. Of these a few contain fragments of resistant parent rock (Shi series) but most are deeply weathered examples in which the decomposing parent rock is difficult to identify. In most cases this parent rock is Upper Birrimian schist or tuff (Asikuma and Yakasi series) but smaller areas of phyllite occur (Nzima and Boi series). Rocks identified in stream beds were mostly greenstones. On gentler slopes these soils have developed an indurated layer in the subsoil (Atonsu series). Alluvial soils, at the northern end of the strip, are inextensive.

The higher parts of the strip appear never to have been farmed and are under original forest. The steeply sloping areas, at the time of the survey (1955), were under regrowth vegetation five to eight years old, with a few very small patches of cocoa on the middle to lower slopes: this was in poor to moderate condition. The lower northern end was under a young regrowth vegetation, two to four years old.

Sample strip 6 at Tanokrom (Fig. 21) includes a steep hilly area where the soils appear particularly fertile for the area, and certainly considerably better than those recorded on Sample strip 5. From a central valley 700 feet above sea level the ground on the strip slopes very steeply indeed up towards high ground at either end. A flattish hill-top area, over 1,250 feet above sea level, is included in the strip at the western end.

The flattish summit soils have very gravelly subsoils overlying a mottled indurated layer (Atonsu series). This summit and that on Sample strip 5 probably represent remnants of the Aya surface (page 10). On the very steeply sloping soils below the summit shallow red and brown sedentary soils over upper Birrimian greenstones and schists were recorded. Of these, many contain fragments of parent rock (Wiawso and Shi series), while others are more deeply weathered (Atukrom and Asikuma

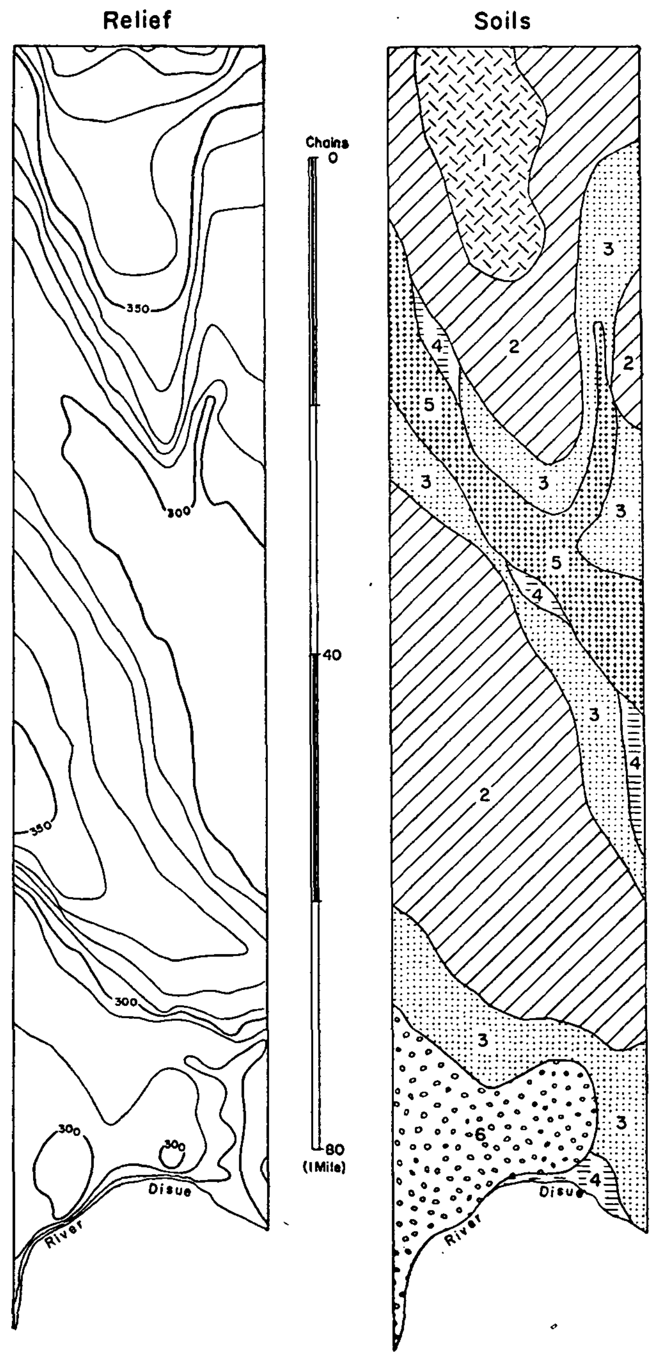


Fig. 22. The Yakasi association: relief and soil maps of Sample strip 7 at Yakasi, near Enchi. Contour heights are in feet.

1. Atonsu and Omappe series.
2. Yakasi series with subordinate Asikuma and Boi series.
3. Kwaben series.
4. Chichiwere series.
5. Oda series.
6. Birim and Samreboi series (terrace soils).

series). Most of the soils are ochrosols. Non-gravelly soils were also found on these steeply sloping areas: these are Enchi series (deeper examples) or eroded Atukrom series (shallower examples). In the relatively inextensive valley bottoms, Kwaben, Kakum and Oda series were recorded.

The land-use of this area forms the subject of a separate report (Ahn, 1956): on and near the strip are areas of cocoa up to fifty years old, all in relatively good condition except for the oldest trees which are now dying. Young cocoa on the strip and near it grows well, even though planted on previously cultivated soils. Coffee and citrus also grow relatively well, while food crops—mostly plantain and cocoyam—appeared to yield better than any observed within the basin. The relative fertility of this area appears to be connected with the youth of most of the soils on steep sites and the fact that decomposing greenstone is present either in the subsoil or at no great depth in the weathered substratum.

Vegetation and land-use

The vegetation and land-use of this association are considered together with those of the adjacent Yakasi association on pages 99–101 below.

2C. THE YAKASI ASSOCIATION

The Yakasi association occupies 163 square miles, or less than 6 per cent of the basin, and is found covering most of the lower hills in the Enchi area and the intervening valleys, of which the most important are the Susan and Jensui. The soils of this association are similar to those of the Yakasi-Shi association except that high flat topped hills and associated soils are absent, so that there is a greater proportion of the lower sedentary soils and of valley alluvial soils.

Soils

The most extensive soils are Asikuma series (page 89), a deep yellow-brown sedentary soil developed over schists and tuffs, and Yakasi series (page 96) its more acid equivalent. On lower slopes there are subordinate areas of Ansum and Disue series (pages 90 and 96), the associated colluvial soils, and these merge into terrace soils, particularly Birim series (page 62), and into Kwaben series in the valley bottoms. Relief is relatively gentle in this association so that red soils such as Atukrom and Elibo series are almost absent and soils associated with steep high hills (Wiawso, Shi and Tanokrom series) and their flat summit areas (Nsuta, Sutri, Atonsu and Omappe series) are also found only rarely, though on flattish lower sites indurated soils of Atonsu and Omappe series do occur.

The normal sedentary soils, Asikuma and Yakasi series, are of moderate to rather low fertility largely depending on topsoil acidity. These are deep yellow-brown soils associated with a proportion of Nzima and Boi series (pages 59 and 75) developed over local patches of phyllite.

The alluvial soils of this association are considerably more fertile than the more extensive sedentary ones. Both Kwaben and Birim series (pages 77 and 62) support cocoa and a range of food crops. These soils are often locally extensive along the major rivers.

Detailed sample strip on the association

Sample strip 7 near Yakasi (Fig. 22) was the only strip recorded on this association. This included relative low hills, under 400 feet above sea level, sloping down to the river Disue, here about 280 feet above sea level. Alluvial soils associated with the Disue are extensive: within the strip they include Kwaben series on the lower parts and a more extensive area of Samreboi series developed in a low terrace some 20 feet above the river. Small patches of sandy soils (Chichiwere series) are found on the river banks. The higher soils on the strip are mostly deep, pale yellow-brown, moderately gravelly sedentary soils developed over Upper Birrimian schists and minor areas of phyllite. Most of these are relatively poor oxysols (Yakasi series, with some Boi series) with occasional ochrosols (Asikuma series). Many of these soils are very slightly indurated in the deep mottled subsoil. On flatter areas where the induration is better developed, these soils are mapped as Atonsu and Omappe series.

Nearly all of the strip when recorded (1955) was under regrowth vegetation, five or six years old. Good cocoa was seen on some of the alluvial soils on and near the strip, yielding relatively well, particularly on the terrace soils, but the very small cocoa patches on the higher sedentary soils were poor in comparison. There was surprisingly little food farming in the area. Further details on this strip are given in an interim report on the Enchi area (Ahn, 1956).

Vegetation

In this and the following sections on land-use the Yakasi and Yakasi-Shi associations are considered together.

In the very south of this area, in the southern part of the Boin river forest reserve, there is an area of the *Cynometra-Lophira-Tarrietia* rain forest (Part I, page 15 and Part III, page 239). The remainder of the area is best described as belonging to the *Celtis-Triplochiton* association since both these trees are common throughout, though this is modified by the presence of some rain forest trees not usually found in this association. In the Yoyo River forest reserve, in particular, *Cynometra ananta* is locally plentiful (this small area could perhaps be best considered as an outlier of the rain forest) while *Tarrietia* is fairly common in the Boin River forest reserve.

Most of the area is protected by forest reserves. Nearer Enchi and the larger villages the natural forest has been replaced by cocoa and food farms and by regrowth vegetation.

Land-use

The present pattern of land-use

The land-use of the whole of the Upper Birrimian area round Enchi can conveniently be described together. It includes two major soil associations, the Yakasi-Shi association on the higher parts and the Yakasi association on the lower. In addition, minor areas of the Yoyo and Pepri associations occur over small granite patches found scattered among Upper Birrimian rocks, while in the south-east of the area a small area of mixed Upper and Lower Birrimian soils has been demarcated.

The total area of this Upper Birrimian area is 460 square miles, of which 250 square miles are under forest reserves. Only a relatively small percentage of the remainder has yet been cultivated, and most of this is in the Enchi-Yakasi-Yankomam area. An indication of the extent of present cocoa cultivation is given in Fig. 23 which shows cocoa farms surveyed by the Division of Agriculture up to early 1957: it is not complete as some farms south of the main road had not yet been surveyed. About 6,000 acres had been surveyed within the Enchi area of the basin in which total Cocoa Marketing Board purchases in 1955–6 (Part I, page 49) were of the order of 550 tons, so that, allowing for a few farms south of the river not yet surveyed, average yields per acre may be estimated to be about two to three 60lb. loads. The map indicates that in the Enchi area cocoa farms are fairly extensive but that most of the acreage is on the lower slope and bottom soils associated with the river Disue and its tributaries. Away from Enchi there are minor areas of cocoa at Donikrom, to the west, and along the footpath north through Tanokrom to Akwantambra in the Bia basin. The best cocoa seen in the area was at Tanokrom, on Shi series. That on lowland alluvial soils (Kakum, Kwaben and Birim series), along the Disue between Enchi and Yakasi for example, was moderately good. The least successful cocoa is on the general run of deep middle slope sedentary soils, particularly on the more acid ones (Yakasi and Disue series).

The distribution of food farming within the area is somewhat similar to that of cocoa except that it is a little more concentrated round the settlements than is cocoa. The main farming area is the Yakasi-Enchi–Yankomam-Jensui area, with scattered food farming at forest villages further away from Enchi. The most productive food farms seen were again on the high steep hill on which Tanokrom is situated (Shi series) but this village is 17 miles north of Enchi and too far from major settlements to be able to sell much food outside. In the Enchi area itself there is a shortage of plantains and these and other foodstuffs were imported from the Asankrangwa area and even from Ashanti. This is surprising in view of the ample areas of original forest within easy distance of Enchi still awaiting exploitation. The farmers in this area have neglected food farming to some extent and are content to rely on their cocoa for a cash income. Among the younger generation little interest in farming is shown and farming standards here seem among the lowest in the basin. Little rice is grown, despite the presence of suitable lowland soils. Cassava is the staple food, and some local plantain is produced, though most is imported. Within the area, Jensui and Yankomam send food supplies to Enchi.

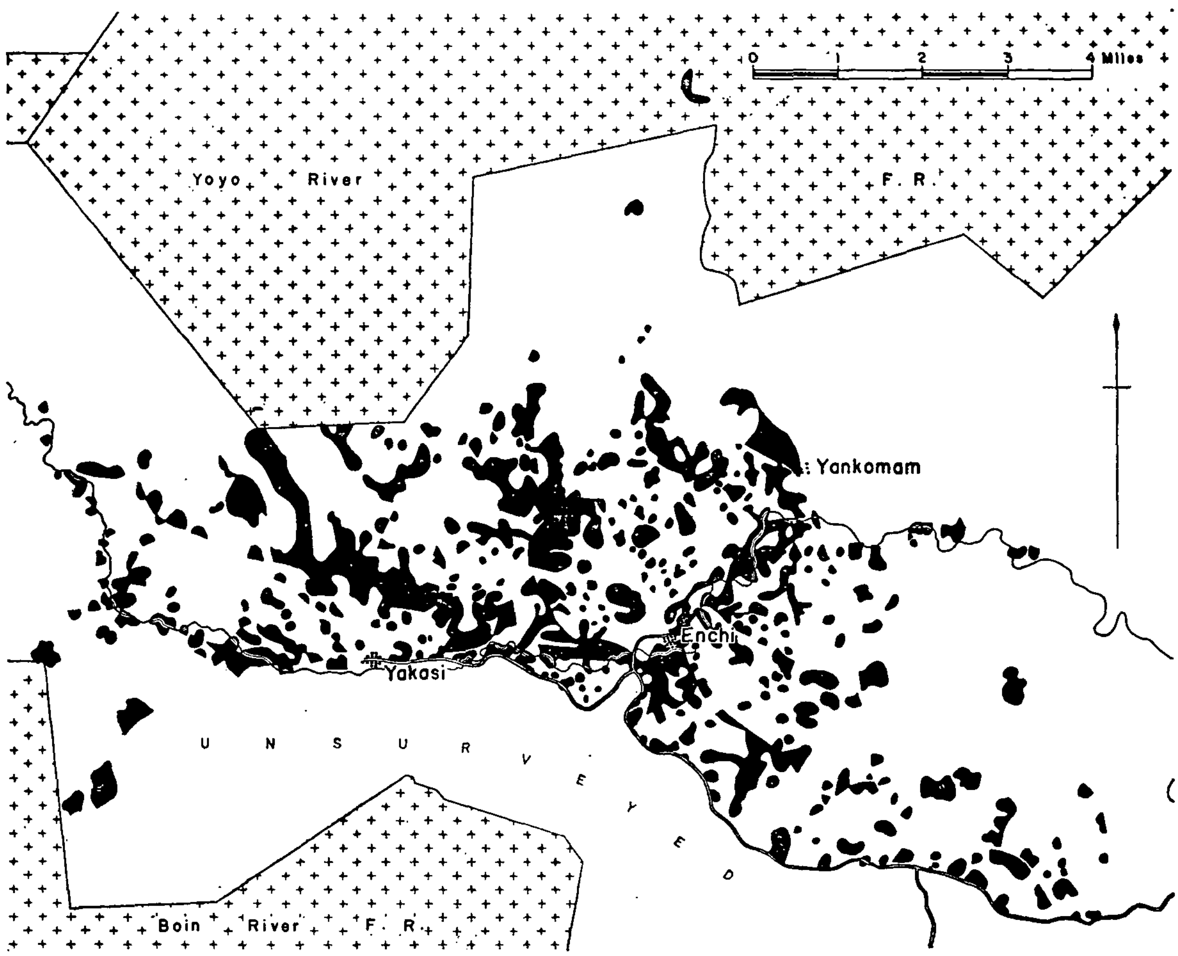


Fig. 23. Distribution of cocoa farms in the Enchi area. (Based on field sheets of the Cocoa Survey Branch.)

Future land-use

This is an area which has considerable agricultural possibilities, though it is little developed as yet. The soils are somewhat mixed and about half of them are oxysols which are less fertile than the remaining ochrosols, but within the area are a number of soils capable of supporting good cocoa for considerable periods.

Of the upland sedentary soils, perhaps up to 10% can be classified as being very productive soils suitable for both cocoa and food crops. These are the relatively shallow soils over greenstone and epidiorite (Wiawso, Shi and Tanokrom series) usually found on the steep sides of the higher hills. Many of these suffer from inaccessibility since they are often well away from the lower central area of maximum settlement and many of them are in the forest reserves. The soils round the village of Tanokrom form an excellent example of such a steep upland area of fertile greenstone soils. Food crop yields are high and cocoa grows even on previously farmed sites.

Of the remaining upland soils, most are relatively deeply weathered soils of lower fertility. These can be divided into the ochrosols, on which cocoa will grow moderately well, and the oxysols on which cocoa will grow indifferently or fail. Food crops on the ochrosols will give good yields for three or four years after clearing, whereas on the oxysols yields will fall off very rapidly after the first year. Broadly speaking this extensive intermediate zone between the higher and most productive sedentary soils above and the fairly fertile alluvial valley soils of the valleys below is a zone where agriculture is relatively uncertain and likely to give lower returns than on the steep soils described above or on the alluvial soils.

The third category comprises the lowland alluvial soils which, if not as fertile as the limited first group, are far more accessible and extensive. The major series here are Kakum and Kwaben series, both of which support moderately good cocoa, and Birim series which is better drained but somewhat similar in agricultural potential. Rubber would do well on these soils. The grey bottom clay soils (Oda series) and sandy alluvial soils (Chichiwere series) are considerably less valuable, but the poor drainage of the clay soils makes them suitable for rice and chewing cane.

Considerable areas of well drained upland soils are also suitable for coffee, which could be grown on a large scale in this area.

Future development will probably take the form of a continuous expansion along the better bottom soils, both for food crops and cocoa, with a corresponding but perhaps later development of associated upland soils. Occasional areas of fertile soils in group one are worth developing even if far from the lorry road, but for the general run of soils accessibility will be the main factor influencing future agriculture. This is an area, however, capable of supporting a larger population than it does, and without this extra population it cannot be fully developed.

2D. THE SEFWI ASSOCIATION

This is a very minor association found only locally on sloping sites on the eastern flanks of the Bibiani range where it occupies about 3 square miles. The complicated geology of this range includes numerous rocks which have been altered by heat and pressure, including a band of altered sands. It is on this arenaceous belt where the parent rock consists of sandstones, quartzites, quartzitic greywackes and sandy conglomerates that the Sefwi association has developed. This association consists of only two series as there are no associated valley bottom soils.

Soils

Sefwi series

This is a shallow sedentary soil distinguished by frequent pieces of gritty or sandy parent rock contained in the profile. A thin dark brown humous sandy light clay topsoil overlies an orange-brown sandy clay subsoil containing concretions and small pieces of partly weathered sandstones, sandy quartzite, quartzitic greywacke or similar rock. Between 3 and 4 feet (rarely more) this merges into a weathered substratum containing frequent boulders and patches of gritty or sandy friable decomposing rock. This soil is usually fairly acid in the topsoil, being an oxysol or oxysol-ochrosol intergrade. It is found only on the flanks of the Bibiani range where the gradient is quite steep. The soil is infertile and relatively inaccessible.

Ankasa series

Ankasa series is a yellow-brown sandy colluvial soil, found below Sefwi series. This is the normal colluvial soil of acid granite areas and is described below, page 105.

Vegetation and land-use

This association is found along the boundary of the Suraw forest reserve. Some of it is within the reserve and some below and just outside it. Vegetation is forest of the *Celtis-Triplochiton* type. Little, if any, of this soil association has ever been cultivated, nor, because of its infertility and the steep gradient, would it be worth cultivating in the future. It should undoubtedly be left as at present, with a covering of forest to protect it.

SOILS DEVELOPED OVER GRANITES (GROUP 3)

Nearly all granite soils have sand or grit in them, and many also contain mica flakes, so that they are usually fairly easy to recognise in the field. Very often granite soils are less deeply weathered than soils over Birrimian formations and pieces of the parent rock can be found near the surface. In certain localities massive granite is quarried out for road metal.

Soils developed over granite form the same general pattern as those over other rocks in the forest zone: gravelly sedentary soils are found on the summits, slope-wash clays occur on the lower slopes, and various alluvial soils occupy the valley bottoms. The product of the weathering of granite is a clay matrix containing grit, sand and mica.

The upland granite sedentary soils contain fewer ironstone concretions than corresponding soils developed over phyllite, and seem to be proportionately less extensive in area, so that a greater percentage of the association is covered with gritty slope-wash clays without gravel. The lower slope and valley bottom soils are usually either sands or gritty clays, though non-gritty levee deposits are also found, due to the power of the streams to separate fine particles from coarse.

The topography of granite areas is quite distinct, consisting not of long steep slopes, as in some of the Birrimian areas, but of a regular succession of rounded rolling hills, sometimes quite steep though not very high. Any traverse cut through such an area is all slopes, with little or no flat ground either in the valley bottoms or on the hill tops. The stream pattern is close and regular.

Most of the granite within the basin is a medium-grained biotite granite, very pale in colour but flecked with the small dark spots of biotite (black mica). In Upper Birrimian areas, granite intrusions with little or no visible mica are found, whereas other minor areas are coarse-grained and give rise to distinctive soils containing large quantities of coarse quartz grit. In addition, in marginal granite areas, the soil parent rock is biotite schist, which is transitional between the granites and the surrounding phyllites. Granite soils within the basin therefore fall into the following four groups, of which the first is by far the most important and the last two are very minor:

(*a*) *Soils developed over biotite granites of the Cape Coast type*

Soils of this type form the Ankasa association and constitute about 80 per cent of the total area of 384 square miles of granite soils within the basin, being found mainly in the principal granite area of the Ankasa river forest reserve. These are highly acid sandy clay soils in which concretions are relatively rare. The principal sedentary soil is Abenia series, but Ankasa series, an acid colluvial soil, is far more extensive. Sands and gritty clays are found in the valley bottoms. All the soils of this association, except Kwaben series, are highly leached and infertile.

(*b*) *Soils developed over biotite schist*

Sedentary soils developed over biotite schist lack the grit and sand of normal granite soils, but contain mica in the weathered substratum. They are less extensive and with their associated lower-slope soils account for about 15 per cent of the granite soils within the basin. The normal sedentary ochrosol is Nsaba series, a yellow to orange-brown silty, micaceous and moderately concretionary soil going down to easily recognised purplish biotite schist, and this is associated with Akroso series, a sandy colluvial clay. Areas of these soils have been mapped as the Nsaba association. The oxysol equivalents of Nsaba and Akroso series, found in the south of the basin, are Ninisu and Ankasa series.

(*c*) *Soils over fine-grained non-micaceous granites*

Fine-grained non-micaceous granites form scattered but usually small intrusions in the Upper Birrimian hills. Small patches of these soils have been mapped in the northern part of the Bibiani range and to the north of Enchi. These areas mapped have a total area of only 9 square miles, though other very minor areas also occur. Soils developed over these granites form the Adujansu and the Yoyo associations.

(d) Soils over coarse grained non-micaceous granites

Soils developed over very coarse-grained granites are relatively extensive in the Upper Tano and Bia basins to the north but only some 6 square miles of the Pepri association developed over this parent material occur in the Lower Tano Basin.

Non-granite soils within granite associations

Large streams, such as the Tano, which pass through granite areas build up on their banks alluvial deposits which have their origin elsewhere. In the central granite areas of the basin, Kwaben series, developed in Tano alluvium, is quite distinct from and superior to the soils derived from local granites. These riverside soils, easily accessible by canoe, form the best soils in an otherwise poor area.

3A. THE ANKASA ASSOCIATION

This association includes Ankasa series and related soils developed over medium-grained biotite and biotite-muscovite granite and a very minor admixture, particularly near the margins, of soils of Ninisu series developed over biotite schist (Fig. 24). The association occupies 330 square miles in the narrow south-central part of the basin, mostly within and immediately to the north of the Ankasa River forest reserve.

The relief of this area is rolling, consisting of numerous fairly steep rounded hills rising to about 500 feet above sea level in the east and somewhat less in the west as the ground descends gradually towards the Tano. The area is dissected by a regular and complicated pattern of streams whose valleys are 100–200 feet below the adjacent summits.

The rainfall is heavy, averaging between 70 and 80 inches per year. As a result the soils are somewhat pale-coloured i.e. yellow-brown to orange-brown on the uplands, with red soils almost completely absent, and are leached and therefore acid in reaction. The natural vegetation is forest of the evergreen rain forest type.

By far the most extensive soil in the association is Ankasa series, a gritty non-gravelly clay, which occupies most of the slopes. Very little of this association has yet been used for agriculture and what farming there is suggests that this is an area of very limited agricultural possibilities as regards at least the normal food crops of the forest zone, though oil palm and rubber have possibilities.

Soils

Abenia series

Abenia series is the usual sedentary soil of high rainfall granite areas, consisting of a yellow-brown to orange-brown gritty or sandy clay. It has, however, far less gravel in the profile than the normal sedentary soils of other associations within the basin and is not so extensive, proportionately, as these are. It merges on the one hand into skeletal soils, which are not common, and on the other into the very extensive associated gritty colluvial clay, Ankasa series.

A pale grey-brown light clay topsoil overlies a slightly gritty or sandy, light yellowish brown to pale orange-brown, light clay subsoil containing occasional quartz gravel and stones and only rare ironstone concretions. Mica flakes are usually present. This subsoil merges into a decomposing granite substratum at an average depth of 4–5 feet.

Drainage is only moderate and under the very heavy rainfall of this association the soil remains moist throughout the year. This series has been little cultivated as yet. It is highly acid, topsoil pH values of 4·6 and below being common. The nutrient status is very low, particularly in exchangeable bases, and the humous topsoil is thin. This series cannot support economic cocoa and yields of food crops are not encouraging.

Ninisu series

Ninisu series is a non-gritty sedentary soil developed over biotite schist. Biotite schist is found

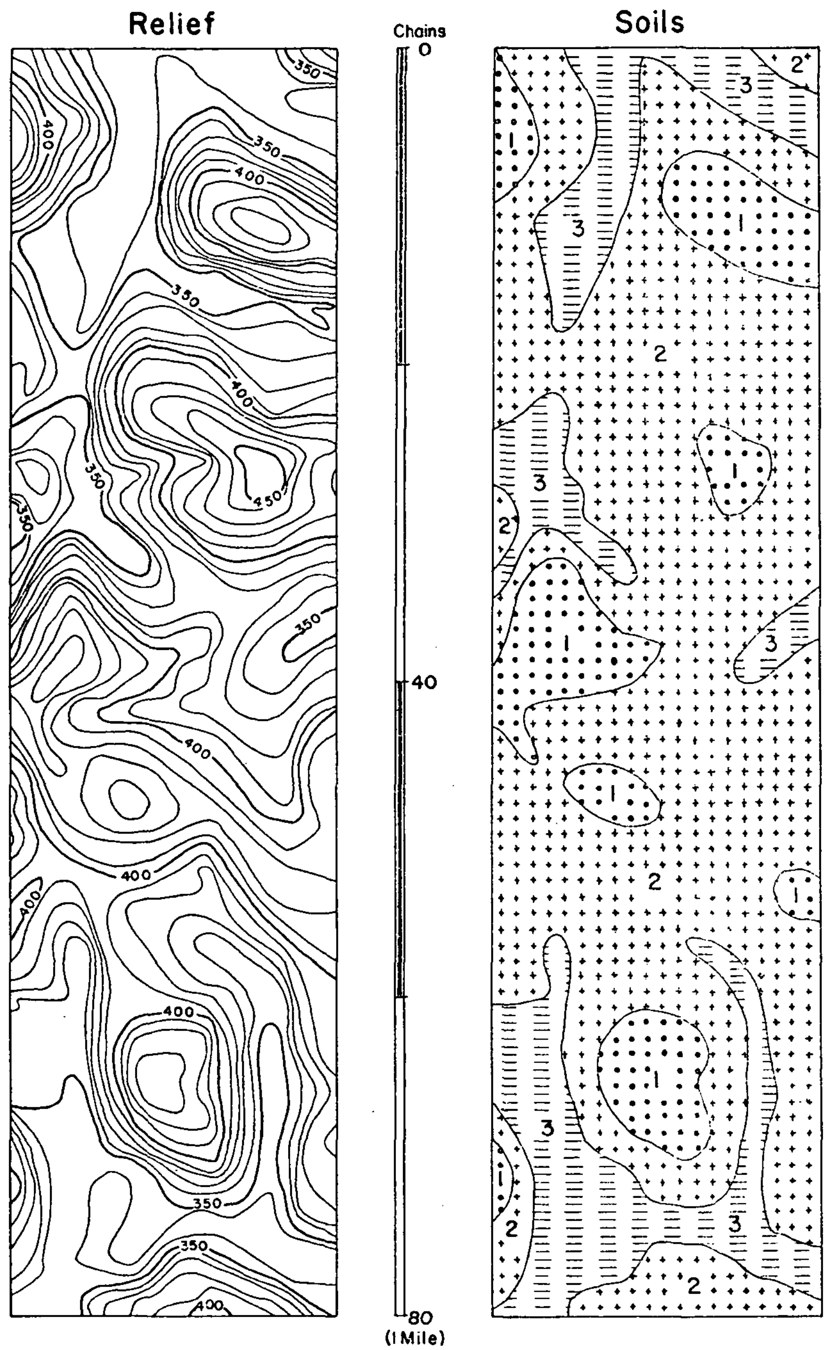


Fig. 25. The Ankasa association: relief and soil maps for Sample strip 8 on the Samreboi-Prestia road. Contour heights are in feet.

1. Abenia series.
2. Ankasa series, with minor areas of Adiembra series on the steeper slopes.
3. Lower slope and valley bottom soils: mostly Firam series with some Nta, Kwaben and Chichiwere series.

usually at or near the margins of granite areas, but is sometimes intimately mixed with biotite granite. When weathered, the parent rock is recognised by its purplish colour and the absence of grit.

A thin greyish brown humous topsoil overlies a yellow-brown to orange-brown light silty clay subsoil containing only a relatively small amount of ironstone concretions and quartz gravel. This merges at varying depths into a weathered substratum containing frequent traces and partly-weathered soft lumps of purplish, non-gritty, friable, biotite schist.

Drainage is slightly better than in Abenia series, and the soil remains moist throughout the year. Natural fertility is low, being similar to Abenia series, except for shallow examples which are somewhat more fertile.

Adiembra series

Adiembra series is an inextensive immature soil developed on very steep slopes, consisting of a thin humous topsoil directly overlying the gritty loam of the weathered granite substratum.

Ankasa series

Ankasa series is a gritty, or at least sandy, yellow light clay, and forms the most extensive series in the association. It is partly colluvial and is found even on some upper-slope and summit sites where a normal concretionary sedentary soil would be expected. It merges into upland sedentary soils (Abenia, Ninisu and Adiembra series) on the one hand and into valley bottom alluvial soils on the other.

A thin greyish brown, humous topsoil overlies a subsoil of fairly uniform, gritty or sandy, yellow-brown light clay, usually 3–4 feet thick, which merges into a substratum of decomposing granite. The transition between subsoil and substratum is occasionally marked by a slight stone-line. External drainage is good because of the normal sloping site, but internal drainage is rather slow, and the soil remains moist through the dry season.

Ankasa series is highly acid and strongly leached, so that its nutrient reserves are very low indeed. It is the poorest major soil in the basin and has limited agricultural possibilities. Cocoa fails on this series very soon after planting, and food crop yields, even on newly cleared ground, are poor. Rubber and oil palm, tolerant of poor acid soils and high rainfalls, are probably the best crops for this series.

Nta series

Nta series is a sandy lower-slope associate of Ankasa series. A thin, greyish brown, humous topsoil overlies 2–3 feet of pale yellow to pale yellowish brown sand or loamy sand. This overlies weathered granite material below. This soil is found on lower slopes between Ankasa series and sands and clays (Ofin and Firam series) of the valley bottoms, but is relatively inextensive. Drainage is very free. The soil is loose and easy to cultivate, but is relatively poor in nutrients and has a low agricultural value. It is best suited to pineapples, cassava and coconut palms.

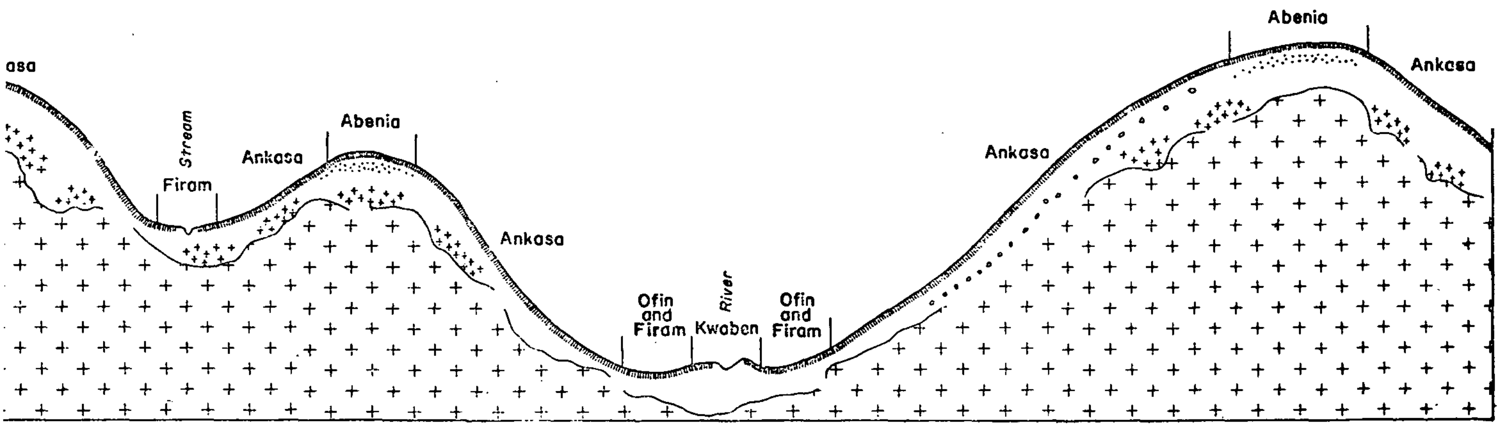


Fig. 24. The Ankasa association.

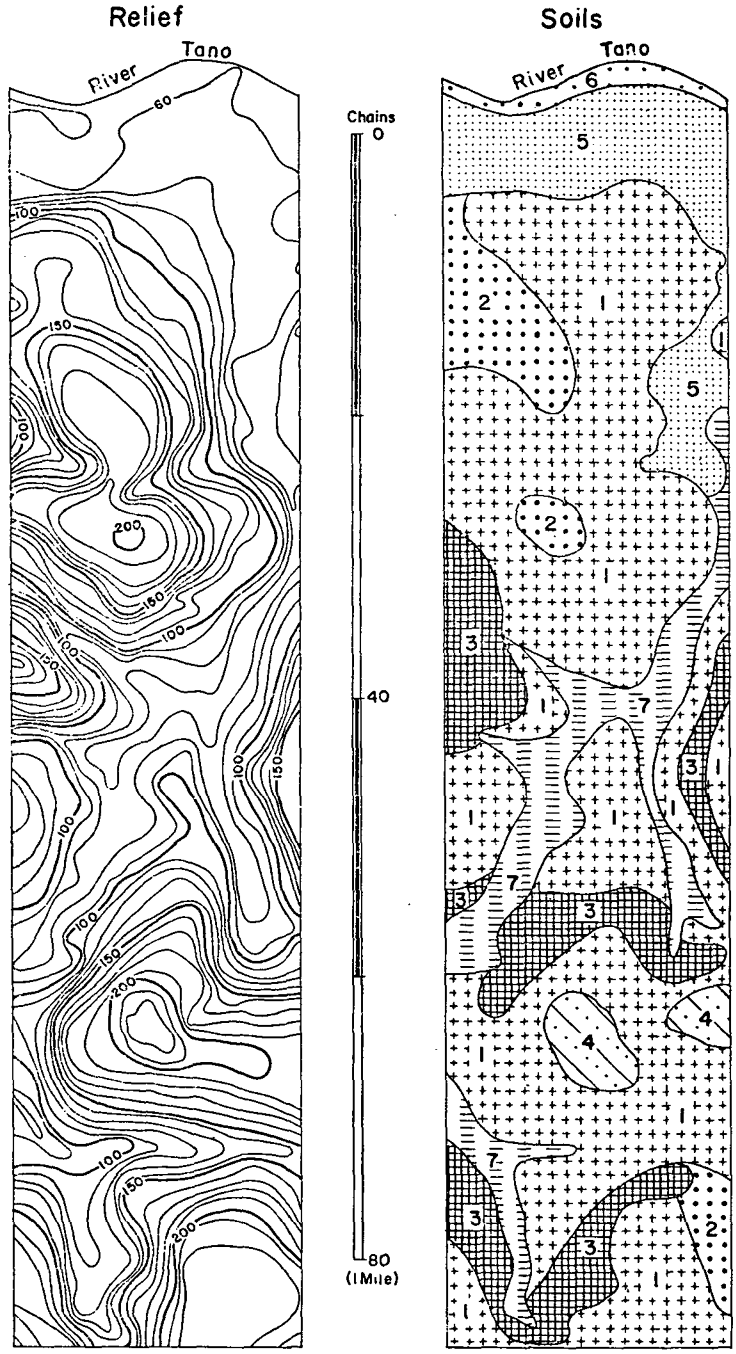


Fig. 26. The Ankasa association: relief and soil maps of Sample strip 9 at Abenia, on the Tano. Contour heights are in feet.

1. Ankasa series.
2. Abenia series.
3. Adiembra series.
4. Ninisu series.
5. Kwaben series.
6. Chichiwere series.
7. Lower-slope and alluvial soils too mixed to be mapped on this scale: Firam, Nta, Ofin and Kwaben series.

Ofin series

Ofin series is a sandy soil somewhat similar to Nta series except that it is found in poorly drained valley-bottom sites and is consequently paler in colour. A thin, greyish brown, slightly humous topsoil overlies a pale grey to greyish white or off-white sand or loamy sand. A stone-line or occasional gravel beds may be present, separating the subsoil from weathered rock below.

This soil is extremely poor in nutrients, being almost sterile, and has the further disadvantage that it is liable to flooding in wet periods but dries out rapidly at other times. As a result it is of little value to the farmer. It often provides sand for the making of concrete blocks.

Firam series

Firam series is an acid, grey, gritty clay of poorly drained valley bottoms. A dark greyish brown humous topsoil overlies 2–3 feet or more of grey gritty clay, which merges below this into weathered rock. The subsoil may contain gravel beds. This soil is very poorly drained, becoming waterlogged during heavy rains and remaining moist throughout the year. The humous topsoil is sometimes quite well developed and base exchange capacity is higher than most soils in the complex, but nutrient reserves are low. The soil is suited to crops, such as rice and chewing cane, requiring damp conditions.

Kwaben series

Kwaben series is the yellow-brown alluvial light-clay soil of levees found throughout the basin. It is the most fertile soil in the association, being the only series within it capable of supporting economic cocoa. It is described above (page 77). Unfortunately it is of very limited extent in this association. Small areas of it are found associated with minor streams and rivers, while a narrow band of this series occurs along the banks of the Tano where it has the advantage of being accessible by canoe.

Detailed sample strips on the association

Three sample strips were recorded on this association, on the Samreboi–Prestea road, near its northern boundary, at Abenia, on the Tano and in the centre of the association, and near Bou, in the extreme south of the association.

Sample strip 8 (Fig. 25), on the Samreboi–Prestea road, includes an area of the typically strongly rolling dissected topography associated with this association. Numerous steep-sided small hills rise to a common summit level at 440–450 feet above sea level. These are separated by a close network of valleys some 100 feet lower. On the flattish hill summits relatively small areas of only slightly gravelly Abenia series were recorded, but most of the upland areas were covered by the non-gravelly yellow-brown sandy or gritty clays of Ankasa series, which forms by far the most extensive soil in the area. On some sites this is shallow and grades into Adiembra series, in which soft decomposed granite occurs a little below the topsoil. Valley bottom soils are mostly gritty grey clays or loams.

Almost the whole of this strip was under the original forest, disturbed only by timber extraction, in which the commonest large tree was *Tarrietia utilis*. At the time of the survey there was little or no cultivation in any of the adjoining areas of the association. A more detailed report on this strip is included in a report on the Samreboi area (Ahn, 1955*d*).

Sample strip 9 (Fig. 26) at the small village of Abenia on the Tano includes hilly areas similar to, but lower than, that of Strip 8. The hills here rise to a common summit level 200–220 feet above sea level with valleys up to 150 feet below this. The Tano itself is there about 50 feet above sea level. As in Sample strip 8, the valley slopes are often very steep. The soil pattern on the uplands closely resembles that of Strip 8, though Adiembra series is relatively a little more extensive. The average topsoil pH of upland soils on the strip is about 4·7. Where the strip joins the Tano there is a band, 200 yards across, of alluvial soils (Kwaben series) which extends inland up some of the valleys.

The land-use on the strip and on adjoining riverside areas shows clearly the relative fertility of the Tano alluvium as compared with the very poor upland soils. Cocoa on the strip and outside it is confined to these river-bank soils. Of the upland areas, about one-third of the strip behind the alluvial soils is, except for a small cassava patch on Ankasa series, now under regrowth thicket or forest: a little abandoned and dying cocoa can be seen amid some of this thicket. The remaining two-thirds of the strip is under original forest. Outside the strip the Tano alluvium was seen to support cocoa and

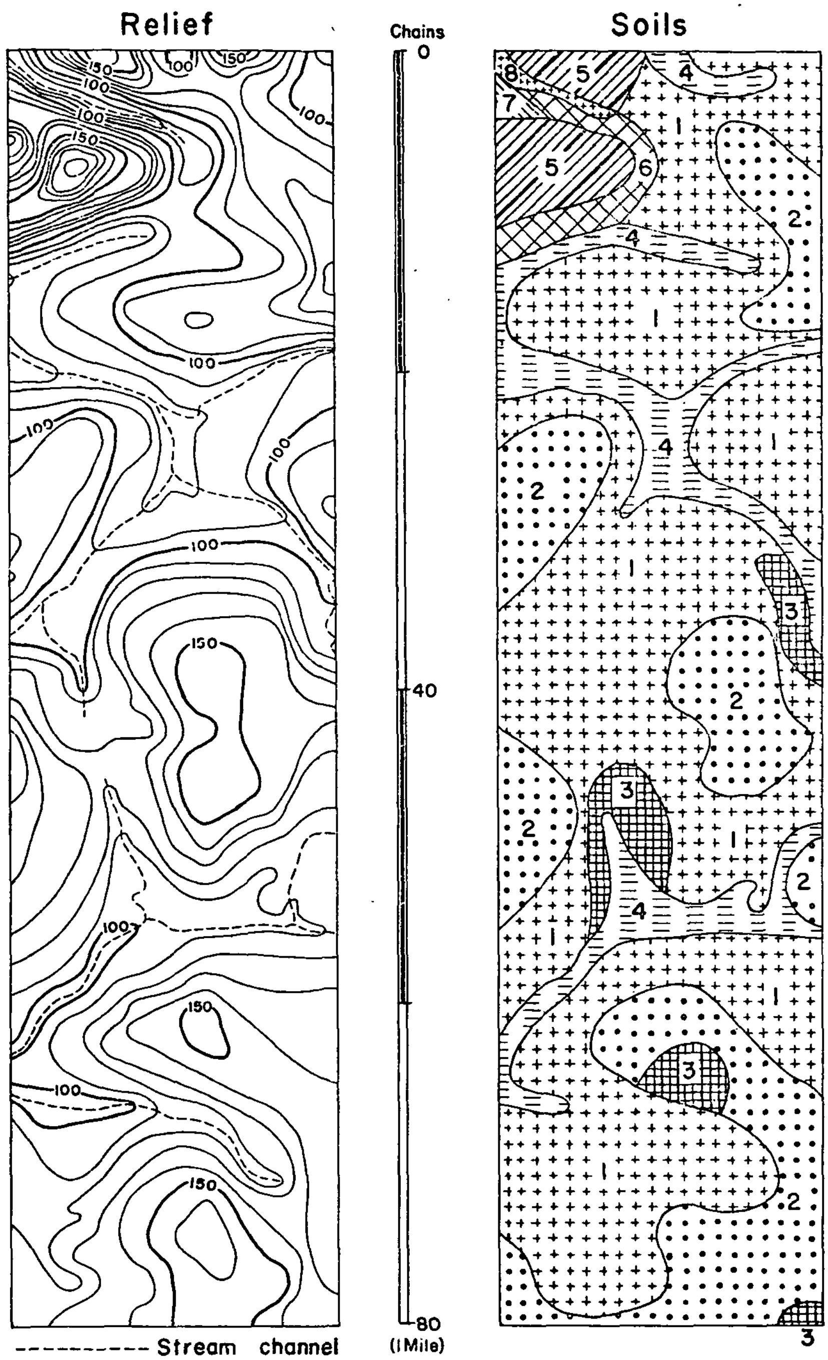


Fig. 27. The Ankasa association: relief and soil maps of Sample strip 14, 3 miles north of Bou, in Nzima. Contour heights are in feet.

Soils of the Ankasa association

1. Ankasa series.
2. Abenia series.
3. Adiembra series.
4. Lower-slope and alluvial soils, principally Firam series with some Nta, Ofin, Chichiwere, and Kwaben series.

Soils of the Boi association

5. Boi series.
6. Ebowu series.
7. Bremang series.
8. Oda series.

a range of food crops: on the remaining soils only cassava was successful. The village of Abenia forms the subject of a separate report (Ahn, 1955*e*).

Sample strip 14 (Fig. 27), 3 miles north of Bou in Nzima, is interesting because the rolling relief of the granite areas of over nine-tenths of the strip contrasts very markedly with the extremely steep gradients of the north-west corner where the soils are developed over phyllite. The distribution of the granite soils is very similar to that recorded for Strips 8 and 9: Ankasa series is again by far the most extensive series. Topsoil pH values of 126 chisel holes sampled averaged 4·6–4·8.

Two-thirds of the strip are either still under original forest or under secondary thicket or forest vegetation, four to twelve years old, in which a few abandoned cocoa trees were found. The southern third of the strip was under cultivation at the time of the survey (1956). This included some cocoa, mostly 12–15 years old, yielding very poorly indeed, with some younger cocoa 4–5 years old, apparently healthy. Food farms near the hamlet on the strip included a large variety of crops and vegetables, and coconuts were being planted.

Vegetation

This association falls entirely within the southern evergreen rain forest area where *Tarrietia*, *Cynometra* and *Lophira* are common. Of these, *Tarrietia* (Nyankom); is a valuable timber tree, very plentiful in the north of this association. *Celtis* and *Triplochiton*, so common further north, are entirely absent from the rain forest, which is described further in Part I, pages 15–16 and Part III, pages 239–240.

Over half of the association is under reserved forest, but even outside the reserves there has been very little clearing or cultivation.

Land-use

The present pattern of land-use

This association is, as yet, virtually unused for agriculture. Part of the road from Samreboi to Prestea passes through the north-east corner of the association, but apart from a few temporary patches of clearing to provide food crops, mostly cassava, for timber workers there has been no farming in this section. The failure of farmers to move in along timber roads in this area is in strong contrast to timber areas in Ashanti, for example, where farmers are quick to make use of timber tracks and often even precede the timber cutters, and indicates that local farmers are well aware of the poor agricultural possibilities of these soils and the low food crop yield they give.

There is also a very limited amount of farming associated with a few very small villages along the Tano, of which Abenia is the largest. Moderately good cocoa and food crop yields are obtained here from a narrow belt of Kwaben series along the river, but immediately behind this on the acid sedentary soils of the complex cocoa has failed and of the food crops only cassava gives satisfactory returns.

A minor patch of this complex appears well to the south of the main area, in Nzima, north of the village of Ebowu. Some of this has been cultivated. Cocoa on Abenia and Ankasa series, though it appears healthy, gives little or no yield. Cassava and pineapples are the most successful food crops.

Future land-use

It is very unlikely that the forests of this association will be cleared for agriculture while there are still major areas of potentially more productive unused forest soils in other parts of Ghana. What little cultivation has already taken place has not encouraged farmers to come in, despite the presence of timber roads. The leached and acid soils of the complex are unsuited to cocoa and food crops yields are low.

The crops best suited to this association are oil palm and rubber, with rice in the poorly drained areas. Liberica coffee might also be tried, together with citrus and pineapples. Apart from very minor areas in Nzima, all the unreserved areas of the association are to the north and north-west of the Ankasa River forest reserve. Of these areas, the north-eastern part is served by the Samreboi-Prestea timber road but the rest is, as yet, very inaccessible and the population is so thin as to be almost negligible. It is very doubtful if there will be any increase in population or farming for many years to come.

3B. THE NSABA ASSOCIATION

This association is developed in Lower Birrimian and granite areas where the soil parent material is biotite schist, an altered rock transitional between phyllite and granite. One area of 7 square miles has been mapped south of Sefwi-Bekwai. Other minor areas probably occur. Those patches of biotite schist further south, south of Asankrangwa, usually give rise to the oxysol equivalents of the soils contained in this association, i.e. to Ninisu, Ankasa and Kwaben series, and are included within the Ankasa and Ninisu associations.

Soils

Soils of the Nsaba association have characteristics between those of soils developed over phyllite and those over granite. They contain mica but are non-gritty. Within the basin, red soils are usually absent.

Nsaba series

Nsaba series is a yellow-brown to orange-brown, silty, micaceous sedentary soil of middle and upper slopes and summits. A thin, greyish brown, humous light clay to loam topsoil overlies a moderately gravelly, slightly micaceous, yellow-brown to orange-brown silty light clay subsoil which contains moderate amounts of ironstone concretions and a little quartz gravel. This extends for 4–7 feet before merging into a loam containing traces of weathered, friable, purplish biotite schist.

This series is usually well drained, and is fairly retentive of moisture in the dry season. Examples with topsoil pH values about 6·0 are generally productive soils, suited to cocoa and a wide range of food crop, but most of the examples within the basin have topsoil pH values between 5·5 and 6·0, or are Nsaba-Ninisu intergrades with topsoils of 5·0 to 5·5, with consequently reduced amounts of bases and lower agricultural value.

Akroso series

Akroso series is the normal sandy light clay colluvial soil associated with granite ochrosols. It is found in granite areas in the north of the basin but further south it is replaced by Ankasa series, its oxysol equivalent.

A thin, dark greyish brown, humous and often sandy light clay to loam topsoil overlies a yellow brown, fairly uniform, sandy or gritty light clay subsoil, usually 4–5 feet thick. A stone-line may be present between this sobsoil and the non-transported loam of mottled weathered granite with which it merges below.

Drainage of this series is moderately good in the upper layers, and moisture retention during dry periods is usually satisfactory. This soil is not as extensive as the upland sedentary soils with which it is associated. It is less fertile than Nsaba series, but the less acid examples are moderately productive and will support cocoa. Within the association Akroso-Ankasa intergrades, with a topsoil pH range of 5·0–5·5, are quite common. This series is often associated with Nta series, a yellow sandy soil described above, page 105, which is usually found lower down the slope.

Alluvial soils

The alluvial soils of the association are *Ofin*, *Firam* and *Kakum series,* described elsewhere (pages 107 and 62).

Vegetation and land-use

The vegetation and land-use of areas of this association are similar to those of surrounding phyllite areas. In planning land-use there is little need to distinguish between minor areas of this association and the Nzima association. The vegetation and land-use of the major area of this association immediately south of Sefwi-Bekwai are discussed under the Nzima association above (pages 59–65).

3C. THE NINISU ASSOCIATION

This association is found a little to the north of the main granite area of the Ankasa-Firam association, and occupies about 27 square miles. It is not well defined and consists of a mixture of soils developed over biotite schist with soils of the surrounding association developed over phyllite.

Soils

The upland soil is Ninisu series described above (page 103) which is associated with Ankasa series (page 105) on the lower slopes. Alluvial soils are the same as in the Nzima-Boi association. The patches of Ninisu association mapped are merely scattered northward extensions of the partly granitised biotite schist areas common within the Ankasa association.

Vegetation and land-use

The vegetation and land-use of these minor areas do not differ from those of the Nzima-Boi association described above (pages 70–74).

3D & 3E. THE ADUJANSO AND YOYO ASSOCIATIONS

These associations are found developed over minor areas of medium to fine-grained non-micaceous granite which occur, usually in small patches, in Upper Birrimian areas. The relief of these areas is usually fairly steep and rolling, and the rainfall is about 65 inches, becoming a little more in the south of the Upper Birrimian area. Only three areas of these soils have been marked on the map but other minor areas occur within areas of Upper Birrimian geology.

Soils

The Adujansu association is the ochrosol association, whereas the Yoyo association is its acid (oxysol) equivalent. Those patches occurring in the Bibiani range are usually either ochrosols or ochrosol-oxysol intergrades, while those in the Enchi area to the south are oxysols.

Adujansu series

Adujansu series is a pale reddish brown ochrosol developed over fine-grained non-micaceous granite. A thin dark greyish brown sandy light clay to loam topsoil overlies a subsoil, 3–5 or more feet thick, of reddish brown fine sandy clay with varying but usually small amounts of ironstone concretions and quartz gravel, and occasionally with some quartz grit. This merges into a loam of decomposing granite in which there are frequent traces of the weathered parent material. This series is distinguished from many other granite soils by the apparent lack of included mica.

Adujansu series is fairly well drained, loose and light-textured, but may dry out in the dry season if exposed. In the Upper Tano Basin where near-neutral examples are found this soil can support economic cocoa, but within the Lower Tano Basin most examples of this series have a topsoil pH of 5·0 to 6·0 so that they fall within the lower range of ochrosols, or are ochrosol-oxysol intergrades of very moderate productivity.

Bechem series

Bechem series is the paler less well drained lower associate of Adujansu series from which it differs mainly in its yellow-brown to orange-brown subsoil. Within the basin, this series is more extensive than Adujansu series.

Yoyo series

Yoyo series is the oxysol equivalent of Bechem series, with a topsoil pH below 5·0. In acid areas red soils are uncommon so that Yoyo is the usual upland soil, though a redder soil, the acid equivalent of Adujansu series, may occur rather rarely: this is Santomang series. Profile morphology is the same as that of Bechem, the only difference being one of reaction. This is a leached soil, poor in bases, and of low agricultural value.

Colluvial and alluvial soils

The remaining soils of the catena are the same as those of the Ankasa association (*Ankasa, Nta, Ofin,* *Firam* and *Kwaben series*) described above, pages 105–107.

Vegetation and land-use

These associations form minor and, as yet, generally uncultivated patches in Upper Birrimian areas. Vegetation and land-use of these areas are described under the Atukrom and Yakasi associations, pages 91–92 and 99–101 above.

3F. THE PEPRI ASSOCIATION

This association is fairly extensive in the Upper Tano Basin, but only one area of about 6 square miles occurs in the Lower Tano Basin. This is situated in the north, near the Tano, adjoining the boundary of the two basins. It occupies the lower parts of a hilly area, as yet unused for agriculture.

Soils

Sedentary soils of this association are distinguished by the frequent quartz gravel they contain. This is derived from the parent rock, a coarse-grained granite.

Kobo series

Kobo series is a deeply weathered orange-red well drained sedentary soil consisting of a thin greyish brown humous gritty light clay topsoil overlying a deep pale orange-red light clay subsoil, containing a moderate amount of concretions and very frequent to abundant coarse quartz gravel, which merges at about 4 feet into a gravelly loam of decomposing granite.

This soil absorbs water readily and is well drained, but it is very liable to dry out in dry periods, and for this reason it cannot support cocoa. Nutrient status is moderate to low, and the soil is easily eroded.

Pepri series

Pepri series is the paler, orange-brown, slightly less well drained lower associate of Kobo series. Morphology is similar except for the orange-brown subsoil. This soil is more extensive than Kobo series, but its agricultural value is very similar.

Colluvial and alluvial soils

The remaining soils of this association are similar to those of the Ankasa association, described on pages 105–107, above.

Vegetation and land-use

That part of the association within the basin has not yet been used for agriculture. Vegetation is forest of the *Celtis-Triplochiton* type.

SOILS DEVELOPED OVER TERTIARY SANDS (GROUP 4)

In the south-west of the basin the soil parent material is a deep sandy light clay deposit which overlies the Apollonian formations and overlaps small areas of the adjacent Lower Birrimian and granite rocks. These deposits are referred to in this report as the Tertiary sands. Their usual thickness is 25–50 feet or more, thinning out slightly at the edges, but remaining at about 30 feet thick over considerable areas. From the soil point of view the underlying rock is only of interest in as much as it affects drainage, for it is out of reach of nearly all roots. The drainage of the Tertiary sand deposits is itself very free, but this is accentuated when they are underlain, as they frequently are, by pale coarse sands beds of the Apollonian formations assumed to be of Cretaceous age. Where the underlying rock is granite, as at Aiyinasi Agricultural Station (Ahn, 1957) drainage is free only as far as the transition zone where the deposits merge with granite material. This may explain why a small proportion of soils developed over the Tertiary sands are indurated.

The Tikobo association developed over these Tertiary deposits is remarkable in many ways. The grey soils of the valley bottoms (Aiyinasi series) are very inextensive and nearly all the association consists of Tikobo series and Nuba subseries, which differ only in respect of the texture of the first 30 inches. In practice therefore, all the area except the valley bottoms is covered with soils of a single series and the catena effect, so common elsewhere, is in little evidence here. Secondly, these upland soils are uniform not only in expanse but also down the profile. Below the topsoil lies 20–30 feet or more of uniform sandy light clay to loam, with no obvious distinction between subsoil and weathered substratum.

The drainage of these deep uniform sandy soils is very rapid. Water soaks in so quickly at the surface that there is no run-off except during the usual very heavy downpours of May and June. This water quickly drains through the profile. Of the many deep pits dug in these sands no normal pit ever had any water in it, even after heavy rains. This rapid disposal of the heavy rainfall received in this area makes the effective rainfall from the plant point of view somewhat less than on heavier soils. 85 inches or more of rain per year washing through a sandy soil obviously causes extensive leaching with the result that there are only very small quantities of bases left in the soil, and the soil is therefore highly acid in reaction. Since the buffer capacity of a sandy soil is so low, however, the pH may change considerably under a relatively slight influence, for example a bone or snail shell locally raising the pH to a less acid level, and this lack of stability probably contributes to the fact that although Tertiary sand soils are among the most acid in the basin they also include a few examples with less acid topsoils.

The original topography of the area was probably somewhat flattish. Some flattish summits remain, but are now split up and dissected by deep and steep-sided valleys. The steep sides of these youthful valleys are due to the lack of surface run-off mentioned, so that water sinks straight into the ground but seeps out on the valley floors and cuts them back. Nevertheless there are relatively few streams, most of the minor valleys being quite dry during the major part of the year. This fact contributes to the correspondingly limited extent of grey alluvial soils. In a few sites which are particularly low-lying in relation to sea level drainage water may accumulate, and here a black peaty soil with a high organic matter content (Mpataba series) develops.

The only variations on the simple soil pattern described above occur when large quantities of pebbles or ferruginised sandstone fragments occur in the profile. Occasional beds of rounded stream-rolled pebbles occur in the original deposits. Fragments and even large boulders of ferruginised sandstone are also locally frequent, suggesting that an extensive sheet of this sandy ferruginous pan was broken up to leave remnants here and there. A further slight modification, the occasional induration of the subsoil, especially near the eastern edges of the area, has already been mentioned.

The whole of the Tertiary sand area has been mapped as the Tikobo association.

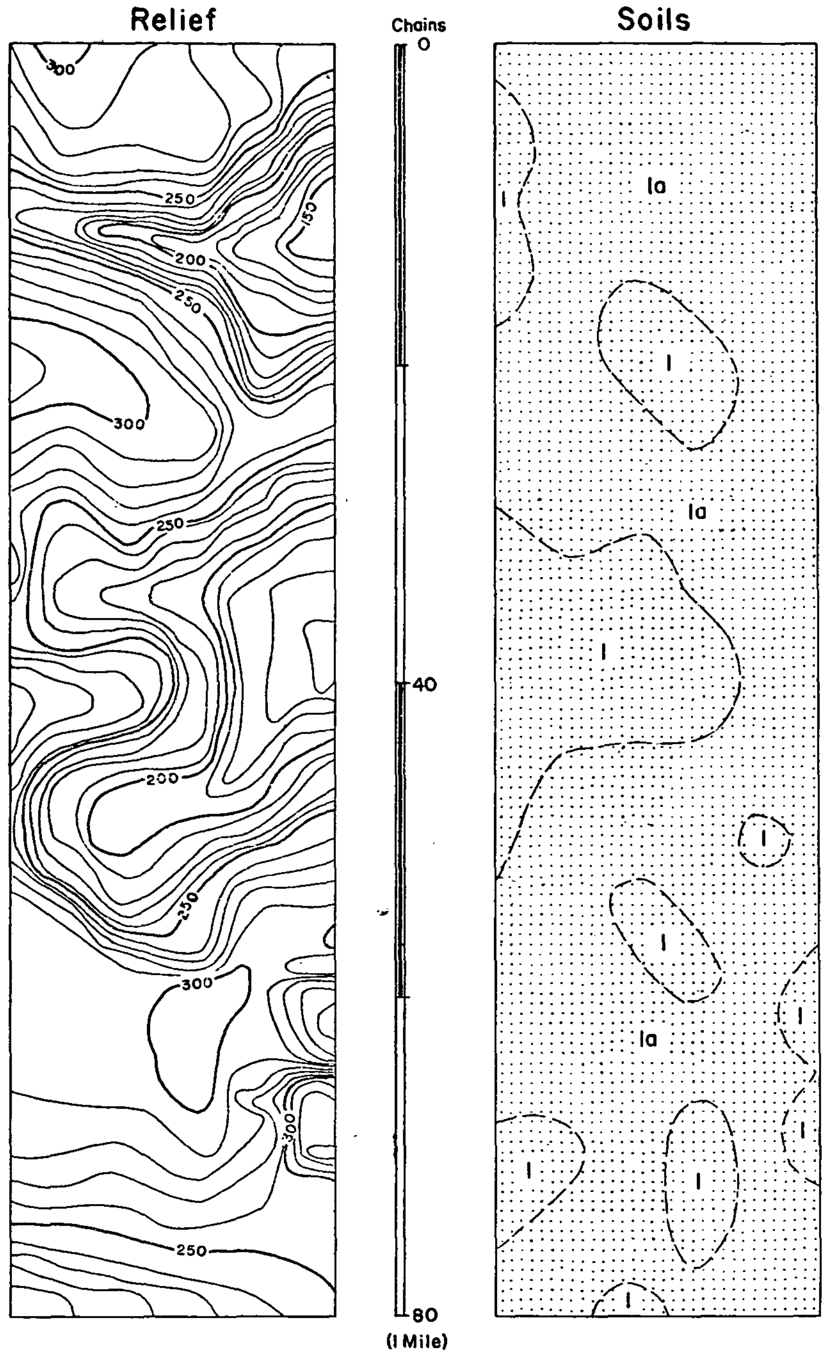


Fig. 28. The Tikobo association: relief and soil maps of Sample strip 13, north of Nuba. Contour heights are in feet.

1. Tikobo series.

1*a*. Nuba subseries.

4. THE TIKOBO ASSOCIATION

This association is developed over deep Tertiary sands (*see* preceding paragraphs) where the rainfall is 80–85 or more inches per annum. The association covers about 205 square miles, but a further 74 square miles of poorly drained and often waterlogged marshy areas between it and the sea can conveniently be considered here too. To the south, the association grades into somewhat similar sandy soils of the Fredericksburg association, described below, developed over more recent sands.

Soils

Tikobo series

Tikobo series is by far the most extensive soil of the association, and is found on all sites except valley bottoms. A thin pale greyish-brown humous sandy loam topsoil overlies a considerable depth of uniform non-gravelly yellow-brown to orange-brown sandy light clay which continues more or less unchanged for 25–30 feet or more except that beyond 5–6 feet the texture lightens to a loam.

This series is very well drained. Surface water is absorbed rapidly and passes quickly through the soil. The water-table is low and was not encountered even in a pit going down to 60 feet.

Tikobo series is light-textured and very easy to work. It has the further advantage of occurring in large uniform expanses, including areas of fairly flat upland topography. Because of its great depth, which allows ample root room, and its light texture and free drainage it is ideally suited physically to coconut and oil palms, crops which grow well on this series despite its low nutrient status due to the leaching effect of the heavy rainfall. The very loose texture of the surface horizons makes this series very suitable for groundnuts. For the remaining food crops, this series is somewhat less good: plantains and cocoyams do not do well; yields of maize, cassava and pineapples are only moderate.

Nuba subseries

Nuba subseries is a subseries of Tikobo, differing from it only in its lighter texture. Whereas a normal Tikobo series is loam in texture to about 15 inches, and then grades into light clay, Nuba series is loamy for 30 or more inches, sometimes throughout the profile. This makes the soil even lighter-textured than Tikobo series. In other respects the two soils are similar. Nuba subseries is found on all sites except valley bottoms, intimately mixed with Tikobo series. In certain areas it is locally more extensive than Tikobo series, but its total area is probably a little less than that of Tikobo series.

Aiyinasi series

Aiyinasi series is very inextensive compared with Tikobo and its subseries Nuba, being confined to relatively small areas in valley bottoms. It is a grey sandy alluvial soil developed in material derived from local upland soils.

A thin greyish-brown humous sandy loam topsoil overlies 2–4 feet, occasionally more, of brownish grey sand to sandy loam. This soil is only occasionally flooded, but the water table may be near the surface during the rainiest parts of the year, particularly in May and June.

This soil is light-textured and easy to work, but is as low as, or lower in nutrients than the associated upland soils. Its site suggests its use for small stream-side patches of chewing cane or small rice farms.

Mpataba series

Mpataba series occurs very irregularly, being confined to the very few areas of poor drainage within the association. It becomes commoner where the association joins the swampy areas round Lake Amansuri, and is frequently found in these swamps, often under a few feet of water.

Mpataba series consists simply of an accumulation of peaty organic matter, waterlogged for a considerable proportion of the year, overlying grey sand or clay. The organic matter varies in thickness between a few inches to well over a foot.

This series would have to be drained before it could be used, but the organic matter, as in all peat soils, would then dry up and shrink, leaving little more than the grey leached and acid layer below.

These swampy areas have little agricultural use at the moment, though marginal areas suggest

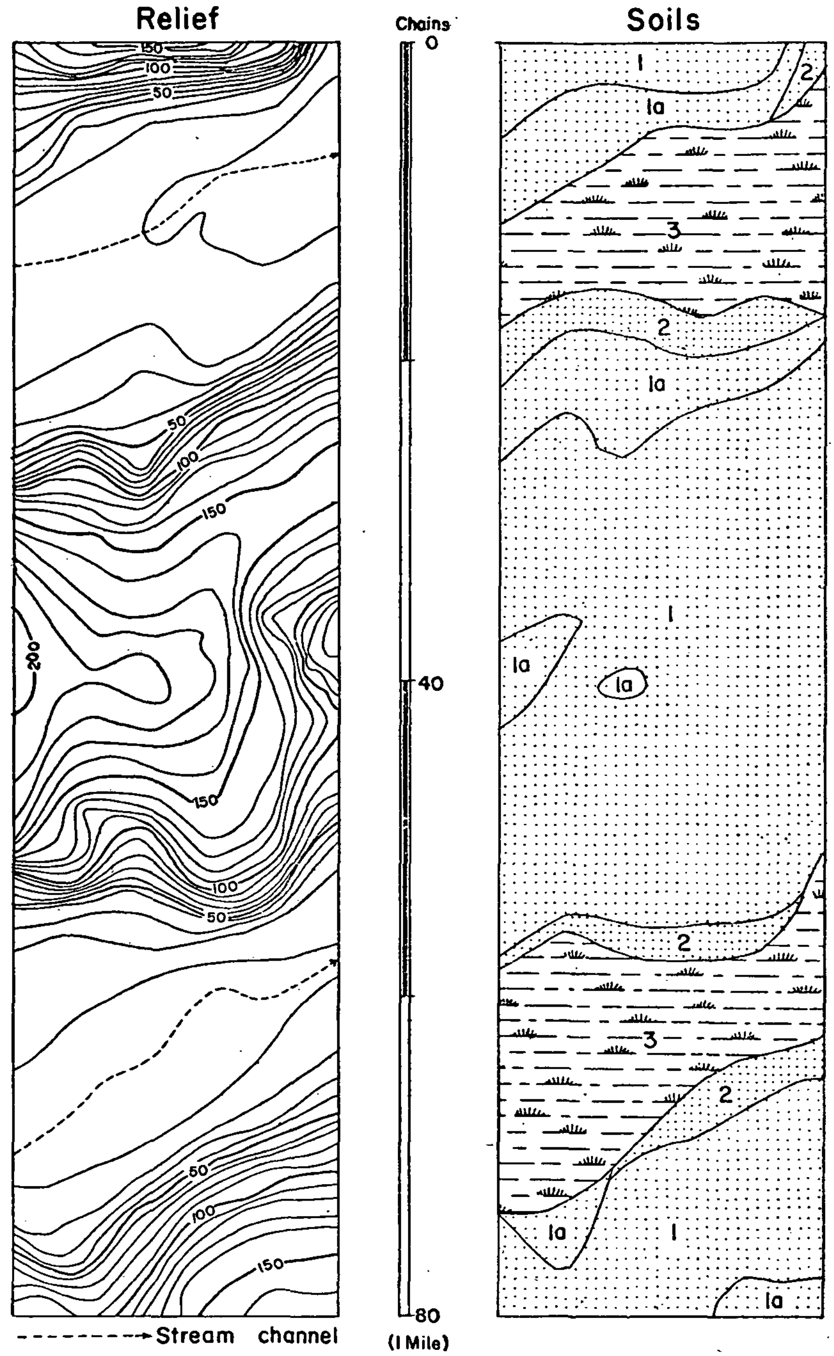


Fig. 29. The Tikobo association: relief and soil maps of Sample strip 12, 1 mile north of Bonyere. Contour heights are in feet.

1. Tikobo series.
1*a*. Nuba subseries.
2. Aiyinasi series.
3. Mpataba series.

themselves for swamp rice production if the water level can be controlled economically.

Remaining soils of the association

A very small proportion of the total upland area is occupied by soils which, though broadly similar to Tikobo series, differ from it in various ways. Of these, *Menzezo series* can be regarded as a Tikobo in which frequent small fragments and nodules of sandy ferruginous pan are found throughout the profile, while *Mpem series* contains frequent beds of stream-rolled pebbles in the subsoil, and often some grit as well. *Basachia* and *Mambuen series* differ from Tikobo series in the more important respect of containing an indurated layer, usually developed below about 50 inches from the surface, which completely alters the normal free drainage so characteristic of the rest of the association. Of these, Basachia series contains small fragments of sandy pan similar to those of Menzezo series, while Mambuen is free of these. These series are found only locally, usually on flattish upland sites, but are particularly extensive at Aiyinasi Agricultural Station, where they occupy about half of the upland areas (Ahn, 1957).

Along the major streams and rivers, very small areas of *Kwaben series* occur (page 77) and these form the only soils in the association suited to cocoa production.

Detailed sample strips on the association

Three sample strips were recorded on this association. In addition a detailed survey was made of the soils of Aiyinasi Agricultural Station.

Sample Strip 11, near Mpataba, on the main Esiama–Half Assini road, includes a typical area of flattish-topped low hills a little under 100 feet above sea level dissected by flat-bottomed but fairly steep-sided valleys some 50 feet lower. Nearly all the upland areas consist of a single series, Tikobo, which grades into small areas (mostly on lower slopes) of its lighter-textured subseries, Nuba. The valley bottom soils are grey sands (Aiyinasi series) which on waterlogged sites merge into the peaty Mpataba series. Very small patches of yellow-brown alluvial clays (Kwaben series) also occur on lower slope sites: within the strip they total only about 2 acres out of 160.

Most of the strip at the time of the survey (early 1956) was under regrowth thicket vegetation, five to six years old. Adjoining the road an area of cassava had been interplanted with young coconut seedlings at 29 x 29 feet. Several other farms on the strip were also under cassava, all on well drained upland soils. Poorly drained valley bottom areas were all under secondary swamp regrowth vegetation two to ten years old.

Sample Strip 13, north of Nuba, includes a dissected upland area of broken forest as yet undisturbed by cultivation (Fig. 28). The flattish hill summits are here at about 300 feet above sea level and are dissected by steep-sided valleys with flat bottoms about 150 feet lower. All the valleys are dry, and even the lower slope and bottom soils are well drained yellow-brown sandy light clays similar to those on the uplands. All the soils on the strip are Tikobo series, and its lighter-textured subseries, Nuba. On the particular area included in the strip these lighter-textured soils were commoner than the normal series, but these two very similar soils grade into each other and their distribution shows little relation to the relief. The forest on the strip is a poor pole forest with relatively few large trees: typical rain forest species are almost absent, while trees usually associated with drier forest areas were recorded in small numbers, suggesting that the very rapid drainage of the soils of the strip have influenced the composition of the forest. The humous topsoils in this area are particularly thin, and the topsoil reaction is unusually acid, being in the range 3·2 to 4·6 and including the most acid soils recorded within the basin.

Sample Strip 12, north of Bonyere (Fig. 29), includes the relatively broad ill-drained bottom areas of two valleys shortly before they reach the sea. In these waterlogged areas organic matter accumulates to form a thick mat overlying grey sand or clay below (Mpataba series). These areas are thought to be typical of the more extensive swampy stretches of the Lake Amansuri area. Between the valleys the ground rises steeply from 10 to 20 feet above sea level to about 200 feet above sea level, so that these upland areas form part of the Bonyere ridge. All these upland areas, and therefore most of the sample strip, are occupied by Tikobo series grading into very subordinate areas of Nuba subseries: these occur on some summits but are mostly on lower slopes. Between the well drained upland soils and the valley-bottom swamps a narrow band of grey sands (Aiyinasi series) was recorded.

Most of the poorly drained valley-bottom areas were not cultivated at the time of the survey (1956), being under secondary swamp forest vegetation about ten years old. Cultivation was confined to the well drained upland areas, of which over half were under current cultivation and the remainder were under thicket regrowth 4–5 years old. Of the cultivated areas, about 20 per cent were under cassava, most of the rest was under mixed cassava and plantain, sometimes with maize, the greater part of which was also interplanted with young coconut seedlings. Minor crops grown included pineapples, cocoyam, pepper and groundnuts. There were few mature coconut palms on the strip but frequent coconut farms six to eight years old had been established on land nearby.

Aiyinasi Agricultural Station occupies about 800 acres near the eastern boundary of the association where the Tertiary deposits thin out somewhat. The relief of the station is, however, typical of the association, consisting of broad, gently undulating to nearly flat summit areas, here at 120–160 feet above sea level, dissected by the steep-sided valleys of the Basachia and Mambuen streams and their tributaries, the lower parts of which are as little as 30 feet above sea level. The Basachia stream appears to have cut through the Tertiary deposits to small areas of underlying material derived from granite rocks.

About three-quarters of the station consists of upland areas where the soils are developed in Tertiary deposits. Of these soils, about half are the normal free-draining Tikobo series characteristic of most of the association, the remainder being soils with an indurated layer in the subsoil (mostly Basachia series) which are uncommon in the association as a whole. In these soils, internal drainage is much slower than is usual for upland soils of the association. Of the lower-slope and valley-bottom soils, most are grey soils developed in local alluvium (Aiyinasi series) with small areas of gritty or pebbly soils (mostly Mpem series).

Considerable areas of the upland soils are now under oil palm trials, including fertiliser trials (using different combinations of nitrogen, potash, magnesium and phosphorous fertilisers and lime), varietal trials, including Nigerian and local varieties, and spacing and intercropping trials with palms of the Dura type. The oil palm experiments were begun in 1954 and coconut trials on a smaller scale were begun in 1956. Minor trials on the station include fertiliser experiments with maize, groundnuts and cassava, also on upland soils. In due course information obtained here should add considerably to our knowledge of the agricultural techniques best adapted to the well drained but rather infertile upland soils of the area, though some allowance will have to be made, when interpreting results obtained, for the fact that a proportion of the station soils are not of the free draining type typical of most of the association. More detailed information is available in a separate report on the station (Ahn, 1957), which includes a discussion of results obtained with oil palm trials on comparable soils in Nigeria.

Vegetation

The natural vegetation of this association is forest of the rain forest type, characterised by *Cynometra*, *Tarrietia* and *Lophira*, though it is noticeable that the vegetation is not as characteristically of the wet forest type over the very free-draining Tertiary sands as it is over poorer drained soils developed over granite or phyllite. *Terrietia*, for example, seems confined to the lower, less well drained areas of this association, whereas it occurs frequently on all sites on adjacent phyllite and granite associations. Conversely, dry forest trees such as *Antiaris africana* appear occasionally on this association but not on adjoining ones. In low-lying wetter parts subject to waterlogging, swamp forest of the *Raphia-Calamus-Ancistrophyllum* type is found (Part III, page 243).

The original forest on this association is somewhat thin in character, with frequent pole size trunks and relatively few very big trees. The upper canopy is at about 90 feet, somewhat less than usual, and there are few emergents above this level.

Most of the association south of the main road and about 20 per cent of that north of the road has been cleared and is now cultivated, or under coconuts or regrowth.

Land-use

The present pattern of land-use

The upland soils of this association are well suited to coconut palms. The spread of coconut plantations has been the main feature of the last thirty years and will no doubt continue until most of the Tertiary sand area is planted to this crop. In contrast to cocoa, coconuts can be established on old food farms and fallow ground. Coconuts have the further advantage of yielding throughout the year, not at one main and one very minor season as in the case of cocoa, and no disease has broken out yet in the area, though insect attack reduces yields in some years. Moreover it appears that the manuring of coconuts is better understood than that of cocoa, and is likely to give profitable returns.

Coconuts were first established by the Division of Agriculture at Atuabo in the early 1920's. The obvious success of this enterprise led to a widespread planting along the coastal sands behind the littoral. More recently, coconuts have extended further inland and young coconuts interplanted among food crops are a common sight along the road, so much so that there is some concern about further food supplies. The Omanhene of Eastern Nzima, for example, has reserved certain lands on which coconut planting is prohibited. It seems safe to assume that the major development of the next few years will be the spread of coconuts over most of the remaining Tertiary sand area.

Most of the land south of the main road is now cleared for food crops, and coconuts here are on the increase, though mostly in the young stages. This is an irregular area bounded on the south by the Amansuri marshes, the most extensive parts being the Aiyinasi–Bokaso area (where a road now crosses the Amansuri to Krisin), the Mpem–Boluan area south of Tikobo II, and a well farmed area south of Nuba. Elsewhere the marshes approach relatively close to the road.

Of the villages now on the main road, some, such as Nuba, have moved to their present position from sites further south. The principal road-side villages are Awiebo, Aiyinasi, Tikobo II (1 mile from the main road), Nvelenu, Samengyi, Mpataba, Nuba, Tikobo I, Nauli, and Tachinta, and from all of these some clearing north of the road has been undertaken. From Tikobo I a road has been built to Alenda Wharf on the Tano. The extent of present clearing, shown in the land-use map, is very uneven. Clearing extends well away from the road at Tikobo II, for example, whereas original forest can still be seen from the road itself near Nuba.

The usual food crops of the area are cassava, maize, groundnuts, vegetables and gourds, with some plantains but with very little cocoyam and no yam. It is a common practice now to plant coconut seedlings with the food crops on new farms.

Both oil palm and cocoa occur only in very minor quantities. The upland soils of the association are not suited to cocoa, though a little moderately good cocoa occurs on Kwaben series near Samengyi. Oil palm, on the other hand, is very well suited to the soils and climate of this association, growing wild in large numbers (Yawson, 1951) and plantations of the better varieties would probably give higher returns than coconuts. There is however little local interest in this crop at the moment due to the difficulty of getting seedlings of improved varieties, the extra labour involved in picking the fruits as compared with coconuts, and the expensive machinery needed for satisfactory oil extraction. Coconuts, by contrast, germinate easily and are readily available, fall down of their own accord when ripe, do not have to be processed immediately, and can be manufactured into copra simply by splitting and drying in the sun. Other aspects of coconut cultivation are discussed in Part I (page 48).

Future land-use

This is undoubtedly an area which should be planted to coconuts and oil palms as soon as possible. Both crops have been proved to do well here and both the local inhabitants and the economy of the country as a whole would benefit if copra exports were increased and possibly improved oil palm plantations established as well. The latter would need the establishment of an oil-extracting plant which would not be justified unless a considerable supply of palm nuts were available. The total area of Tertiary sand and similar Quaternary coastal sand soils (described below) is 295 square miles and most of this is suitable to both oil palm and coconuts. A percentage would have to be reserved for food crops, though even the importing of some of the food supplies from other forest areas less suited to coconut and oil palms would not be a disadvantage if it would increase exports of these two cash crops. Both are likely to find a ready sale abroad in the foreseeable future since it appears that the present world fat shortage is likely to continue for a considerable time to come, so that prices should remain relatively stable.

Various spacing, fertiliser, and variety trials on oil palms are being carried out at Aiyinasi Agricultural Station (page 118) though older-established trials on similar soils in Western Nigeria have given rather varied and inconclusive results (Haines & Benzian, 1956). The best response has been with potash fertilisers, particularly in Dahomey where big yield increases on native plots are reported (Prevôt, 1955). In the case of coconuts, a spacing of about sixty trees to the acre (27 feet triangular, or 30 feet x 25) is considered best for most soils, while potash responses obtained on Tertiary sands in the Ivory Coast are reported to be particularly encouraging. Quite striking yield improvements have already been obtained from the recently begun fertiliser experiments on the original Division of Agriculture plantations at Atuabo (Gordon, 1956) where the soils are similar ones developed over more recent coastal sands. These results are discussed further below, page 122, while estimates of the total coconut acreage in Nzima are given on page 125.

The main agricultural advantages of the Tertiary sand soils are their uniformity (so that agricultural techniques, once developed, can be applied to most of the area) and their ease of working, and in these respects they contrast favourably with most Ghanaian forest soils. The nutrient status is often very low, but might be relatively easily modified to suit a wide range of requirements provided that organic matter is kept high enough to retain chemical fertilisers. These advantages, and the very free drainage coupled with the high rainfall, suggest that crops not usually thought of in connection with the forest zone, such as tea and tobacco, could be given a trial, and that the range of possibilities here might be considerable. The light texture is ideal for groundnuts, which should grow well if manured, while the acid reaction and free drainage suggest pineapple growing. The main question is whether any of these alternative crops will be as easy to introduce or as profitable once established as are coconuts and oil palm.

It has been suggested in the past (Rae, 1943) that the Amansuri swamp area could be drained and the water controlled for swamp rice production. The soils are, however, acid peaty soils (Mpataba series) which are so poor in nutrients that it is doubtful if the low yields they would give would justify any expensive reclamation work. In addition, the organic matter would shrink and decompose as soon as exposed to the air, leaving little except sterile grey acid sands and sandy clays. Even without water control there are plenty of border areas suitable for rice cultivation which are not used, and rice production, which was considerable in the 1920's and 1930's (Robb, 1929), has now declined seriously. The reason for this is not any lack of suitable land but the fact that coconuts give a farmer an easier living and a better return for this labour.

SOILS DEVELOPED OVER COASTAL SANDS (GROUP 5)

Along the coast there is a belt of varying width of geologically Recent sands. Soils developed over these sands form a separate group (Table 8). Within the group there are sands of various ages: the youngest are on and just behind the beach, while the older ones, remnants of older beaches and dunes, occur further inland. The whole of the spit west of Half Assini between the Juen Lagoon and the sea consists of these Recent sands which widen out again in the Lake Amansuri area. In this area they merge inland into soils developed over Tertiary sands.

There are two main classes of soils within the group. The first class, comprising 95 per cent of the total, consists of free-draining sandy soils supporting forest or coastal thicket. The small second class consists of poorly drained soils, much finer in texture and often containing hard organic pan in the subsoil, which support only sedges and grasses. These soils underlie a series of small savanna patches behind the coast which are thought to occupy the sites of former lagoons (Ahn, 1959).

Immediately behind the beach are found pale loose soils which consist merely of beach sand which has been colonised by beach vegetation and thicket species. This is Krisin series. Behind this is an extensive stretch of the major soil of the area, Fredericksburg series, a brown medium-grained sand. Occasionally this series is leached white in the upper subsoil (Princes series).

All these soils are extremely low in nutrients since they consist largely of sterile transported quartz sand, with no source of nutrients from decomposing material below. In practice, what little nutrients are available are associated with the organic matter, and occur mostly in the topsoil. Despite these limitations those soils which are well drained are capable of supporting coconut palms, and food crops such as cassava and groundnuts.

5. THE FREDERICKSBURG ASSOCIATION

The association occupies the whole of the Recent sands area (Figs. 2 & 7) and covers 91 square miles. Fredericksburg series alone accounts for about 90 per cent of the association, and this is the normal series on which the extensive coconut plantations of the area are found. The remaining minor series of the association includes some pedologically interesting groundwater podsols, some of which support only grass and sedges, but these soils are inextensive and of little agricultural value.

The climate of this association is similar to that of the Tertiary sand area, the main feature of which is the very high total rainfall of over 85 inches with relatively short dry seasons and a very heavy concentration of rainfall in May and June, though the effectiveness of the rainfall is reduced by the excessive drainage of most of the upland soils.

Soils

Krisin series

Krisin series is confined to a narrow belt immediately behind the present beach and consists of pale yellow coarse beach sand which has been colonised by beach vegetation or planted with coconuts. It contains frequent small fragments of sea shells, which give the series its neutral reaction.

A greyish brown topsoil with little or no humous staining overlies several feet of pale yellow coarse loose beach sand containing shell fragments. Rainfall is immediately absorbed and drainage is excessively rapid. Fresh water may seep seawards at 10–15 feet below the surface. The soil consists of little except sterile beach sand and there is little organic matter, though the shells supply calcium and possibly magnesium and phosphorus. The soil is generally of low productivity, but supports coconuts.

Fredericksburg series

Fredericksburg is a deep brown sandy soil which forms the most extensive series in the association, covering about 90 per cent of the area. A greyish brown humous sandy loam topsoil overlies a subsoil consisting of a considerable depth of uniform medium brown fairly loose sand, loamy sand or sandy loam.

Rain is rapidly absorbed at the surface and internal drainage is rapid to excessive. The upper layers of the soil dry out fairly rapidly but the rainfall is heavy, being 85 inches or more, and showers are frequent. There are also quantities of fresh water seeping seawards through the lower subsoil and these are tapped by palms.

The nutrient status of this soil is very low, and it is leached of most of the exchangeable bases.

Fredericksburg series is very extensively planted with coconuts, to which it is suited by virtue of its depth and good drainage. The original Atuabo plantation was on this series and recent fertiliser trials here have given very promising initial results. Big yield increases were obtained with nitrogen alone and with a complete NPK dressing: other increases were obtained with potash with either nitrogen or phosphorus (Gordon, 1956). Although longer term results are required before these responses can be subject to more reliable statistical examination, they suggest that coconut yields from existing plantations can be profitably increased and the potential production of the area raised accordingly. It should be noted that these trials were carried out on palms thirty years old yielding about thirty to forty nuts a year and that the most successful treatment, an NPK dressing, increased this figure to over sixty nuts: the application of fertilisers to seedlings would bring them into bearing earlier than usual and might give even better results.

The loose texture also makes Fredericksburg series suitable for groundnuts, which are sometimes interplanted between young coconuts. Other food crops are grown by local farmers but give generally low yields: of these cassava gives the most satisfactory returns and is widely grown. Maize and plantains are sometimes seen but returns are very moderate. Gourds and vegetables are quite common on this series, and pineapples grow satisfactorily by local standards.

Aiyinasi series

Near streams, Fredericksburg series grades into the grey sand of Aiyinasi series, described above (page 115).

Princes series

Princes series, a very minor soil of the association, is a leached version of Fredericksburg series in which the lower topsoil consists of white or greyish white sand. A very thin, greyish brown, humous sandy light loam upper topsoil overlies 2–4 feet or more of white or greyish white medium sand. This merges into medium brown sand below, the junction between the leached white sand and the underlying normal brown sand sometimes being marked by a narrow zone of slight induration.

This series is uncommon, being found only on certain flattish sites amid the normal Fredericksburg series. It is almost sterile, and has little or no agricultural value. On some examples even cassava and coconuts have failed.

A deeper version of this soil consisting of sterile leached white sand throughout is known as *Assini series.*

Soils of the savanna patches

Behind the shoreline are six major and several minor flat patches where only grass and sedges grow. These total about 4 square miles in area, the larger ones being at Eikwe, Beyin, Atuabo, Ngaliche,

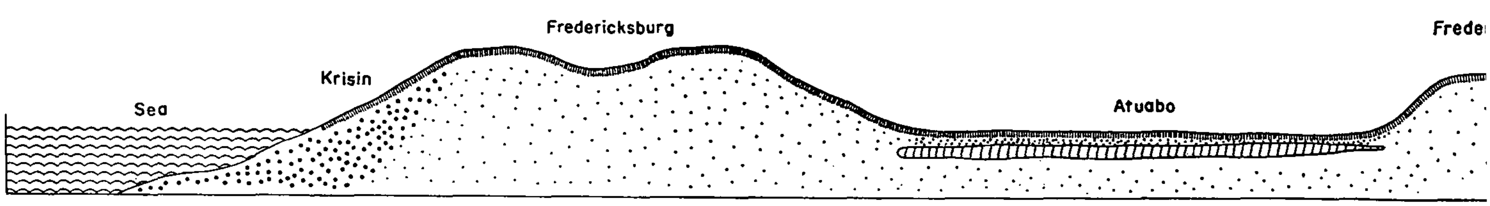


Fig. 30. The Fredericksburg association.

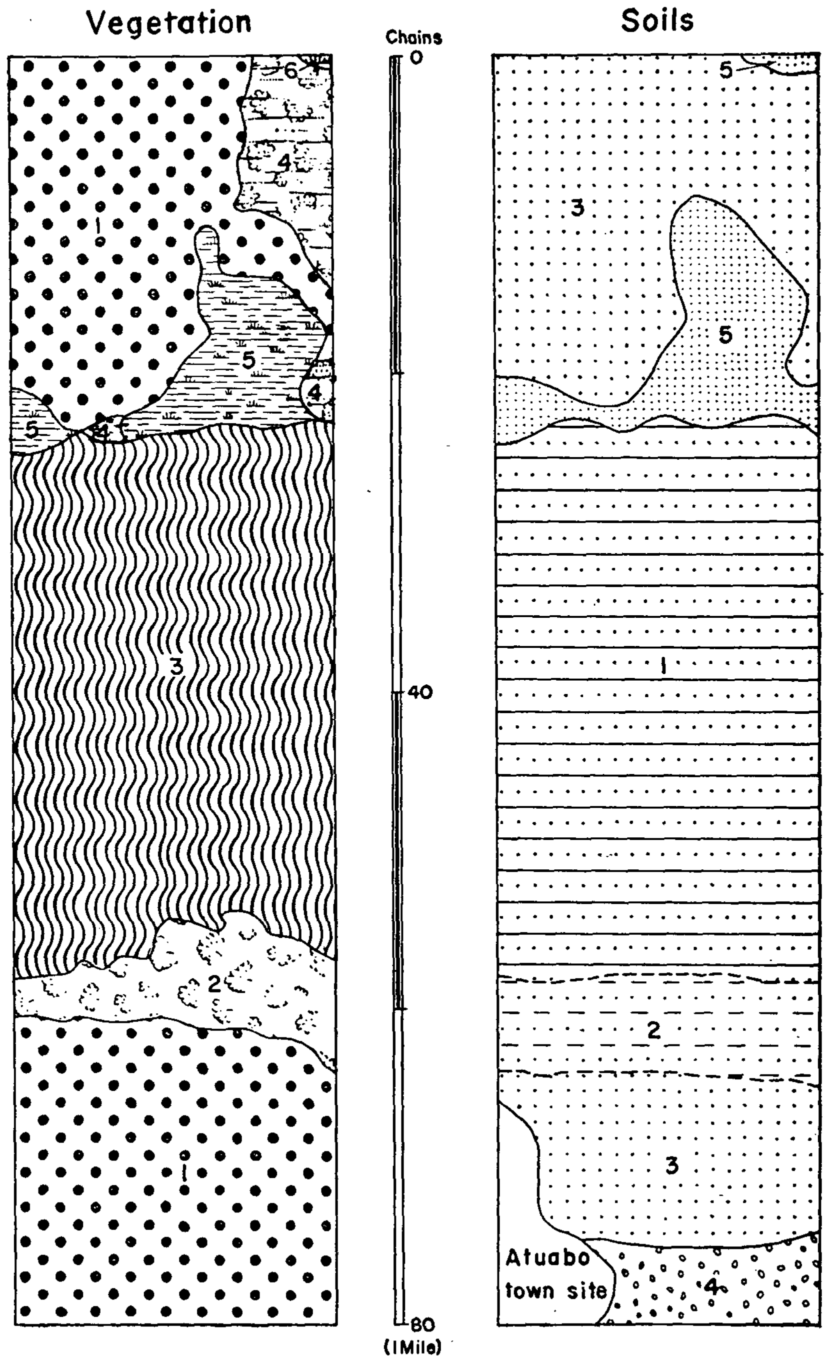


Fig. 31. The Fredericksburg association: vegetation and soil maps of Sample strip 17 at Atuabo.

Key to vegetation map (Recorded in November, 1956)

1. Coconut palms.
2. Low thicket with stunted coconut palms and small patches of grass.
3. Short grass savanna.
4. Thicket (with frequent *Syzygium guineense*).
5. Swamp forest.
6. Swamp regrowth.

Key to soil map

1. Atuabo series.
2. Transitional soils between Atuabo and Fredericksburg series.
3. Fredericksburg series.
4. Krisin series.
5. Aiyinasi series.

Mpein and Esiama. The usual soil of these poorly drained savanna areas is *Atuabo series*, in which a very thin greyish brown, slightly humous, loamy fine sand topsoil overlies 2–4 feet of pale, almost white, very fine sand. This in turn overlies a layer of dark brown massive organic pan, usually about 18 inches thick.

This series is waterlogged for part of the year, but dries out at others. Only grasses and sedges survive on such sites. All attempts to grow crops, including coconuts, on this series have failed and these areas are best left as at present, providing poor rough grazing for local shorthorn cattle (Ahn, 1959).

On the patch behind Esiama, a slightly different soil is found. This is *Esiama series* which consists of silty loam to light clay, instead of fine sand, and has no organic pan. As in Atuabo series, the colour is very pale and the drainage poor, and only grasses and sedges will grow.

TABLE 8

COASTAL SAND SOILS: KEY TO SERIES

	Approximate percentage of association	*Area in square miles*
Under forest, thicket, cultivation or forb regrowth:—		
With shell fragments		
(i) Pale yellow beach sand—Krisin series	2%	2
Without shell fragments in the profile		
(ii) Brown medium sand—Fredericksburg series	90%	82
(iii) Grey or white sand, brown sand below—Princes series ..	2%	2
(iv) Grey to white sand throughout—Assini series	½%	½
Supporting grass and sedges only:—		
(v) Fine white sand over massive brown organic pan—Atuabo series	5%	4
(vi) Grey to white loam or light clay—Esiama series	½%	½
Total	100%	91 sq. mls.

Detailed sample strips on the association

Sample strip 17 at Atuabo (Fig. 31) was sited at right-angles to the coast and shows a narrow band of Krisin series about 6 chains wide immediately behind the beach, which merges into a broader band of Fredericksburg series inland. Both these soils supported mature coconuts. At about ¼ mile from the shore the Fredericksburg series grades gradually into Atuabo series. In the transitional zone the palms planted were stunted or dead, and low thicket merged into the short grass savanna of the Atuabo series. At its northern end this area of Atuabo series grades into grey sandy soils (Aiyinasi series), supporting swamp vegetation, and further slightly higher areas of Fredericksburg series supporting coconut palms. The central savanna areas are almost flat and about 15 feet above sea level: the better drained dune sands (Fredericksburg series) rise to about 30 feet above sea level (Plate *6c*).

Sample strip 18, near Esiama, represents the eastern part of the association where it is relatively narrow: on this strip the Fredericksburg association extends for ½ a mile behind the coast and then merges into soils of the Tikobo and Boi associations (mostly Mpem series, a gravelly gritty soil frequent near the boundaries of the Tikobo association). The dune sands near the coast (Fredericksburg series) were under mature coconuts, but ill drained depressions amid these sands supported only swamp vegetation. Most of the remainder of the strip was under thicket regrowth or coconuts with very minor little patches of cassava, sugarcane, pineapples and groundnuts. Pineapples are fairly extensive in the area, yielding moderately well in the first year but deteriorating rapidly thereafter.

Vegetation

Apart from the small areas of grassland already mentioned, which still persist, the original vegetation of this coastal sand area consisted of coastal thicket behind the shore grading into forest of the rain-forest type inland. A few patches of forest remain, including some on the spit west of Half Assini between the Juen lagoon and the sea where the predominant trees are *Lophira alata* and a species of *Parinari*. Swamp forest and swamp thicket are locally common where the association adjoins the swampy areas round lake Amansuri. Most of the original thicket vegetation has now been cleared for coconut and food farms.

Land-use

The present pattern of land-use

The original demonstration coconut plantation established in the early 1920's by the Division of Agriculture was at Atuabo, mostly on Fredericksburg series (Fig. 31). Since then plantations have been planted along most of the littoral from Kikam in the east to Newtown in the extreme west, though in some cases they form only a narrow strip immediately behind the shoreline. Most of the remainder of the association behind the main coastal towns of Beyin, Atuabo, Eikwe, Krisin and Esiama is fairly intensively cultivated with frequent food farms and relatively small areas of fallow. Population density here is relatively high, being the highest in the whole of the basin. In a few areas, outside Esiama for example, land may be cropped continually twice a year with groundnuts and gourds with little or no fallow between. Cassava is the main food crop. Fish from the sea and the Juen lagoon supplement the diet and, when dried, form an export additional to the copra and coconut oil of the area.

The Nzimitienu—Newtown area west of Half Assini is sparsely populated in comparison with the area behind the main coastal towns, and here there are frequent patches of thicket and uncleared original forest.

The extent of coconut palms in Nzima in 1958 was estimated (Coombes, 1958) at 10,000 acres, of which 60 per cent was under mature palms. This acreage was thought to produce about 3,000 tons of copra, or nearly 30 per cent of the Ghana total. These palms are mostly on the Fredericksburg association, though most of the new planting is probably on the Tikobo association further inland. Present planting in Nzima is probably of the order of 500–600 acres per year.

Future land-use

Most of the association is already farmed or under coconuts, though certain thicket areas remain and will no doubt be planted to coconuts until only a minimum of land reserved for food crops remains. There is now little or no rice cultivation, but this used to be important in the swampy land bordering the Amansuri area (Robb, 1929). Rice production declined as farmers devoted their time to coconuts instead, though it could be revived. The main area of land awaiting clearing is west of Half Assini. Although this area includes a slightly higher proportion of poor leached soils of the Princes—Assini type than in the closely cultivated areas behind the main coastal towns, there is still some scope for development, and most of this area will in due course no doubt be planted to coconuts as well. When this stage has been reached, increased production from the association will depend on the use of chemical fertilisers, as suggested by the Atuabo experiments discussed above (page 122), and possibly of green manures. Increased animal husbandry based on fodder crops or grasses sown between the coconuts, or on the by-products of oil extraction, is a possibility which would have the advantage of supplying animal manures to these low-humus soils. The addition of organic matter might be expected to increase the effect of chemical fertilisers by retarding the rate at which they were washed out of the soil.

PART III

Detailed soil and vegetation descriptions

INTRODUCTION

SCOPE OF PART III

PART III gives a detailed technical description of every soil series found in the basin, including analytical data where available, and an account of the vegetation in which typical and important species are listed. This section may be regarded as an appendix to Parts I and II, which are relatively general and non-technical.

ARRANGEMENT

The soils are arranged in the same major groupings of associations based on parent material and climate as were used in Part II, these associations and the soils they contain being listed in the table of contents. This arrangement is intended to simplify reference from one part to the other. The soils can be classified in many ways, and an alternative grouping of the individual series of the basin into major soil groups based on soil genesis is also given below.

DEFINITION OF TERMS USED

Some of the terms used have been discussed generally in Part II (page 53) and a glossary explaining technical terms is given at the end of this report.

CLASSIFICATION OF SERIES INTO HIGHER SOIL GROUPS

The classification into higher groups employed in the Soil and Land-Use Survey was worked out by C. F. Charter in 1955 (Charter, 1957 and Brammer, 1956). This is based on a consideration of all the major soil forming factors (climate, vegetation, relief and drainage, parent material and age) and groups soils into a number of orders, suborders, great soil group families and great soil groups accordingly.

According to this classification, most of the upland soils of the basin are *latosols*, a great soil group family belonging to the order of *climatophytic earths*, soils whose characteristics are predominately determined by climate and vegetation. Latosols are the red or yellow, very highly weathered, usually kaolinitic, soils characteristic of large areas of the tropics: in these soils weathering is so complete that only unweatherable residues usually remain. Latosols are sub-divided according to their acidity into the great soil groups of *oxysols* and *ochrosols* described in Part I. A second great soil group family within the same order of climatophytic earths are the *basisols*, soils which are neutral or nearly so in reaction due to bases being liberated from the parent material. In the basin, only Anum and Abu series, *forest brunosols*, belong to this family.

The second order of *topohydric earths* includes soils whose characteristics are predominately determined by relief and drainage, the suborders including *planopeds*, on flat topography of peneplains, marine or river terraces, *depressiopeds*, developed in depressions such as poorly drained valley bottoms, and *cumulopeds* developed in depressions where peat has accumulated. These in turn include *groundwater podsols* such as Atuabo series, acid and very acid *gleisols* such as Kakum and Kwaben series, and very acid *cumulosols* such as Mpataba series.

The third order is that of *lithochronic earths*, whose characteristics are determined by parent material or age. These are all soils in which profile development is retarded. Within the basin are found *lithosols*, with an immature profile due to the steepness of the slope and/or the resistant nature of the parent rock, and *regosols* in which the parent material is inert, such as a loose sand. Immature soils of steep slopes, such as Tanokrom series, are lithosols: Krisin series is the only regosol within the basin.

Order	Sub-order	Great Soil group family	Great Soil group	Series and No.	Soil Type: Sedentary	Soil Type: Colluvial	Soil Type: Alluvial	Parent Material: Lower Birrimian	Parent Material: Upper Birrimian	Parent Material: Granites	Parent Material: Tertiary sands	Parent Material: Coastal sands
Climatophytic Earths	Hygropeds	Latosols	Forest Ochrosols	Bosum ... 4	X			X				
				Nzima ... 5	X			X				
				Atonsu ... 6	X			X	X			
				Nsuta ... 7	X			X	X			
				Amuni ... 9	X			X				
				Kokofu ... 10		X		X				
				Sang ... 11		X		X				
				Birim ... 16			X	X	X	X		
				Awaham ... 17			X	X	X	X		
				Atukrom ... 28	X				X			
				Asikuma ... 29	X				X			
				Wiawso ... 30	X				X			
				Shi 31	X				X			
				Atewa ... 32	X				X			
				Ansum ... 35		X			X			
				Nsaba ... 51	X					X		
				Akroso ... 52		X				X		
				Adujansu ... 53	X					X		
				Bechem ... 54	X					X		
				Kobo ... 57	X					X		
				Pepri ... 58	X					X		
			Forest Oxysols.	Yago ... 2		X		X				
				Bobo ... 3		X		X				
				Boi 19	X			X				
				Omappe ... 20	X			X				
				Sutri ... 21	X			X				
				Ebowu ... 23	X			X				
				Bremang ... 24		X		X				
				Samreboi ... 26			X	X	X	X		
				Amoku ... 27			X	X	X	X		
				Elibo ... 39	X				X			
				Yakasi ... 40	X				X			
				Enchi ... 41	X				X			
				Disue ... 42		X			X			
				Sefwi ... 43	X					X		
				Abenia ... 44	X					X		
				Ninisu ... 45	X					X		
				Ankasa ... 47		X				X		
				Nta 48		X				X		
				Santomang 55	X					X		
				Yoyo ... 56	X					X		
				Tikobo ... 59	X						X	
				Nuba (Sub-series) ... 60	X	X					X	
				Menzezo ... 63	X						X	
				Mpem ... 64	X						X	
				Basachia ... 65	X						X	
				Mambuen ... 66	X						X	
				Fredericksburg ... 68	X							X
		Basisols	Forest Brunosols.	Anum ... 36	X				X			
				Abu ... 37		X			X			

					Soil Type			Parent Material				
Order	*Sub-order*	*Great Soil group family*	*Great Soil group*	*Series and No.*	*Sedentary*	*Colluvial*	*Alluvial*	*Lower Birrimian*	*Upper Birrimian*	*Granites*	*Tertiary sands*	*Coastal sands*
Topo-hydric Earths	Plano-peds.	Very Acid Planosols.	Ground-water Podsol.	Princes ... 69	X							X
				Assini ... 70	X							X
				Atuabo ... 71	X							X
				Esiama ... 72	X							X
	De-pres-sio-peds.	Very Acid Gleisols	Forest Very Acid Gleisol.	Kwaben ... 25			X	X	X	X	X	X
				Aiyinasi ... 61			X				X	X
			Forest Acid—Very Acid Gleisols.	Densu ... 15			X	X	X			
				Chichiwere 13			X	X	X			
				Oda ... 14			X	X	X			
				Boppa ... 18			X	X	X	X		
				Ofin ... 49			X			X		
				Firam ... 50			X			X		
		Acid Gleisols.	Forest Acid Gleisol.	Kakum ... 12			X	X	X	X		
		Neutral Gleisols.	Forest Neutral Gleisol.	Rubi ... 38			X		X			
	Cumulo-peds.	Very Acid Cumulosols.	—	Mpataba ... 62			X				X	
Litho-cronic Earths	Litho-peds	—	Lithosols	Yenahin ... 1	X			X				
				Kobeda ... 8	X			X				
				Totua ... 22	X			X				
				Piki 33	X				X			
				Tanokrom ... 34	X				X			
				Adiembra ... 46	X					X		
	Rego-peds.	—	Regosols	Krisin ... 67	X							X

TABLE 9

CLASSIFICATION OF LOWER TANO BASIN SOILS INTO SOIL GROUPS, FAMILIES, SUB-ORDERS AND ORDERS (BASED ON SOIL GENESIS)

The above classification and the soil series within the basin included in each great soil group are shown in Table 9. This is based on C.F. Charter's scheme, but omits orders, sub-orders, great soil group families and great soil groups not present in the basin.

COLOUR

In Part II colour is described in the general terms used in the field, e.g. orange-brown, while in Part III both the description and the numerical notation are as given in the Munsell colour charts.

TEXTURE

The texture given represents the result of a simple field manipulative test. The soil is passed through a 2 mm. sieve and enough is kneaded to the sticky point to make a ball, one inch in diameter. This is rolled out into a thin roll 6½ inches long: if this can be bent into a circle the texture is clay, if not it is loam. If the ball cannot be rolled out the texture is loamy sand: normal sand cannot be shaped into anything more than a crude pyramid when wet. These tests are practical and are intended to show how the soil behaves in the field. Detailed mechanical analyses have been carried out on very few soils, though all pit samples analysed are subjected to gross mechanical analyses defining the percentage of fine earth (less than 2 mm.), fine gravel (2–6·25 mm.), coarse gravel (6·25–20 mm.), and stones (over 20 mm. in diameter). The remaining analytical tests are carried out on the fine earth fraction only, a fact which must be born in mind when converting milli-equivalents to lbs. per acre.

CLAY FRACTION

The normal clay mineral is kaolinite. Montmorillonite is thought to be present in a few plastic soils such as Anum, Abu, Rubi and Densu series, none of which is extensive. Illite and other clays, in minor amounts, may be more widespread, especially in soils developed in alluvium.

STRUCTURE OF THE SUBSOIL AND DIVISION INTO SOIL HORIZONS

In the opinion of the author most of the soils described have no regular structure in the subsoil, though the humous layers are usually crumbly. The normal subsoil breaks into lumps when dug but these are irregular. This lack of structure is described in the text as *structureless*, though this does not imply that the soil lacks cohesion or is necessarily loose.

The absence of a structural subsoil raises the question as to whether normal tropical latosols possess a true pedological subsoil, or B horizon. The author's opinion is that a B horizon, particularly a textural one, does usually exist. The horizons in the systematic descriptions are, however, mainly sampling horizons for laboratory purposes and do not necessarily correspond to pedological horizons. For this reason less specific terms such as subsoil and weathered substratum have been employed.

SUBSERIES, PHASES AND VARIANTS

Subseries and variants, if they occur, are mentioned for each series, but since almost all series have vegetational phases (depending on whether they are under high or secondary forest, thicket, forb regrowth or are cultivated) and most upland soils have eroded phases, these are not specifically mentioned in each case.

ANALYTICAL METHODS AND DATA

Little is known about the absolute nutritional requirements of tropical crops and what levels of any particular nutrient are critical under local conditions. Analyses therefore are by themselves of limited value unless correlated with field trials. In the absence of these, the safest way of using them is to compare analyses of different series and to make preliminary deductions from these comparisons. Thus it is quite clear from the analyses given in this section that Atukrom series, for example, has more bases than Tikobo series, and that Atuabo and Beyin series have only a fraction of the phosphorus of the remaining soils in the area: whether these absolute amounts are adequate or not for any particular level of crop production remains to be investigated. For this reason the analyses have usually been compared with the average figures for ochrosols, ochrosols-oxysol intergrades, and oxysols within the basin (Table 5) which form a convenient starting point.

Reaction of the soil is determined in the field by colour indicators (Lamotte method) and in the laboratory by glass electrode, using a soil-water ratio of 1 : 2.

Mechanical analysis of the gently ground air-dry soil first separates the fine earth (less than 2 mm.) and then fractionates the remainder into stones (over 20 mm.), coarse gravel (20–6·25 mm.) and fine gravel (6·25–2 mm.). The moisture content of the remaining fine earth is determined immediately after sieving, a 10g. sample being over dried at 105°C to constant weight. The moisture content of the coarse fraction is negligible. Mechanical analysis of the fine earth, where required, is carried out by the beaker sedimentation method after the removal of organic matter, calcium carbonate and easily soluble manganese peroxide. Fractions are then separated according to the international Atterberg scale, i.e. 2–·625 mm., ·625–2 mm., ·2–·02 mm., ·02–·002 mm., and less than ·002 mm.

Organic matter is determined by the Walkley-Black method, taking one ml. of N potassium dichromate as the equivalent of 3·9 mg. of carbon. Organic matter is then calculated by multiplying the carbon content by 1·72. Total nitrogen is determined by the Kjeldahl method, using a selenium catalyst.

The determination of the exchangeable bases present is usually carried out by leaching with neutral N ammonium acetate solution, removing the ammonium salts and then determining calcium and magnesium by the improved versenate method, manganese by photometry and potassium by a version of the cobaltinitrite method correcting for the presence of calcium carbonate or water soluble salts. The total cation exchange capacity is now determined with ·5 N barium acetate of pH 8·2 and washing with 80 per cent alcohol: this has been found to give more exact results than the ammonium acetate method, which generally gives a somewhat lower figure.

Total phosphorus is determined by extraction from a 5 g. sample with 70 per cent perchloric acid, the phosphorus content in the solution then being determined by the molybdo-vanadate method, using the Spekker photometer with mercury arc lamp and filters.

Further details on the above methods are contained in de Endredy, in press, and in the works cited there. All the analytical results reproduced in this report were carried out in the Branch laboratories under the general direction of Dr. A. S. de Endredy and K. A. Quagraine, Soil Analysts, and to these colleagues the author is indebted for continued co-operation and advice.

SOIL PROFILE DIAGRAMS

The figures given on the left-hand side of the profile diagrams included below are in feet. Those on the right-hand are in inches and indicate the upper and lower limits of each layer.

Fig. 32. (overleaf) Topsoil reaction of pits within the basin. These are distributed as follows:

		Ochrosols	*Inter-grades*	*Oxysols*
Lower Birrimian areas	B1/A ..	11	3	—
	B1/B ..	20	41	28
	B1/C ..	3	8	21
Upper Birrimian areas	B2/A ..	16	6	2
	B2/B ..	21	24	21
Granite areas ..	G ..	1	15	39
Tertiary sand areas	T ..	7	22	23
Coastal sand areas	.. ..	8*	17	19
Total	.. ..	87	136	153

*Including regosols with a topsoil reaction above pH 5·5

KEY

- ● Ochrosol
- ○ Oxysol
- ⊕ Intergrade
- ▱ Sample strip

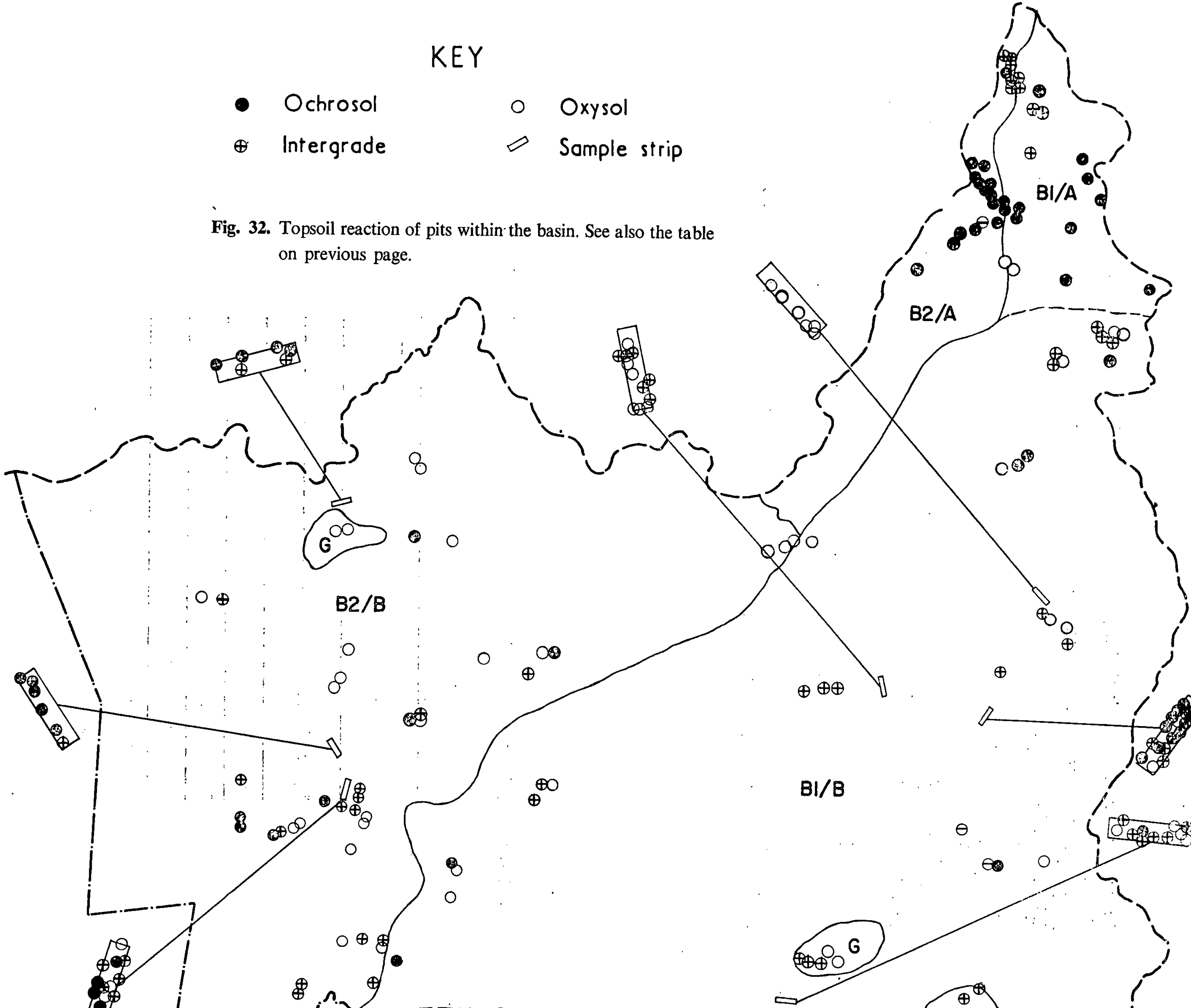
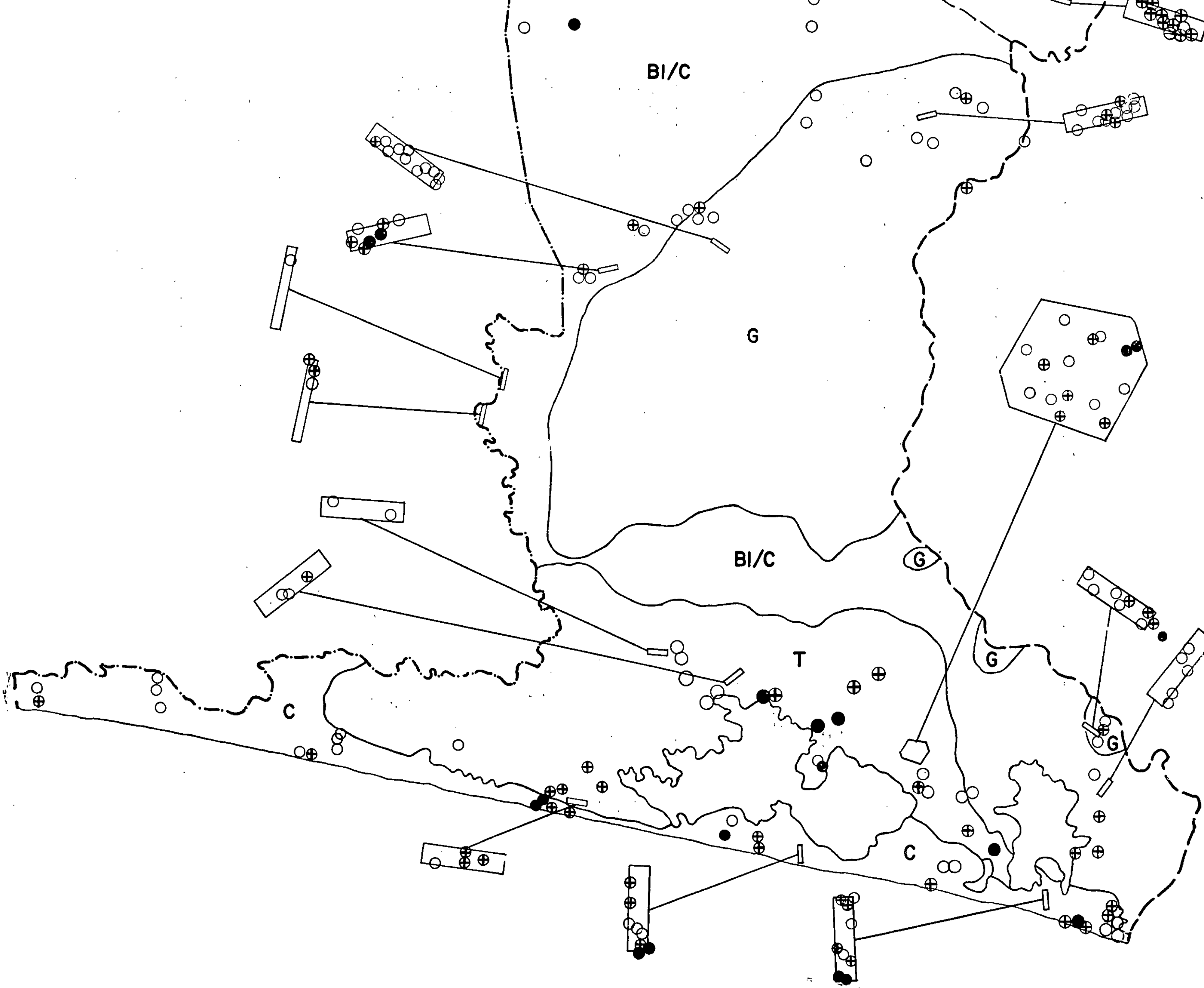


Fig. 32. Topsoil reaction of pits within the basin. See also the table on previous page.


BI/C
G
BI/C
G
G
G
T
C
C

SECTION I—SOILS

SOILS DEVELOPED OVER LOWER BIRRIMIAN ROCKS (GROUP 1)

1A. THE YENAHIN ASSOCIATION

1. Yenahin series

YENAHIN SERIES is a shallow lithosol usually less than a foot deep, overlying massive bauxitic pan. It is confined to the flattish summits of peneplain remnants of the Aya surface, such as those near Yenahin and those of the Afao hills, on which massive bauxite sheets have been developed. Within the Lower Tano Basin this series is very minor in extent, being confined to that small part of the summit area of the Afao hills included within the basin. The summits here are 1,600–1,700 feet above sea level.

Detailed description

A dark greyish brown humous topsoil, 2–4 inches thick, often containing small fragments of bauxitic pan or bauxitic and/or ironstone concretions, overlies up to 6–8 inches of dark brown sandy loam to light clay containing frequent to abundant concretions and pan fragments. This in turn overlies massive bauxitic pan.

Range in characteristics

The shallower examples of this series may consist of only 3–4 inches of soil above the pan, the usual depth being about 9 inches. This series grades into Katie series, a similar but deeper concretionary soil overlying bauxitic pan, and into Aya series, a deeper non-concretionary red or brown drift soil also overlying solid bauxite. These three series are all confined to the flattish summit sites described above.

Agricultural value

External drainage is very slow because of the flat site: internal drainage is confined to the few inches of soil above the bauxite. During rains, this series may become waterlogged and the shallower examples often consist of no more than a dark peaty topsoil, rich in organic matter, overlying the bauxite: such seasonably flooded soils may support only grasses, sedges and forbs adapted to poor drainage, and underlie the small savanna patches found on some of the Aya surface summit areas. Slightly deeper and better drained examples support thicket or forest. The soil has little or no agricultural value, and is inaccessible and inextensive. The topsoil reaction is usually highly acid and, despite a high organic matter content, base status is low. The water relationships are extreme, since the soil is swampy during rains but may dry out in the dry season, and this further limits the agricultural potential of this soil, which is best left under its natural vegetation.

2. Yago series

Yago series is found on the steep slopes of hills of the Aya surface and is developed in the drift material derived from the breaking up of the flat summit areas above. This drift material usually consists of several feet of light clay containing boulders of bauxitic pan. Well drained examples with a reddish subsoil are classified as Yago series; the slightly less well drained yellow to orange-brown associate is Bobo series, below.

Detailed description

A dark brown to greyish brown light clay topsoil, only slightly humous, and about 2 inches thick, overlies several feet of reddish brown silty light clay containing occasional to frequent small boulders of bauxitic pan, often a foot or two in diameter, and minor amounts of smaller bauxitic fragments, ferruginised rock and quartz stones. These boulders may occur anywhere in the profile, so that a sample at any one point may go to bauxite at a few inches already or show several feet of light clay free of included rock. Below the transported material, usually at 5–8 feet, there is a transition to the weathered products of the underlying phyllite.

Agricultural value

External drainage, because of the usual very steep site, is very rapid indeed: internal drainage is moderately rapid. The normal topsoil reaction is pH 5·5 or below, so that this series is an oxysol: nutrient status is fairly low, but the main agricultural disadvantage is the very steep gradient and consequent liability to accelerated erosion and loss of topsoil once the existing forest cover is removed. This soil is best left under forest, and most examples are already included within the Afao Hills forest reserve.

3. Bobo series

Bobo series is associated with Yago series, above, being slightly less well drained and yellow-brown in the subsoil. It is found wherever the slope flattens slightly, and is less extensive than Yago series. Profile morphology and agricultural value are very similar to Yago series except that, since the normal site is less steep, the dangers of erosion are also less and the soil can be used for agriculture provided some cover is maintained. It is often found on lower sites than Yago series, including some sites outside the Afao Hills forest reserve. On these lower slope sites it has been observed to support moderate cocoa and can be expected to support good coffee.

4. Bosum series

Bosum series is a well drained reddish brown highly concretionary and brashy soil developed in the fragmented products of the breaking up of bauxitic pan sheets. It is found on steep hill slopes below existing bauxitic pan sheets on the summits, or on the slopes and summits of hills once capped by such a sheet which has now been disintegrated. Within the basin it occurs in small areas near the summits of the Afao hills and on the slopes and summit areas of the steep hill south of Akoti, in the extreme north of the basin. In addition to the very frequent to abundant bauxitic and/or ironstone concretions and brash which characterise the subsoil, there may be somewhat larger bauxitic pan boulders, but the soil is not underlain by a continuous bauxitic sheet as is Yenahin and associated series.

Detailed description

A thin dark greyish brown humous topsoil, 1–2 inches thick (sometimes absent) and often containing concretions and brash, overlies a reddish brown light clay subsoil 3–5 feet thick containing very frequent to very abundant ironstone and bauxitic concretions, often angular or irregular in shape, frequent small pieces of bauxitic pan and ferruginised rock brash, and, occasionally, scattered larger pan boulders. This subsoil grades below into a substratum consisting of the weathered products of the underlying rock, which, within the basin, is usually phyllite.

Agricultural value

Both internal and external drainage are very rapid, the humus content and fine earth fraction both being low, so that water retention in dry periods is poor and the nutrient status of this brashy soil is also low. A further disadvantage is the liability to rapid erosion after clearing, and this series has little agricultural value unless cleared with great care and planted to a tree crop such as coffee, which is probably the best crop suited to such a well drained soil. Clearing for annuals should be avoided. The series is not extensive and is often somewhat inaccessible.

5. Nzima series

Nzima series is one of the most extensive forest ochrosols found in Ghana, and has a typical three-horizon sedentary forest profile consisting of a topsoil, a highly gravelly subsoil, yellow-brown to orange-brown in colour, and a weathered substratum. The weathered substratum contains traces of decomposing rock and merges into soft weathered parent rock below. The parent rock is usually phyllite, occasionally other metamorphosed clay sediments such as sericite schist, greywacke or mudstone. Within the basin, the usual rainfall associated with this series is 60–65 inches per annum: with higher rainfalls, the more acid equivalent of this series, Boi series, is usually developed instead. In drier forest areas outside the basin Nzima series is associated with a red, better drained, but otherwise similar soil (Bekwai series) occurring on summits and upper slopes, but within the Lower Tano Basin this series is absent and Nzima series is found on all upland sites from lower slopes to summits. It occupies a much greater area than any other series of the association.

Detailed description

The detailed description is based on thirty-eight pits dug within the basin (Fig. 33).

Range in characteristics

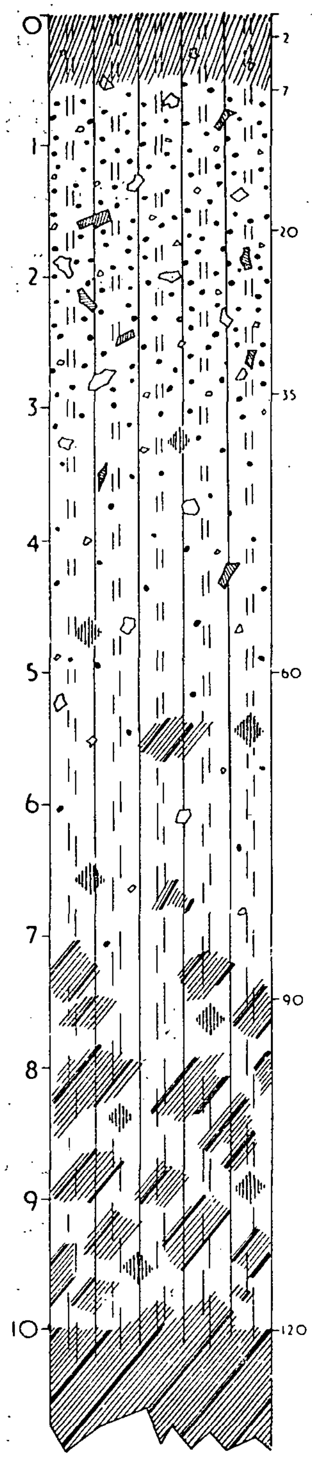
Nzima series is widespread and varies slightly according to the locality: the above description represents the average of all pits in the Lower Tano Basin. The average is somewhat deeper than the average profile for the whole forest zone, in which the weathered substratum, for example, begins at 47 inches, as compared with 60 inches above.

The amount of quartz gravel and, particularly, of quartz stones varies considerably over short distances, as does the content of ferruginised rock brash, i.e. irregular and often flattish pieces of phyllite hardened through being impregnated with iron. When either quartz stones or rock brash are particularly plentiful, stony or brashy subseries respectively are formed. On steep slopes the profile is shallower and the content of concretions less than usual.

Agricultural value

The cultivation characteristics of this series are typical of most sedentary forest soils, with a humous topsoil about 7 inches thick which is light-textured, free of stones and easy to work, and a gravel zone below this which, though not compact, is not so easily handled. The frequent concretions and stones do not, however, hold up root penetration. The crumb structure of the topsoil is stable so long as it is not completely cleared of vegetation, in which case the topsoil is liable to become puddled, and run off and erosion to increase. Under a moderate vegetation cover there is marked topsoil erosion only on the steeper sites, but cultivation may stir up the gravel of the subsoil, mixing it into the topsoil.

The fertility of individual examples of this series varies mainly according to the vegetation phase and the thickness and reaction of the topsoil, but also depends to a lesser extent on the parent material, since greywacke, for example, may release more nutrients than does phyllite. Generally speaking this series, when newly cleared from the original forest, has a medium to fairly good base status and the better examples can support moderate to good cocoa for about twenty years, after which there is a slow decline. Under cultivation for annual crops, fertility is lost more rapidly but can be restored by six to ten years of bush fallow to a satisfactory level for annual crops provided that there has been no serious loss of the topsoil due to accelerated erosion and exposure of the gravel layer below. Cocoa, however, will not usually grow well after such a fallow period, and on previously cultivated soils coffee is likely to give better results.



Topsoil

0-2 inches: dark brown (10YR 4/3) humous silty light clay, crumbly and loose. Modetately acid (average pH 6.0, range 5.5 to 6.8).

2-7 inches: brown (10YR 5/3) slightly humous silty light clay to clay, structureless and slightly loose, sometimes containing rare quartz gravel, subangular quartz stones or scattered ironstone concretions. Moderately acid (average pH 5.7, range 5.4 to 6.6).

Subsoil

7-20 inches: brown to strong brown (7.5YR 5/4–5/6) silty light clay to clay, structureless and firm, containing very frequent ironstone concretions, occasional quartz gravel and stones and rare ferruginised rock brash. Moderately to very acid (average pH 5.5–5.6, range 5.2 to 6.6).

20-35 inches: as above, but sometimes with slightly less included gravel, and very acid in reaction (average pH 5.3–5.4, range 4.4–6.2).

35-60 inches: as above, but yellowish red (5YR 4/6), and containing less included stones and gravel, i.e. with occasional ironstone concretions and rare to occasional quartz stones, quartz gravel and ferruginised rock brash. Very acid (average pH 5.3–5.4, range 4.4 to 6.4).

Weathered substratum

60-90 inches: strong brown, mottled red and yellow silty heavy loam, structureless and firm, containing rare concretions, quartz stones, quartz gravel and ferruginised rock brash, and with rare traces of decomposing phyllite. Very acid (average pH 5.2, range 4.8 to 5.6).

90-120 inches: highly mottled silty loam to heavy loam, structureless and soft, with frequent traces of decomposing phyllite. Very acid (average pH 5.2, range 4.8 to 5.6).

Below 120 inches: highly mottled loam of decomposing phyllite, either structureless or laminated and friable. Very acid (average pH 5.1). This continues for many feet before merging into unweathered phyllite.

Fig. 33. Nzima series.

External drainage on the usual sloping site is good. Internal drainge is adequate in the topsoil and subsoil, but slows down considerably in the weathered substratum. The fine earth fraction of the subsoil is about 30–40 per cent, and of this about half is clay, with the proportion of silt increasing down the profile as the parent material is approached. This relatively high proportion of silt may give this series a slightly lower moisture-retaining capacity than other forest ochrosols with a higher clay content, but within the basin, where rainfall is relatively high and dry seasons short, there is little possibility of this series drying out.

The following notes refer to three examples of which the analyses are given in Table 10. Of these, the first example has also been subjected to a complete mechanical analysis (Table 11).

B 707 *was sampled in the Kumasi region, about* 1 *mile north of the Ofin river at Dunkwa on a gently undulating upper slope site with a rainfall of about* 65 *inches per annum. The detailed description is as follows:—*

Topsoil

0-3 inches: dark brown (10YR 4/3) humous clay, crumbly and porous, with rare ironstone concretions. Moderately acid (pH 5.8).

3-9 inches: yellowish brown (10YR 5/4) slightly humous clay, structureless and firm, containing occasional to frequent ironstone concretions, occasional angular quartz stones and rare quartz gravel. Very highly acid (pH 4.5).

Subsoil

9-25 inches: dark yellowish brown (10YR 5/4) light clay, structureless and firm, containing very frequent to abundant irregular ironstone concretions and rare quartz gravel. Highly acid (pH 4.5).

25-37 inches: reddish yellow (5YR 6/8) light clay, structureless and firm, containing occasional soft and hard ironstone concretions and frequent patches of weathered phyllite. Highly acid (pH 4.8).

Weathered substratum

37-56 inches: yellowish brown (10YR 5/6) heavy loam, structureless and firm, with very frequent patches of laminated friable weathered phyllite. Highly acid (pH 5.0).

56-69 inches: as above, but strongly mottled yellow and orange, and with greater amounts of weathered phyllite. Highly acid (pH 5.0).

69-95 inches: light loam of decomposing phyllite.

B 831 *was sampled on Sample strip* 2, *north-west of Asankrangwa, from a very steep middle slope site where the rainfall is about* 65 *inches. Morphology is similar to B* 707 *above except that concretions are fewer.*

B 833 *was sampled on Sample strip* 4, *north of Samreboi, from a gently rolling middle slope site. The rainfall here is probably* 65–70 *inches. Profile morphology is similar to B* 707 *above except that the soil is somewhat indurated from* 51–78 *inches and the whole profile is considerably deeper.*

Of the above three examples, B 707 (Table 10) is a particularly fertile example which has a relatively high content of bases in the upper topsoil, but this content drops very rapidly in the lower topsoil and upper subsoil which are considerably more acid. The two remaining profiles are thought to be more typical of the basin and have, in their upper topsoils, only about one quarter of the bases present in the upper topsoil of B 707, these totals also being associated with a considerably lower carbon and nitrogen content. In the lower horizons, however, all three soils have similarly low base contents, emphasising the fact that differences in nutrient status between individual examples of the series are largely differences between their respective topsoils.

The full mechanical analysis of B 707 (Table 11) shows that the coarse gravel fraction, consisting mostly of ironstone concretions, reaches 63 per cent in the upper subsoil, in which horizon the fine earth drops to 30 per cent. Within the fine earth fraction of the whole profile, the clay fraction varies between 45 and 61 per cent, being least in the topsoil, while silt increases downwards as the parent rock is approached, reaching 25 per cent at 95 inches.

TABLE 10

ANALYTICAL DATA FOR NZIMA SERIES

Series and Profile Number	*Vege-tation*	*Lower depth of horizon in inches*	*pH*	*% Fine earth*	*Exchangeable Bases (m.e. per 100 gm.)* Ca	Mg	Mn	K	S (TEB)	T (CEC)	*Ca/Mg*	*Mg/K*	*C*	*N*	*C/N*	O.M.	*Moisture % Air-dry*	*Total P: p.p.m.*
Nzima																		
B 707 ...	Broken forest.	3	5·8	85	20·74	7·14	1·33	·80	30·01	37·86 (*b*)	2·90	8·92	7·40	·590	12·54	12·73	4·71	
		9	4·5	61	·77	·72	·09	·12	1·70	13·82	1·07	6·00	1·81	·164	11·04	3·11	2·46	
		25	4·5	31	·58	·72	·01	·16	1·47	12·99	·81	4·50	1·02	·105	9·71	1·75	2·78	
		37	4·8	81	·68	·76	·02	·08	1·54	11·00	·89	9·50	·56	·064	8·75	·96	2·85	
Nzima																		
B 831 ...	Secondary forest.	2	5·7	88	4·53	2·17	·20	·45	7·35	8·84 (*a*)	2·09	4·82	2·88	·284	10·14	4·95	2·18	314
		8	5·3	31	·96	·63	·02	·12	1·53	5·25	1·52	5·25	·74	·105	7·05	1·27	1·80	233
		17	5·2	60	·38	·50	·01	·06	·95	5·57	·76	8·33	·48	·083	5·78	·83	2·18	223
		30	5·4	27	·49	·45	·01	·06	1·01	5·70	1·09	7·50	·55	·092	5·98	·95	2·09	251
Nzima																		
B 833 ...	Broken forest.	3	5·6	100	4·92	1·07	·49	·27	6·75	9·02 (*a*)	4·60	3·96	3·22	·276	11·69	5 54	1·95	213
		7	6·1	96	1·73	·39	·10	·14	2·36	3·62	4·44	2·78	·73	·078	9·36	1·26	1·03	112
		16	6·1	64	·81	·26	·02	·04	1·13	3·00	3·12	6·50	·43	·050	8·60	·74	1·04	111
		30	6·0	18	·85	·30	·02	—	1·17	3·96	2·83	—	·42	·055	7·64	·72	1·41	71

(*a*) As determined with ammonium acetate.

(*b*) As determined with barium acetate.

TABLE 11

MECHANICAL ANALYSIS OF NZIMA SERIES (PROFILE NO. B707)

Lower Depth of Horizon in inches	*Gross Mechanical Analysis per cent. Air-Dry*				*Mechanical Analysis of Fine Earth per cent. Oven-Dry*								*Per cent. Oven-Dry*		Moisture per cent.
	Stones > 20*mm.*	*Coarse Gravel* 20-6·25*mm.*	*Fine Gravel* 6·25-2*mm.*	*Fine Earth* <2*mm.*	*Very Coarse Sand* 2-·625*mm.*	*Coarse Sand* ·625-·2*mm.*	*Fine Sand* ·2-·02*mm.*	*Silt* ·02-·002*mm.*	*Clay* <·002*mm.*	CaCO3	*Loss on Solution*	*Total*	*Ignition Loss*	*Corr. Ignition Loss*	
3	Nil	9·9	5·1	85·0	·41	3·49	20·28	15·30	45·80	·06	14·24	99·58	20·08	—	4·5
9	2·2	30·5	6·3	61·0	2·96	6·35	28·34	10·67	47·11	·01	4·38	99·82	9·73	—	2·40
25	Nil	63·1	6·4	30·5	5·82	4·06	19·69	9·45	58·44	·02	3·19	100·67	9·97	—	2·70
37	Nil	15·3	4·1	80·6	1·81	3·57	17·56	13·52	61·68	·02	1·88	100·04	10·16	—	2·77
56	Nil	2·0	1·4	96·6	·56	1·94	19·15	21·75	55·21	Nil	1·31	99·92	9·14	—	2·40
69	Nil	Nil	Nil	100·0	·52	3·74	25·19	21·63	47·31	Nil	1·12	99·51	8·52	—	1·72
95	Nil	1·0	·9	98·1	·30	2·40	24·30	25·33	46·43	Nil	·96	99·72	7·59	—	1.70

6. Atonsu series

Atonsu series is a yellow-brown forest ochrosol in which the normal sedentary profile is modified by the development of an indurated layer in the lower subsoil. The development of this induration seems to be favoured by flat upland sites, and Atonsu series is usually found on the flattish summits of hills, often representing the remains of dissected peneplains, and elsewhere where the slope flattens. The gravel content of the subsoil is often higher than in Nzima series, and the topsoil is often gravelly too. This series is found in areas of both Upper Birrimian and Lower Birrimian geology under rainfalls of up to 65 inches per annum: under heavier rainfalls the more acid Omappe series (Series 20, page 168) is developed instead.

Detailed description

The detailed description is based on all pits and chisel holes dug within the basin (Fig. 34):

Range in characteristics

The indurated layer may begin at between 2 and 7 feet below the surface. Less indurated soils, transitional between Atonsu and Nzima series, are also found.

Agricultural value

This series is considerably less productive than Nzima series because of the higher gravel content and the presence of the indurated zone below the gravel layer. The low fine earth fraction of both topsoil and subsoil (only 30–50 per cent in an average topsoil and 15–25 per cent in the subsoil) reduces both the nutrient reserves and the moisture retaining capacity of the soil, thus increasing the chances of the soil drying out in the dry season. Yields are lower than are usual for Nzima series, and the soil is more rapidly exhausted. Although cocoa has been seen growing successfully on Atonsu series, this is unusual, and this series cannot normally be expected to support good cocoa.

The flattish site and gravelly topsoil result in a fairly rapid absorption of rainfall and relatively low run off. Within the soil, drainage is fairly rapid in the gravel zone, but is impeded below it by the mottled indurated layer. Root room is reduced by the gravel, and penetration of the indurated horizons is difficult, though some tree roots do penetrate the less hard examples, particularly in cases where the induration is uneven and the paler mottles are a little softer than the more highly indurated reddish brown ones. This mottled zone does not dry out easily, but may give up its moisture only with difficulty.

Two examples of this series from the basin have been analysed, both with relatively high pH values: these are B 875 and B 876, both of which come from near Enchi. B 876 is typical of the Atonsu series developed on flattish but relatively low areas, while B 875 is from a higher site and was dug just outside the Boin River forest reserve. This example from a gently rolling near-summit site under original broken forest had the following morphology:

Topsoil

0-3 inches: dark brown humous silty clay, structureless and loose, containing frequent ironstone concretions.

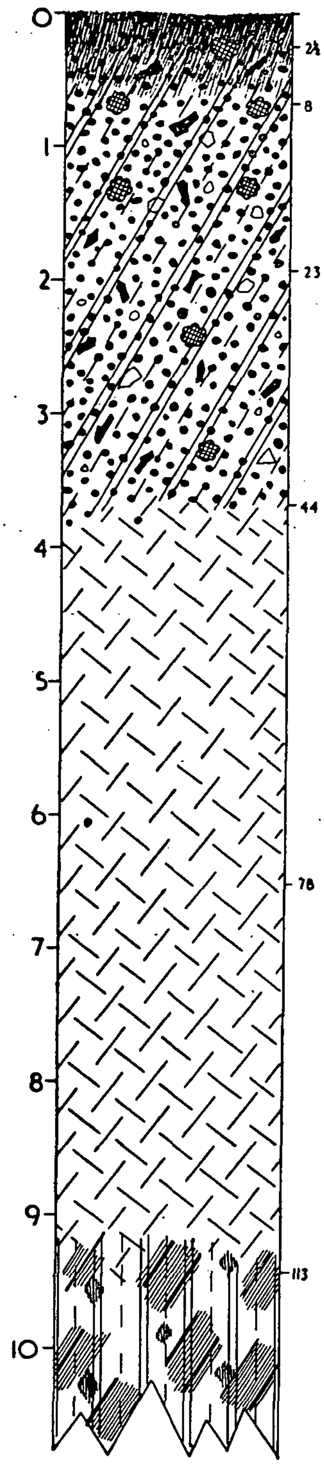
3-7 inches: light brown slightly humous silty clay, structureless and loose, containing abundant small and large irregular ironstone concretions.

Subsoil

7-21 inches: reddish brown silty clay, structureless and loose, containing abundant irregular ironstone concretions and occasional pieces of indurated material.

21-47 inches: reddish brown (5YR 5/6) silty clay, structureless and loose, containing frequent ironstone concretions, rare pieces of ironpan and frequent traces of indurated material.

47-66 inches: indurated material, mottled orange, red, brown and yellow, containing rare embedded ironstone concretions.



Topsoil

0-2½ inches: dark brown (10YR 4/2) humous light clay, crumbly and loose, containing occasional to frequent irregularly shaped ironstone concretions and rare ferruginised rock fragments. Slightly acid (average pH 6.2, range 5.8. to 7.0).

2½-8 inches: brown (10YR 4/3) slightly humous light clay, structureless and slightly loose, containing very frequent irregular small and large ironstone concretions and ferruginised rock brash. Moderately acid (average pH 5.8, range 5.4 to 6.2).

Subsoil

8-23 inches: brown to strong brown (7.5YR 5/4 to 5/6) light clay, structureless and somewhat firm, containing abundant irregular ironstone concretions, frequent ferruginised rock brash, and rare cauliflower heads, quartz gravel and stones. Moderately acid (average pH 5.7, range 5.2 to 6.6).

23-44 inches: as above, but very acid (average pH 5.4, range 4.8 to 5.8).

44-78 inches: strong brown, mottled yellow, grey and red, indurated material, compact and dug only with difficulty. This may contain rare ironstone concretions. Very acid (average pH 5.2, range 4.6 to 5.6).

78-113 inches: light yellowish brown, mottled yellow, grey and red, indurated material as above, but often slightly less hard. Very acid (average pH 5.2, range 4.6 to 5.6).

Weathered substratum

Below 113 inches: light yellowish brown light clay or loam, mottled various colours, with frequent traces of decomposing phyllite, This merges below into soft weathered phyllite.

Fig. 34. Atonsu series.

TABLE 12

ANALYTICAL DATA FOR ATONSU AND NSUTA SERIES

Series and Profile Number	*Vegetation*	*Lower depth of horizon in inches*	*pH*	*% Fine earth*	*Exchangeable Bases (m.e. per 100 gm.)* Ca	Mg	Mn	K	S (TEB)	T (CEC)	Ca/Mg	Mg/K	C	N	C/N	O.M.	*Moisture % Air-dry*	*Total P p.p.m.*
Atonsu B 875 ...	Broken forest.	3	7·0	33·9	31·42	6·64	·30	1·74	40·10	30·03 (*a*)	4·73	3·82	6·11	·579	10·55	10·51	6·24	—
		7	5·7	16·6	6·05	2·75	·17	·63	9·60	13·94	2·20	4·37	2·06	·215	9·58	3·54	4·32	—
		21	5·1	26·6	1·13	1·02	·01	·25	2·41	12·55	1·11	4·08	1·53	—	—	2·63	4·63	—
		47	5·1	22·7	·34	·53	·01	·16	1·04	11·37	·64	3·31	1·21	—	—	2·08	4·99	—
Atonsu B 876 ...	Cultivation	3	6·4	38·0	27·75	5·95	·27	·63	34·60	29·51 (*a*)	4·66	9·44	6·55	·555	11·80	11·80	5·14	—
		10	6·0	17·8	4·14	1·55	·03	·25	5·97	9·15	2·67	6·20	1·40	·144	9·72	2·41	2·69	—
		28	4·9	22·1	1·00	·99	·01	·16	2·16	8·45	1·01	6·19	·90	·130	6·92	1·55	3·59	—
		70	5·2	22·9	·33	·27	·005	·13	·73	4·14	1·22	2·07	·16	·020	8·00	·28	2·18	—
Nsuta B 872 ...	Broken forest.	4	6·0	10·5	26·09	5·07	1·24	1·66	34·06	61·51 (*b*)	5·15	3·27	10·15	·920	11·03	17·46	8·93	—
		10	5·2	21·4	2·02	·73	·34	·25	3·34	29·02	2·77	2·92	1·92	·247	7·77	3·30	7·02	—
		24	4·9	26·7	·90	·40	·03	·14	1·43	28·43	2·25	2·86	1·64	·157	10·45	2·82	8·27	—
		38	5·1	16·6	·72	·71		·09	1·61	24·45	1·01	7·89	1·25	·140	8·93	2·15	7·92	—

(*a*) As determined with ammonium acetate.

(*b*) As determined with barium acetate.

Analytical data for this soil are given, together with those for B 876, in Table 12. B 876 has a similar morphology except that the indurated layer begins at 28 inches. Both examples have low fine earth fractions of about 35 per cent in topsoil 1, dropping to half of this figure in topsoil 2, so that the fairly high base figures expressed in m.e. per 100 gm. represent only low total base reserves. For the same reason both soils, but particularly B 876, have low total air-dry moisture percentages and thus are liable to be droughty. In B 876 the fourth horizon represents the indurated layer and is particularly low in organic matter. In both profiles, nutrient reserves fall off very rapidly below the topsoil. Despite their high pH values, therefore, the low fine earth fraction and poor moisture relationships make these soils of lower agricultural value than most soils in the same acidity group.

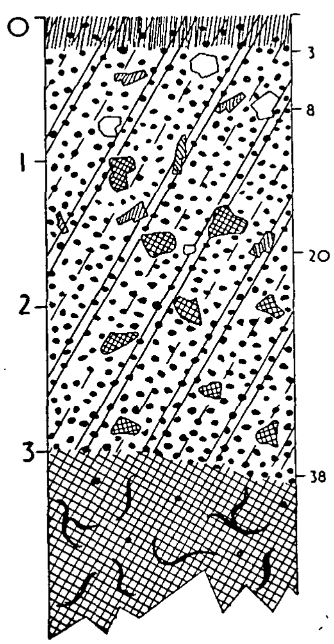
This series is frequently dug for road gravel.

7. Nsuta series

Nsuta series is a shallow forest ochrosol consisting essentially of a gravel layer overlying massive ironpan. It is a shallower and more extreme version of Atonsu series in which the indurated layer is replaced by ironpan, too hard to be broken up by normal digging equipment. It is found on flat summits of hills, on sites which usually represent the remains of former peneplains. Within the basin it is very inextensive, occurring on both Upper and Lower Birimian hills with an annual rainfall of 60–70 inches.

Detailed description

The description in Fig. 35 is based on sixteen pits dug within the basin:—



Topsoil

0-3 inches: dark brown (7.5YR 3/3) humous light clay, crumbly and loose. This may contain frequent ironstone concretions. Moderately acid (average pH 5.9, range 5.8 to 6.2).

3–8 inches: brown (5YR 4/4), slightly humous light clay, structureless and loose, containing rare ferruginised rock brash, rare quartz stones, and occasional to frequent ironstone concretions. Moderately acid (average pH 5.6, range 5.4 to 6.0).

Subsoil

8-20 inches: brown (10YR 4/4), light clay, structureless and somewhat loose because of the included gravel, containing frequent to very abundant ironstone concretions with occasional quartz stones, ferruginised rock brash and pieces of broken ironpan. Very acid (average pH 5.2, range 4.6 to 5.6).

20–38 inches: strong brown (5YR 5/6) light clay, structureless and fairly loose, containing frequent to very abundant ironstone concretions, frequent pieces of pan and rare quartz stones and ferruginised rock. Very acid (average pH 5.1, range 4.6 to 5.6).

Below 38 inches: massive ironpan, usually too hard to be dug.

Fig. 35. Nsuta series.

Range in characteristics

The topsoil is often thin and highly concretionary. The depth at which pan is found varies between about 30 and 50 inches.

Agricultural value

External drainage is slowed down by the flatness of the usual Nsuta site. Internal drainage is rapid in the upper subsoil but is held up by the pan below the gravel layer so that the soil is temporarily waterlogged after heavy rains, the water then flowing out laterally through the gravel layer. Conversely, the soil dries out rapidly during the dry season. The main agricultural limitation for tree crops is the pan at 30–50 inches through which roots cannot penetrate. Base exchange capacity and nutrient status are greatly reduced by the high content of coarse material, and the physical limitations of the series and the dry season drying out mean that the soil can, at best, support only short-rooted annuals.

The following example has been analysed. This was dug along the northern boundary of the Boin River forest reserve, on an upper slope, gently undulating site, where the original high forest was undisturbed. Annual rainfall is about 65 inches.

Topsoil

0–4 inches: dark brown (7.5YR 3/2) humous silty light clay, slightly crumbly and loose, containing abundant ironstone concretions.

4–10 inches: dark reddish brown (5YR 3/4) silty clay, structureless and slightly loose, containing abundant ironstone concretions and rare pieces of ironpan.

Subsoil

10–24 inches: yellowish red (5YR 4/6) silty light clay, structureless and slightly loose, containing abundant ironstone concretions and occasional pieces of ironpan.

24–38 inches: yellowish red (5YR 4/8) silty light clay, structureless and firm, containing abundant ironstone concretions and frequent pieces of ironpan.

Below 38 inches: massive, very hard ironpan.

Analytical results for this profile are given in Table 12. The fine earth fraction is small, being only 10·5 per cent in the topsoil, so that although exchangeable bases expressed as m.e. per 100 gm. of the fine earth fraction are moderately high by local standards, total quantities are in fact very low. For the same reason, organic matter and air dry moisture percentages when considered for the soil as a whole are also very poor, and the soil is subject to rapid drying out. Both bases and organic matter fall off very rapidly below the topsoil, though in gravelly soils of this type nutrient availability (despite low reserves) may be adequate for a short period, after which crop yields rapidly decline.

8. Kobeda series

Kobeda series is an immature soil developed over phyllite. Traces of decomposing rock are encountered immediately below the topsoil. The site is always very steep, generally on upper or middle slopes.

Detailed description

The average description (Fig. 36) is based on all the pits and chisel holes dug within the basin.

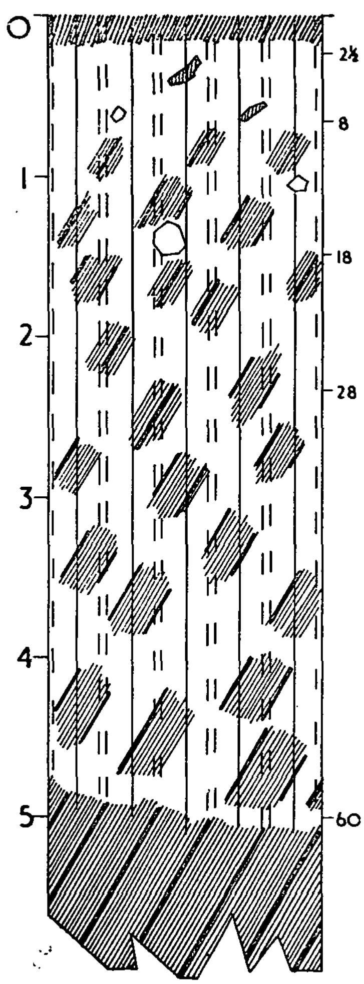
Range in characteristics

The hardness of the phyllite and the depth at which it occurs vary: deeper examples in which a subsoil has developed are classified as Nzima or Amuni series (Series 5 and 9, pages 136 and 149).

Agricultural value

External drainage is very rapid due to the steep gradient, though internal drainage is moderately slow. Dry season moisture retention is satisfactory.

The nutrient reserves are concentrated in the topsoil and fall off very rapidly below this. Since the soil is shallow, however, roots may go down to decomposing parent rock. Although the amounts of nutrients released here will probably not be great, field observations suggest that the nutrient status of this series compares favourably with associated deep sedentary soils. Its main disadvantages are its steep site and consequent liability to accelerated erosion if the soil is left unprotected, and the fact that the normal site is often somewhat inaccessible.



Topsoil

0–2½ inches: brown (10YR 5/3) humous silty clay, crumbly and loose. Moderately acid (pH 5.8).

2½–8 inches: brown (10YR 5/3) silty clay, structureless and soft, occasionally containing rare quartz gravel and ferruginised phyllite. Very acid (pH 5.5).

Weathered substratum

8–18 inches: brown (7.5YR 5/4) silty clay or silty light clay, structureless and firm, containing frequent traces of decomposing phyllite and, occasionally, rare quartz gravel or stones. Very acid (pH 5.5).

18–28 inches and 28–60 inches: as above but with increasing amounts of decomposing phyllite.

Below 60 inches: soft friable decomposing phyllite.

Fig. 36. Kobeda series.

The two profiles analysed (Table 13) are both typical shallow Kobedas on steep (strongly rolling) sites. Profile B 830 has a higher topsoil pH than B 834, contains over twice the exchangeable bases, and is also higher in organic matter. Except for lower magnesium, this soil is similar to the average of all ochrosols within the basin (Table 5) and is moderately fertile. Profile B 834, on the other hand, has a base status nearer to the average of the ochro-oxysol intergrades, though both potash and phosphorus are higher than in B 830. Organic matter totals fall off very rapidly below the topsoil, and emphasise the need for careful topsoil preservation on the steep sites associated with this series. The fine earth fraction on which the analyses are made is reduced in both profiles, but particularly in the substratum of B 830, by the fragments of weathering phyllite, though these may supply some additional nutrients to the soil: in the case of B 834 potash figures here are relatively high.

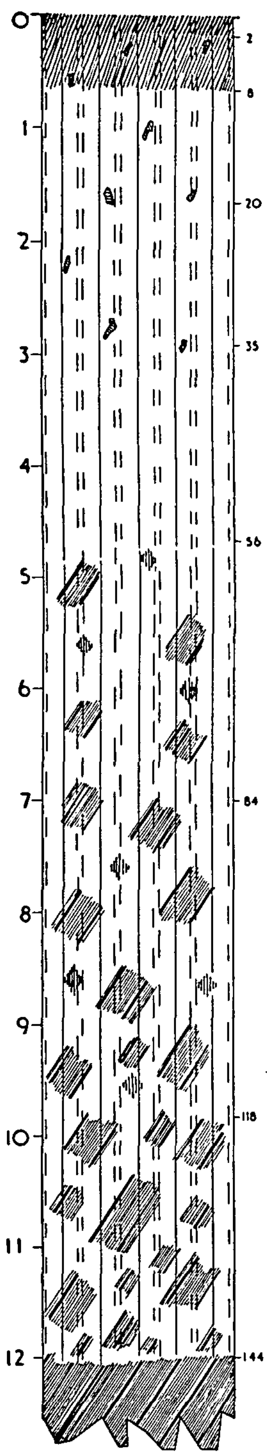
TABLE 13

ANALYTICAL DATA FOR KOBEDA SERIES

Series and Profile Number	*Vegetation*	*Lower depth of horizon in inches*	*pH*	*% Fine earth*	*Exchangeable Bases (m.e. per 100 gm.)* Ca	Mg	Mn	K	S (TEB)	T (CEC)	*Ca/Mg*	*Mg/K*	*C*	*N*	*C/N*	*O.M.*	*Moisture % Air dry*	*Total P p.p.m.*
Kobeda																		
B 830 ...	Broken forest.	3	6·0	100·0	12·90	1·98	·26	·42	15·56	23·59 (*b*)	6·51	4·71	4·42	·365	12·11	7·60	3·29	363
		9	4·7	100·0	1·82	·72	·02	·22	2·78	13·12	2·53	3·27	1·75	·131	13·39	3·01	2·16	220
		16	4·9	28·4	·75	·44	·01	·12	1·31	12·10	1·70	3·67	1·37	·093	14·73	2·36	2·07	238
		26	4·9	26·6	·42	·22	·01	·04	·68	8·57	1·91	5·40	·68	·072	9·44	1·17	1·91	228
Kobeda																		
B 834 ...	Broken forest.	4	5·5	83·6	4·38	1·69	·26	·56	6·89	11·06 (*a*)	2·59	4·04	2·77	·233	11·89	4·76	3·13	645
		9	5·0	80·1	·67	·80	·06	·31	1·84	5·83	·84	3·71	1·05	·120	8·75	1·81	2·57	436
		21	5·0	81·6	·40	·52	·07	·24	1·23	3·86	·77	4·38	·62	·074	8·38	1·07	2·01	350
		36	5·2	80·3	·31	·76	·04	·30	1·41	3·47	·41	2·50	·50	·055	9·09	·86	2·05	295

(*a*) As determined with ammonium acetate.

(*b*) As determined with barium acetate.



Topsoil

0–2 inches: brown (7.5YR 5/4) slightly humous silty clay, crumbly and loose. Moderately acid (average pH 5.8).

2–8 inches: brown (7.5YR 5/4) silty clay, slightly crumbly, soft and somewhat loose, with little or no visible humus. This layer may contain a few scattered ferruginised rock fragments. Moderately acid (average pH 5.8).

Subsoil

8–20 inches: yellowish red to strong brown (5–7YR 5/6) silty light clay, structureless and soft, sometimes with rare to occasional flattish ferruginised rock fragments. Moderately acid (average pH 5.8).

20–35 inches: yellowish red (5YR 5/6) silty light clay, structureless and soft sometimes with rare to occasional ferruginised rock fragments. Very acid (average pH 5.3).

35–56 inches: yellowish red (5YR 5/6) silty light clay, structureless and soft. Very acid (average pH 5.2).

Weathered substratum

56–84 inches: light reddish brown (5YR 6/3) mottled silty heavy loam, structureless and soft, with occasional patches of decomposing phyllite. Very acid (average pH 5.2).

84–118 inches: grey or brown, mottled silty heavy loam, structureless and soft, with occasional patches of decomposing phyllite. Very acid (average pH 5.1).

118–144 inches: mottled light clay (the genera)colour being often either bluish grey or orange-brown), structureless, soft and friable, with frequent traces and pieces of decomposing phyllite. Very acid (average pH 5.1).

Below 144 inches: grey, blue, red or brown decomposing phyllite, soft and friable.

Fig. 37. Amuni series.

9. Amuni series

Amuni series is a deep, soft, red or brown earth found on very steep to extremely steep upper slopes in areas of Lower Birrimian geology. This series is not extensive and is confined to sites of the steep gradient indicated. It is characterised by its softness and ease of digging, its uniformity and, except for scattered ferruginised rock fragments, by its absence of included material.

Detailed description

The average description (Fig. 37) is based on all pits dug within the basin.

Range in characteristics

The depth of this soil (before weathered parent material is reached) varies considerably, but this series is often remarkably deep for the steep site usually associated with it, one example dug going to almost 30 feet. A little ferruginised rock brash is normal, but occasionally quartz stones or rare concretions are found, though only in very minor amounts. Two out of 15 examples dug were slightly indurated in the subsoil, all the remainder having the easily dug, uniform subsoils characteristic of the series. The normal Amuni described above has a topsoil pH of above 5·5, so that it is an ochrosol, but ochrosol-oxysol intergrades are common in the Nzima–Boi association. The oxysol counterpart is Ebowu series (series 23, page 169).

Agricultural value

Both internal and external drainage are rapid due to the steepness of the slope and the porosity of the soil, and the soil is therefore red even in high rainfall areas where red soils are uncommon.

No analyses are available but field observations suggest that the nutrient status compares favourably with associated series. The fine earth fraction usually approaches 100 per cent. Under the relatively heavy rainfall of the basin, dry season moisture retention is usually satisfactory. This series is very easy to work, but the steep and often inaccessible site and the small total area of this series are disadvantages which account for the fact that it has, as yet, been little used. The soft consistency in particular suggests its use for root crops, but very great care is needed to prevent accelerated erosion, to which this series is particularly vulnerable.

10. Kokofu series

Kokofu series is a yellow-brown colluvial forest ochrosol developed in transported silty light clay material. The subsoil is sometimes separated from the weathered bedrock below by a stone-line. This soil is found on middle and lower slopes of areas underlain by Lower Birrimian phyllite and greywacke, where the topography varies from gently undulating to rather steeply sloping, though the normal site is a moderately gentle concave lower slope. In many areas the soil is relatively inextensive. It is found between Nzima series above and alluvial soils below, thus grading downslope into Kakum series in most instances. Normally Kokofu series is a fairly shallow soil, with about 4 feet of transported material above the weathered bedrock.

Detailed description

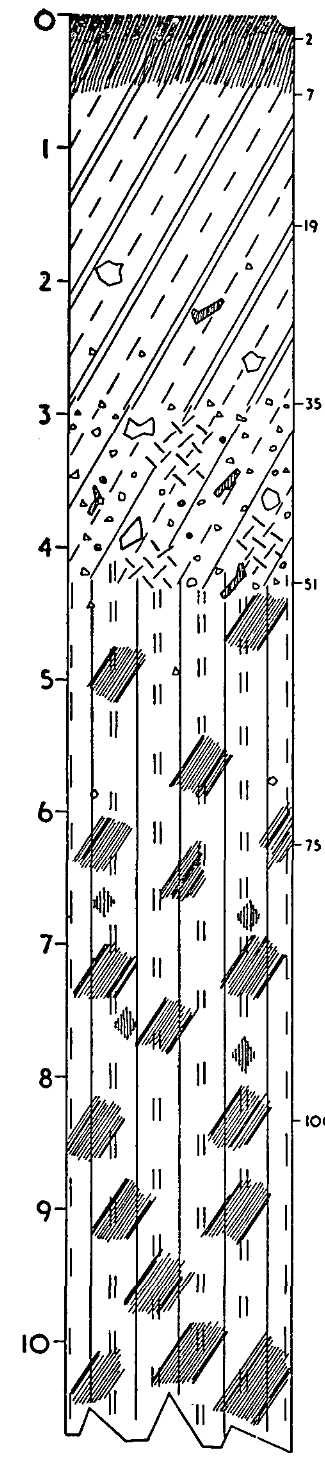
The description given in Fig. 38 is an average one based on all pit and chisel holes dug within the basin.

Range in characteristics

The depth of transported material may be as little as 15 to 20 inches. The stone-line, described above as occurring in the lower subsoil, may be poorly represented or absent. There are also transitional soils between Kokofu and Nzima series, known as Kokofu/Nzima, in which 15–30 inches of transported yellow-brown silty light clay overlies the normal gravelly Nzima subsoil. An otherwise similar soil to Kokofu series which is indurated in the lower subsoil is known as Sang series (series 11, page 151). A Kokofu containing unusually large quantities of angular quartz stones has occasionally been found and constitutes a stony subseries.

Agricultural value

The soil is easy to work, being usually free of stones for the first 2 feet, and forms a good physical medium for root crops. Its main disadvantage is its small total extent and scattered and irregular



Topsoil

0–2 inches: greyish brown (10YR 5/2) humous silty light clay, crumbly and loose. Moderately acid (average pH 5.6).

2–7 inches: yellowish brown (10YR 5/4) slightly humous silty light clay, slightly crumbly and slightly loose. Very acid (average pH 5.2–5.3).

Subsoil

7–19 inches: brownish yellow (10YR 6/6) silty light clay to clay, structureless and slightly firm. Very acid (average pH 5.2).

19–35 inches: reddish yellow (7.5YR 6/6) light clay, structureless and slightly firm. This may contain rare scattered quartz gravel, subangular quartz stones and fragments of ferruginised phyllite. Very acid (average pH 5.2).

35–51 inches: brownish yellow (10YR 6/6) heavy loam, structureless and firm, containing frequent quartz gravel, occasional ironstone concretions, occasional sub-angular and angular quartz stones and fragments of ferruginised phyllite. Patches of slightly indurated clay may be present. Very acid (average pH 5.2).

Weathered substratum

51–75 inches: brownish yellow (10YR 6/6), sometimes mottled purplish red and grey, heavy loam, structureless and firm. This is occasionally slightly indurated and contains traces and patches of decomposing phyllite. Very acid (average pH 5.2).

75–100 inches: brownish yellow, mottled grey and orange, silty heavy loam, structureless and friable, with frequent patches of decomposing phyllite. Highly acid (average pH 4.9).

Below 100 inches: as above, except that traces and patches of phyllite become more frequent, merging into weathered phyllite below.

Fig. 38. Kokofu series.

distribution. The usual degree of slope associated with this series requires moderate care to prevent erosion.

External drainage is quite rapid. Internal drainage is moderately good in the light clay subsoil, probably becoming slower in the weathered substratum. Internal drainage and lateral seep down-slope are increased in cases where the stone-line is well developed and this series normally receives moisture from soils upslope, so that its moisture relationships during dry spells are satisfactory.

No analyses are available, but field observations suggest this series has a nutrient status similar to or slightly higher than Nzima series. It has a higher fine earth fraction than Nzima and it has the further advantage of decomposing rock occurring within root depth. Examples not previously cultivated can be expected to support cocoa, as well as a range of food crops and, on the better drained sites, coffee.

11. Sang series

Sang series is similar to Kokofu series (q.v.) except that an indurated layer has developed in the lower subsoil.

Detailed description

The typical example described in Fig. 39 was dug on a gently undulating lower slope area in Sample strip 2, north-west of Asankrangwa, where the annual rainfall is about 65 inches.

Range in characteristics

The indurated layer begins at between 2 - 5 feet below the surface. The subsoil contains frequent quartz stones in some examples, which form a stony subseries.

Agricultural value

Those examples with only slight induration are very similar agriculturally to Kokofu series (q.v.) In those less common cases where the indurated layer is well developed internal drainage is affected and there may be some restriction of root development, but the exact effect of such a layer is not fully known and requires investigation. This question is discussed further, in the case of Basachia series, which contains a similar indurated layer, in the report on the soils of Aiyinasi Agricultural Station (Ahn, 1957). Sang series appears to be very uncommon.

12. Kakum series

Kakum series is an alluvial yellow-brown silty light clay classified as an acid gleisol. It is found on levee sites and elsewhere in the better drained parts of valley bottoms. It is the most important alluvial soil in forest areas with 65 inches of rain or less per annum where the associated upland soils are ochrosols, but within the Lower Tano Basin its more acid counterpart, Kwaben series, is far more common.

Detailed description

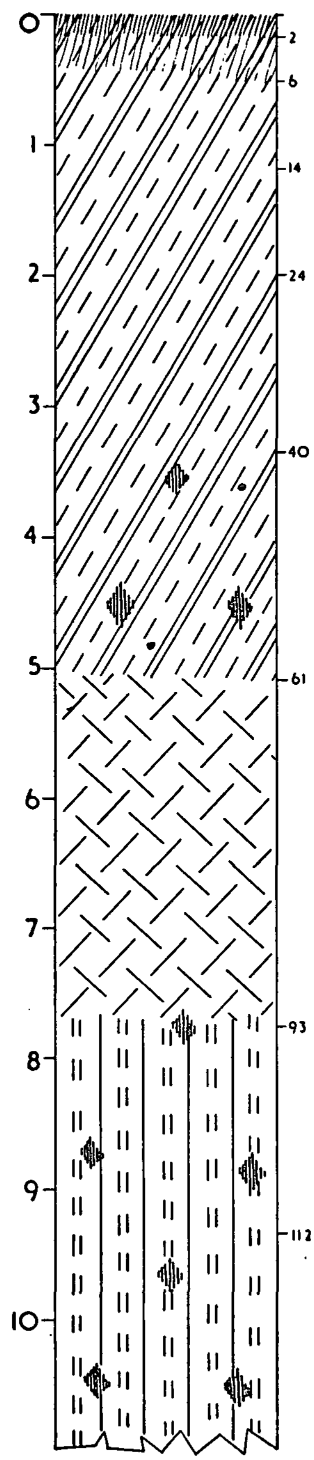
The morphology of this series is the same as for Kwaben series (series 25, page 170) from which it differs in acidity. A normal Kakum has a topsoil reaction of pH 5·5 to 6·5, becoming more acid in the subsoil, whereas Kwaben series has a topsoil pH of less than 5·0 which rises slightly in the lower horizons.

Range in characteristics

As for Kwaben series (q.v.).

Agricultural value

This is an important cocoa soil and in the area occupied by the Nzima association in the north of the basin it supports better cocoa than most of the sedentary soils. It also gives satisfactory yields of most food crops including cocoyam and plantain, but is too damp for coffee. The nutrient status is moderately good by local standards. The physical properties of the series are favourable to local agriculture, since the soil is easily worked by hand implements and is free of stones.



Topsoil

0–2 inches: light brownish grey (10YR 6/2) humous silty light clay, structureless and loose. pH 5.6.

2–6 inches: as above, but pale brown (10YR 6/3) and only slightly humous. pH 5.2.

Subsoil

6–14–24–40 inches: pale brown to very pale brown (10YR 6/3 to 10YR 7/4) silty clay, structureless and fairly firm. pH 4.6 to 4.8.

40–61 inches: brownish yellow slightly mottled red silty clay, structureless and firm, with very rare minute ironstone concretions. pH 4.8.

61–93 inches: red, white and yellow mottled indurated material, structureless and firm. pH 5.0.

Weathered substratum

93–112 inches: yellow and white mottled red silty light clay, structureless and firm. pH 5.0.

Fig. 39. Sang series.

External drainage is often only moderate because of the low-lying site. Internal drainage is usually good, though this series is liable to occasional flooding when the river is at its height. Groundwater is present at 5 - 15 feet throughout the dry season, though this is a factor of more importance in drier areas to the north than it is in the Lower Tano Basin.

The texture of this soil varies somewhat according to the type of associated upland soil. In the granite areas of the Kumasi Region it is often loamy with a considerable fine sand fraction. In the Upper and Lower Birrimian areas of the Lower Tano Basin it is typically a silty light clay with relatively little sand.

Analytical data for three examples of Kakum series sampled within the basin are given in Table 14. The examples analysed are briefly described below:

B 846 *was sampled from a gently undulating levee site next to the river Suraw south-west of Sefwi-Bekwai, where the annual rainfall is about* 65 *inches. The site supported good cocoa. The morphology of the profile was typical of the series, consisting of a dark greyish brown silty clay topsoil overlying a yellowish brown subsoil becoming slightly stained and mottled with depth.*

B 848 *was sampled from Sample strip* 7, *near Enchi, and is an example of a well-drained Kakum series associated with the river Disue. The profile morphology is similar to B* 846 *above except that below* 5 *feet there are some slightly indurated patches. The site is a fairly flat lower slope and the annual rainfall is about* 65 *inches.*

B 849 *was sampled near the river Ehuro, near the south-eastern corner of the Yoyo River forest reserve. The profile is similar to B* 846 *above except that it is better drained and somewhat orange-brown in the subsoil, with frequent MnO_2 stains and somes oft MnO_2 concretions below about* 8 *feet. The site is a flat lower slope which supported good cocoa: annual rainfall is about* 65 *inches.*

Exchange capacity as determined with ammonium acetate is moderately high (barium acetate would give higher figures and lower saturation levels agreeing better with the acid reaction). Manganese is fairly high throughout (as often in this series) but erratic, especially in B.849. Fine earth fractions are high. Subsoil C/N ratios tend to be low, as do the organic matter totals, particularly in the subsoils. Air dry moisture figures show a considerable range: high figures in the subsoil of B.849 reflect the clay content and may be compared with B.850 (page 172) a similar but more acid soil also supporting cocoa. Potash, except in the subsoil of B.848, is similar to the figures for intergrade soils given in Table 5 (page 25).

13. Chichiwere series

Chichiwere series is a light-textured yellow-brown sand or sandy loam found occasionally on river levees. It can be considered as a sandy associate of Kakum series. It is usually inextensive, being found in small areas where the river has sorted the material carried in suspension and deposited mostly sand. It is classified as an acid to very acid gleisol.

Detailed description

The example described in Fig. 40 was dug in the Upper Tano Basin west of Sankori, Ahafo, on a flat leveesite where the annual rainfall is 60 - 65 inches and the vegetation secondary forest: the texture is somewhat heavier than the average of the series, but is given here as being the only example yet analysed.

Analytical data for this profile are given in Table 14 and discussed below.

Range in characteristics

The usual topsoil reaction varies between pH 4·5 and 6·0, it generally being nearer the lower limit in the Lower Tano Basin. Texture varies from sand to loamy sand but may occasionally be a sandy light loam, as in the example above. The depth of the sand varies considerably, but relatively few deep pits have been dug in this series, which, though found frequently in forest areas to the north, is very uncommon within the basin. In some examples the sand is particularly fine.

Agricultural value

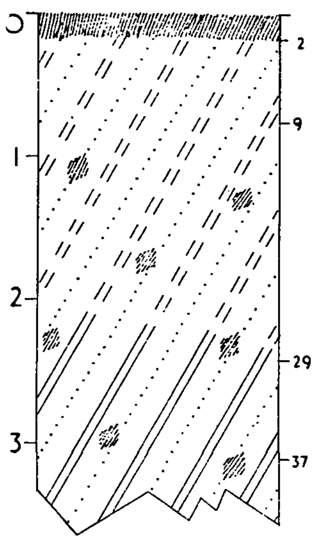
External drainage is moderate, internal drainage is rapid. Because of this the soil dries out quickly and is less reliable in the dry season than Kakum, though better drained than Kakum in the wet season.

TABLE 14

ANALYTICAL DATA FOR KAKUM AND CHICHIWERE SERIES

Series and Profile Number		*Vege-tation*	*Lower depth of horizon in inches*	*pH*	*% Fine earth*	*Exchangeable Bases (m.e. per 100 gm.)*						*Ca/Mg*	*Mg/K*	*C*	*N*	*C/N*	*O.M.*	*Moisture % Air-dry*	*Total P p.p.m*
						Ca	*Mg*	*Mn*	*K*	*S (TEB)*	*T (CEC)*								
Kakum																			
B 846	...	Cocoa	2	6·2	100	12·78	4·33	·52	·23	17·86	21·34 (*a*)	2·95	18·82	3·01	·300	10·03	5·18	3·65	—
			8	5·9	100	4·29	2·15	·79	·11	7·34	10·30	2·00	19·55	·89	·128	6·95	1·53	2·75	—
			20	5·6	100	2·32	2·00	·83	·08	5·23	8·80	1·16	25·00	·48	·087	5·52	·83	2·81	—
			28	5·3	100	·80	1·68	·20	·09	2·77	10·71	·45	18·67	·34	·067	5·07	·58	2·69	—
Kakum																			
B 848	...	Secondary forest.	3	5·2	100	4·28	1·64	·85	·34	7·11	10·18 (*a*)	2·61	4·82	2·95	·269	10·97	5·07	2·12	—
			8	4·4	100	·60	·49	·20	·09	1·38	5·89	1.2	5·44	·76	·097	7·84	1·31	1·55	—
			21	4·6	100	·35	·33	·22	·04	·94	5·65	1·1	8·25	·42	·066	6·36	·72	2·16	—
			44	4·9	92	·46	·35	·16	·02	·99	6·32	1·3	17·50	·28	·055	5·09	·48	2·44	—
Kakum																			
B 849	...	Cocoa	2	5·8	83	9·82	4·96	·95	·37	16·10	18·78 (*a*)	1·98	13·44	3·26	·364	8·95	5·61	4·84	—
			8	4·8	85	2·42	1·94	2·04	·14	6·54	11·79	1·25	13·86	1·43	·193	7·41	2·46	4·18	—
			17	5·0	100	1·15	1·03	·74	·10	3·02	10·45	1·12	10·30	·59	·076	7·76	1·01	4·16	—
			32	5·0	79	·72	·49	·84	·09	2·14	7·62	1·47	5.44	·26	·049	5·31	·45	3·55	—
Chichiwere																			
B 606	...	Secondary forest.	2	5·7	100	2·30	·93	·22	·25	3·70	5·08 (*a*)	2·47	3·72	1·55	·142	10·92	2·67	·85	—
			9	4·8	100	·51	·47	·04	·19	1·21	2·81	1·09	2·47	·42	·048	8·75	·72	·69	—
			29	4·5	100	·20	·24	·01	·06	·51	4·14	0·83	4·00	·19	·033	5·76	·33	1·28	—
			37	4·6	100	·20	·20	·005	·01	·41	5·70	1·00	20·00	—	—	—	—	1·99	—

(*a*) As determined with ammonium acetate.



Topsoil

0–2 inches: greyish brown (10YR 5/2), humous fine sandy light loam, structureless and loose. Highly acid (pH 5.7).

2–9 inches: pale yellowish brown (10YR 6/4), fine sandy light loam, structureless and loose. Highly acid (pH 4.8).

Subsoil

9–29 inches: pale brownish yellow mottled grey, fine sandy light loam, structureless and loose. Highly acid (pH 4.5).

29–37 inches: greyish yellow mottled orange, fine sandy light clay, structureless and loose. Highly acid (pH 4.6).

Fig. 40. Chichiwere series.

It is subject to occasional brief flooding: the water-table is related to the water level in associated rivers or streams.

Texture is very light and the soil unusually easy to work. Because of the low clay content, base exchange capacity is low and from the nutrient standpoint these waterborne sands are poorer than most of the other soils in the association. The series is suited to a root crop with low nutrient demands such as cassava. Its loose texture would also make it suitable for groundnuts. Where the water table is low enough coconuts do relatively well on this series, while it is also used for nurseries and vegetable crops. Its very limited extent within the basin and low natural fertility however make this a soil of little importance.

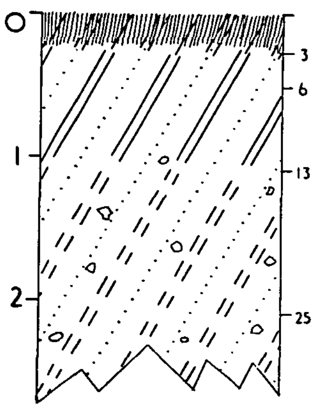
Moisture figures for the example described in Fig. 40 (Table 14) are low in the topsoil, where organic matter is also low. Bases fall rapidly below the topsoil, though exchange capacity increases in the heavier lower horizons where saturation is very low.

14. Oda series

Oda series is a grey ill-drained soil of valley bottoms, classified as an acid or a very acid gleisol. It is developed in mixed alluvium, mostly light clay with occasional sandy horizons. Its low and sometimes waterlogged site is the same as that of Densu series (q.v. below). Oda series is widespread in the Birrimian and granite areas of the basin, though rare in the Tertiary and coastal sand areas, where it is replaced by Aiyinasi series.

Detailed description

A grey to greyish brown light clay to clay humous topsoil overlies a subsoil usually consisting of grey light clay, sometimes with sand horizons. Quartz gravel, sand or pebbles may also be present. The following representative profile (LTB 84) was dug on the Asankrangwa-Samreboi road on a flat, bottom site where the vegetation was secondary swamp forest and the annual rainfall about 65 inches.



Topsoil

0–3 inches: grey (10YR 5/1) humous silty clay, structureless and firm. pH 5.6

3–6 inches: light brownish grey (10YR 6/2) slightly humous silty fine sandy clay, structureless and firm. pH 5.6.

Subsoil

6–13 inches: light grey (10YR 7/1) sandy clay, structureless and firm pH 5.4.

13–25 inches: light grey (10YR 7/2) sandy loam, structureless and fairly loose, containing rare fine quartz gravel. pH 5.4.

Fig. 41. Oda series.

Range in characteristics

As in many alluvial soils, there is a considerable range of texture, as well as of content of included quartz stones and gravel.

Agricultural value

This series is not so heavy to cultivate as the more plastic Densu series, which is relatively rare. Both external and internal drainage are slow, as shown by the grey colour.

The nutrient status of this series is low. The soil is usually moist, and occasionally water logged, and the vegetation is swamp forest or swamp regrowth. This series is suited only to crops adapted to poorly drained soils, such as rice and sugarcane. It is inextensive and usually occurs only in small scattered patches, often between river levees and the lower slopes of hills, or alongside small streams.

15. Densu series

Densu series is a grey plastic heavy alluvial clay found in valley bottoms where drainage is poor. It is classified as an acid or very acid gleisol. The clay fraction is thought to contain some montmorillonite in addition to the usual kaolinite.

Detailed description

A humous grey-brown clay topsoil (0–2 and 2–5 inches) merges into a grey plastic clay subsoil which may or may not contain odd pebbles or beds of pebbles or sand. This alluvial clay material lies unconformably over non-transported material below, which may be brown clay or decomposing phyllite of various colours. Topsoil reaction is in the range pH 4·4 to 6·0.

Agricultural value

Drainage, both external and internal, is poor. The heavy clay is fairly impermeable and, because this series is found in valley bottoms, runoff is so slow that during the wet season it is often permanently waterlogged. Because of the low position the series does not usually dry out in the dry season. On the rare occasions when it does, it dries to a very hard clay.

The soil is a heavy one for cultivation. Its vegetation is usually swamp forest or regrowth swamp vegetation difficult to clear because of the many spiny species it contains. Nutrient status is only moderate but exchange capacity and sometimes organic matter content are high and the water relationships of this series make it well suited to both rice and sugarcane. This is, however, a somewhat rare soil within the basin since the usual poorly drained valley bottom clay is the somewhat lighter textured and non-plastic Oda series which has a lower nutrient status.

Terrace soils

Series 16–18 *and* 26–27

Birim and Awaham series are well drained soils developed in river terrace material. Terraces are associated with most of the major rivers and some of the minor ones. In the Reports on the Bibiani goldfield (Hirst & Junner, 1946) Hirst writes: " Successively higher levels of the streams are marked by deposits of sand or gravel at 10–12 feet, 20–25 feet, 35–40 feet, 60–70 feet and 90–100 feet above the present levels ". The material in which these series are developed is usually a yellow-brown silty clay similar to Kakum series except that well marked pebble beds are more common than in Kakum series and the whole soil has been subject to weathering processes for a longer period: whereas Kakum series is an acid gleisol, Birim and Awaham series are ochrosols: their oxysol counterparts are Samreboi and Amoku series.

Birim series may be free of pebbles, or have pebble beds in the lower layers. These probably represent the bed of a former stream or river. When these pebble beds come near enough to the surface to interfere with cultivation, i.e. within 30 inches, a separate series is recognised: this is Awaham series. A poorly drained lowlying grey terrace soil is Boppa series, but this is very uncommon since most terraces are well drained. The lower terraces, however, are subject to occasional flooding when the rivers rise. The smaller rivers may rise rapidly after individual heavy storms: large rivers such as the Tano usually flood fairly regularly towards the end of the wet seasons. All terrace soils below 30 feet above the present stream must be considered as liable to at least very occasional brief flooding. Floods rise higher where the river valley is relatively narrow, but cover a larger area where the valley broadens out.

Terrace soils are always irregular in distribution since most of the terrace deposits at various levels have subsequently been removed, and it is only here and there that they are preserved. Sometimes the higher ones are found at or near the summits of low hills near the river. In many cases where the terraces have disappeared some stream-rolled pebbles can still be found incorporated in the gravel layers of normal sedentary soils.

16. Birim series

Birim series is the normal ochrosol developed in river terrace deposits. It consists of 5–10 feet or more of yellow-brown alluvial light clay which may contain pebble beds in the lower layers.

Detailed description

The average description (Fig. 42) is based on seventeen pits dug within the basin: reaction is discussed separately below.

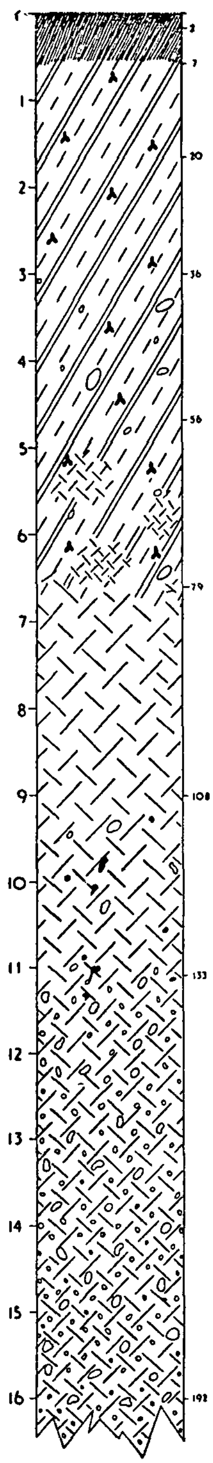
Range in characteristics

The average profile described above has a pebble bed below 133 inches, though these may occur anywhere in the lower subsoil (when they occur within 30 inches of the surface, the soil becomes Awaham series).

The reaction of soils developed in terrace deposits varies in the same way as all upland soils within the basin, and these soils may also be divided into oxysols, ochrosols and oxysol-ochrosol intergrades. The average pH values for pits within the basin divided into these three acidity groups are as follows:—

Average Depth in Inches	*Ochrosol (Birim series)*	*Intergrade*	*Oxysol (Samreboi series)*
0–2	5·9	5·3	4·7
2–7	5·7	5·0	4·5
7–20	5·4	4·9	4·7
20–36	5·4	5·0	4·8
36–56	5·2	5·0	4·8
56–79	5·2	5·0	4·9

11



Topsoil

0–2 inches: greyish brown (10YR 5/2) humous heavy loam, crumbly and loose.

2–7 inches: brown (7.5YR 5/4) slightly humous light clay, structureless and somewhat loose, sometimes with dark brown manganese dioxide stains.

Subsoil

7–20 inches: strong brown (7.5YR 5/6), light clay, structureless and slightly firm, sometimes with occasional manganese dioxide concretions and stains.

20–36 inches: light brown (7.5YR 5/4) light clay, structureless and slightly firm, sometimes with occasional manganese dioxide concretions and stains.

36–56 inches: strong brown (7.5YR 5/6), light clay, structureless and firm, with scattered terrace gravel and pebbles and occasionally with a few manganese dioxide concretions and stains.

56–79 inches: as above, except that this layer is sometimes slightly indurated.

79–108 inches: brown heavy loam, mottled red and grey, and somewhat indurated: no structure, and slightly difficult to dig.

108–133 inches: brownish yellow, mottled grey, white, and red, slightly indurated heavy loam, structureless and very firm, containing occasional scattered terrace pebbles and gravel and occasionally a few rare ironstone concretions.

Parent material

133–192 inches: brown, mottled yellow, grey and red, slightly indurated heavy loam, structureless and very firm, often containing frequent rounded stream pebbles and water-worn gravel.

Fig. 42. Birim series.

Agricultural value

This soil can be regarded as an older and better drained Kakum, showing its age by becoming slightly indurated in the subsoil and even by developing a few small ironstone concretions. The flattish topography and high fine earth fraction consisting of water-borne silt and clay are characteristic of an alluvial soil, but the better drainage, higher site and greater age are more characteristic of upland sedentary soils.

The nutrient status of terrace soils depends largely on the acidity group to which they belong, Birim series being similar to Kakum series and Samreboi series, its oxysol counterpart, resembling Kwaben series, particularly in the case of the lower-lying soils still subject to very occasional flooding. The higher soils may be more comparable to Nzima or Boi series.

Birim series is usually easy to work, well drained and not subject to dry season drought, but its main disadvantage is its scattered and irregular distribution. The largest single area of terrace deposits was found was at Samreboi, which is built on a low-level terrace with well developed pebble beds. The usual flattish site of the series is a further advantage. This soil is often seen supporting good cocoa and a wide range of food crops.

17. Awaham series

Awaham series is a terrace soil, very similar to Birim series except that pebble beds, absent from Birim series or occurring only in the subsoil, are found at or near the surface. It usually occurs in areas where the rainfall is 65 inches per annum or less: the oxysol counterpart, more common in wetter areas, is Amoku series (series 27, page 175).

Detailed description

This is the same as for Birim series except that occasional rounded stream-rolled pebbles may be found in the topsoil, and well developed pebble beds occur within 30 inches of the surface.

The representative example described in Fig. 43 was dug in the Suraw valley, south of Sefwi-Bekwai, on a very gently undulating middle-slope site where the rainfall is about 65 inches per annum.

Range in characteristics

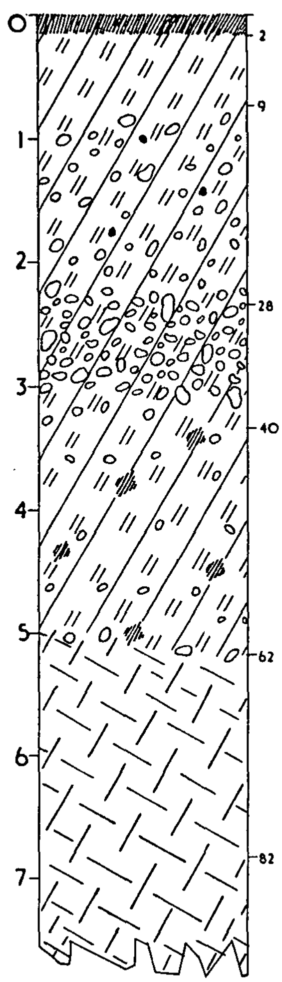
An indurated layer, as in the example described above, occurs in most pits below the pebble beds.

Agricultural value

Agriculturally this series is similar to Birim series (q.v.) except that the pebbles near the surface may interfere with cultivation and occasionally reduce the fine earth fraction of the topsoil.

18. Boppa series

Boppa series is a very minor terrace soil found only rarely within the basin. It is a grey, ill-drained terrace deposit containing stream pebbles. It can be regarded as a very pebbly associate of Oda series. As in the case of Oda series, texture varies somewhat, the soil is poorly drained and low in nutrients, and best suited to rice or chewing cane.



Topsoil

0–2 inches: greyish brown (2.5Y 5/2) silty fine sandy humous clay, crumbly and loose. pH 5.6.

2–9 inches: brown (10YR 5/3) silty fine sandy clay, structureless and loose. pH 5.2.

Subsoil

9–28 inches: yellowish brown (10YR 5/8) silty clay, structureless and fairly firm, containing very frequent terrace pebbles and stream-worn gravel, a little angular quartz gravel, and rare ironstone concretions. pH 4.6.

28–40 inches: brownish yellow (10YR 6/6) silty clay, structureless and firm, containing very frequent to abundant terrace pebbles and stream-worn gravel. pH 4.8.

40–62 inches: orange-brown mottled red silty light clay, structureless and firm, containing frequent stream-worn gravel. pH 4.8.

62–82 inches: orange-red mottled yellow hard indurated material, structureless and difficult to dig. pH 5.0.

Fig. 43. Awaham series.

1C. THE NZIMA-BOI ASSOCIATION

This association includes all soils under 1B and 1D, i.e. numbers 5–27.

1D. THE BOI ASSOCIATION

19. Boi series

Boi series is the most extensive soil in the Lower Tano Basin, being the normal acid sedentary soil developed over Lower Birrimian phyllites and greywackes where the annual rainfall is above about 65 inches. It is the oxysol equivalent of Nzima series, which it outwardly resembles. The main difference between the two series is the greater acidity of Boi series, reflecting the leaching of bases it has suffered due to the higher rainfall. Boi series is also often more deeply weathered, with the deep mottled lower subsoil characteristic of many forest oxysols, and has a slightly thinner topsoil which, by definition, has a reaction of below pH 5·0 whereas Nzima series has a topsoil less acid than pH 5·5. Soils with topsoils in the range pH 5·0 to 5·5 are intergrades between the two series.

Boi series is found on a very wide range of sites from summit to lower slope and occupies most of the upland areas in the Boi association.

Detailed description

The average description (Fig. 44) is based on twenty-four pits dug within the basin.

Range in characteristics

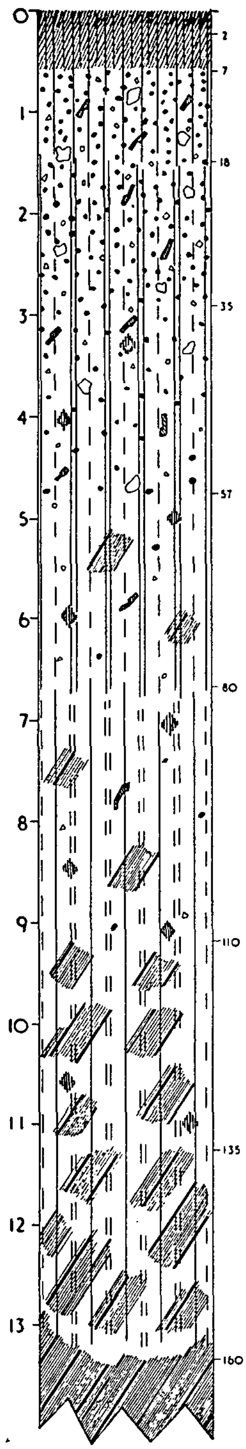
The subsoil is yellow-brown to orange-brown in colour. The depth at which traces of decomposing rock are found varies between about 8 and 20–25 feet. About one-third of the pits, particularly the deeper ones, are slightly indurated in the lower subsoil, below 5–6 feet. There are the same stony and brashy subseries as for Nzima series, containing unusually large quantities of quartz stones or ferruginised rock brash.

Agricultural value

The cultivation characteristics and physical properties of this series are similar to those of Nzima series, its ochrosol counterpart. The normal topsoil has a moderate crumb structure, particularly in the more humous top 2 inches, and is light textured, free of stones and easy to work with local hand tools, though under the heavy rainfalls of the basin clearing and topsoil disturbance should be kept to a minimum. The gravelly and concretionary subsoil below the topsoil is heavier in texture and, because of the included material, less easy to work, though roots penetrate this layer without difficulty. Small holes dug for plantain suckers, cocoyams, tree seedlings, etc., stir up a little of the subsoil gravel. Clearing on the steeper sites has often led to topsoil removal, with the result that gravel is now found at or near the surface. Whereas a well-developed humous topsoil with a leaf litter layer and some plant protection is able to absorb a relatively high percentage of the rainfall, clearing, topsoil removal, and puddling and loss of topsoil structure all result in increased runoff and still further loss of the topsoil, and thus a rapid deterioration both in nutrient status and in water relationships of the soil. On the steeper sites, clearing should be done with caution.

External drainage of this series is usually good, since the normal relief associated with phyllite areas of the basin is dissected and fairly steeply sloping. Internal drainage is moderately good, both in the gravelly subsoil and in the weathered substratum where there is less clay. The permanent water-table in these upland soils is often very deep, so that of the twenty-four pits of this series dug within the basin, to depths of up to 30 feet, none reached water. Nevertheless, water retention in the normal profile is usually quite sufficient, under the high rainfalls and relatively short dry seasons of the basin, to ensure an adequate moisture supply for crops throughout the year. The high rainfall and absence of drying-out are thought to account for the yellowish colour of the subsoil and the absence of red soils from the association.

The nutrient status of Boi series is low compared with an average forest ochrosol subject to less leaching. Total exchangeable bases of a typical Boi series are, in the topsoil, probably only of the order of 10 per cent of a typical ochrosol (*N.B.* Table 5 refers to ochrosols within the basin only: ochrosols from the main ochrosol belt to the north have higher average nutrient status than those southern examples falling within the basin). The main effects of increased leaching are, however, on calcium and magnesium, and the differences in potash in particular are not so great (Tables 5 and 6). Boi series has, on the average, about ·3–·4 m.e. of potash per 100 gm. in the upper topsoil, falling to



Topsoil

0–2 inches: grey-brown to brown (10YR 5/2–5/3) humous clay to light clay, crumbly and loose. Highly acid (average pH 4.7, range 4.0 to 5.0).

2–7 inches: pale yellowish brown to pale brown (10YR 6/3–6/4) slightly humous clay, slightly crumbly and slightly loose. Highly acid (average pH 4.6 to 4.7, range 4.2 to 5.0).

Subsoil

7–18 inches: pale yellowish brown to yellow-brown (10YR 6/4–5/6) clay, and structureless firm, containing very frequent ironstone concretions, frequent quartz gravel, and occasional subangular quartz stones and ferruginised rock brash. Highly acid (average pH 4.7., range 4.4. to 5.2).

18–35 inches: strong brown (7.5YR 5/6) light clay, structureless and firm containing very frequent ironstone concretions, occasional to frequent quartz gravel, occasional quartz stones and ferruginised rock brash. Highly acid (average pH 4.8., range 4.6 to 5.4).

35–57 inches: strong brown (7.5YR 5/6) sometimes stained or slightly mottled, light clay, structureless and firm, containing occasional to frequent ironstone concretions, occasional quartz gravel, quartz stones and ferruginised rock brash. Highly acid (average pH 4.9, range 4.6 to 5.2).

57–80 inches: pale orange-brown mottled red, brown, grey or yellow light clay to heavy loam, structure and firm, containing rare ironstone concretions, gravel and ferruginised rock brash. Highly acid (average pH 5.0, range 4.6 to 5.2).

Weathered substratum

80–110 inches: pale orange-brown mottled red, brown and yellow, heavy loam, structureless and fairly firm, containing rare ironstone concretions, gravel and ferruginised rock brash, and rare traces of decomposing rock. Highly acid (average pH 5.0, range 4.8 to 5.2).

110–135 inches: pale orange-brown, mottled red, brown, grey or yellow heavy loam, structureless and somewhat soft, with traces of decomposing phyllite. Very acid (average pH 5.1, range 4.8 to 5.6).

135–160 inches: highly mottled (but usually predominantly orange-brown) heavy loam, structureless and soft, with frequent traces and fragments of various coloured decomposing phyllite. Very acid (average pH 5.1 to 5.2, range 4.6 to 5.4).

Below 160 inches: decomposing phyllite.

Fig. 44. Boi series.

under ·1 m.e. in the subsoil, an amount which, in the topsoil, represents about 60 per cent of the average for ochrosols within the basin, while in the subsoil, where total quantities are low, both groups of soils contain approximately equal quantities of exchangeable potash.

Nitrogen in the average Boi series is thought to be of the order of ·2–·4 per cent in the upper topsoil, decreasing rapidly below this to under ·1 per cent in the subsoil. These figures are, in the upper topsoil, about 30 per cent below those of the ochrosols within the basin but both organic matter and nitrogen in soils developed under the heavier rainfalls, such as Boi series, seems to be spread down the profile slightly more than is the case with the normal ochrosol, so that, in the subsoil, nitrogen may be slightly higher than in the corresponding ochrosol. For a discussion of nitrification and seasonal changes in nitrate levels *see* Part I, page 24.

Of the third major nutrient, phosphorus, relatively little is known. Total phosphorus in Boi series is probably of the order of 150–400 p.p.m. in the topsoil, often decreasing slightly in the subsoil, but phosphorus actually available to any particular crop is not known. Phosphorus may well be the major nutrient in shortest supply and the restoration of available phosphorus levels (mostly organic phosphorus) may be the main function of bush fallows (*see* Part I, page 23).

Of the major oxysols present in the southern half of the basin, Boi series has a similar or slightly higher nutrient status than those developed over Tertiary sands (Tikobo series, Nuba subseries) and a somewhat higher nutrient status than those over granite (Abenia series). It appears suited to oil palm and rubber, but is less suited to coconut palm than is the deeper, sandy Tikobo series. Coffee, of appropriate varieties, should be confined to the better drained examples. Plantain and cocoyam grow on this series, but yields are low compared with those obtained from a normal forest ochrosal: cassava and pineapples are widely grown on this soil, and citrus appears to do relatively well.

Boi series is associated with a yellow-brown non-gravelly alluvial soil, Kwaben series, occurring on lower slopes and valley bottoms, which, though of similar topsoil reaction, is considerably more productive. This is due, at least in part, to the higher fine earth fraction of Kwaben series. A comparison of the two is given below (page 173), under Kwaben series. Within the Boi association, productive cocoa is usually confined to Kwaben series.

Six profiles of Boi series have been analysed, one of them having been given a full mechanical analysis. The relevant analytical data are given in Tables 15 and 16, the profiles concerned being the following:—

Profile B 835 was sampled on a flat, summit site near Seewum where the annual rainfall is about 65 inches. This example is similar to the average Boi series described above, with abundant gravel to 37 inches, and rather more frequent quartz stones than usual. This example was slightly indurated below 47 inches.

Profile B 836 was sampled on a gently rolling upper-slope site between Jemma and Abenia, in the centre of the basin, where the annual rainfall is over 70 inches. This is similar to the previous example except that it has fewer concretions and stones. The profile is slightly indurated below 75 inches.

Profile B 837 for which the analyses available include a complete mechanical analysis, was sampled on a strongly rolling middle slope site north of Ebowu, Eastern Nzima, where the vegetation was forb regrowth and the rainfall is nearly 85 inches per annum. A detailed description follows:

Topsoil

0–3 inches: greyish brown (10YR 5/2) humous silty light clay, crumbly and fairly firm.

3–7 inches: pale brown (10YR 6/3) slightly humous silty light clay, structureless and firm.

Subsoil

7–16 inches: strong brown (10YR 5/6) silty clay, structureless and firm, containing very frequent ironstone concretions, frequent ferruginised rock brash and rare quartz stones and gravel.

16–27 inches: strong brown (10YR 5/6) silty light clay, structureless and firm, containing rare ironstone concretions, ferruginised rock brash and quartz stones.

27–42 inches: orange-brown, slightly mottled red, silty clay, structureless and firm, containing very rare ironstone concretions and quartz gravel, and rare traces of weathered rock.

42–66 inches: pale orange-brown, mottled yellow, red and olive, silty light clay, structureless and fairly firm, with rare traces of weathered rock.

Weathered substratum

66–138 inches: pale orange-brown heavy loam, mottled red, yellow and grey, structureless and soft, with traces of decomposing phyllite becoming more frequent with depth.

Profile B 838 *was sampled from a gently undulating summit site east of Awiebo in Eastern Nzima where the annual rainfall is about* 85 *inches. This example had fewer concretions and stones in the gravel layer than the average.*

Profile B 877 *was sampled on a rolling upper-slope site* 3½ *miles south of Samreboi on the footpath to Abenia. This example contained only small amounts of ironstone concretions but relatively large quantities of quartz stones and gravel.*

Profile B 998 *was sampled on a gently undulating middle-slope site on Sample strip* 16, *near Ebowu, where the rainfall approaches* 85 *inches per annum. The detailed description is as follows:—*

Topsoil

0–2 inches: pale brown (10YR 6/3) humous silty light clay, crumbly and slightly loose.

2–5 inches: brown (10YR 5/3) slightly humous silty light clay, structureless and loose, with rare ironstone concretions.

Subsoil

5–13 inches: yellowish brown (10YR 5/4) silty clay, structureless and a little loose, containing very frequent ironstone concretions and occasional quartz stones, gravel and cubes of oxidised iron pyrites.

13–26 inches: yellowish brown (10YR 5/6) silty clay, structureless and firm, containing frequent ironstone concretions and rare quartz stones and gravel.

26–42 inches: reddish brown, (5YR 5/4) very slightly mottled yellow and red silty light clay, structureless and soft, with very rare ironstone concretions.

The nutrient status of the above six examples is fairly representative of oxysols in general. The average of all of them is similar to the average for twenty-two Lower Tano Basin oxysols (Table 5), but these average figures are of little value since there are very considerable variations between individual examples: total exchangeable bases in the upper topsoil, for example, vary from only 1·63 m.e. per 100 gm. of the fine earth fraction to 6·24 m.e.

Of the individual bases, exchangeable calcium shows the greatest variation. Manganese is fairly low throughout. Potash figures on the other hand, though low, are reasonably good for this type of soil, and in oxysols potash forms a larger proportion of the total bases than it does in ochrosols, a fact which might indicate a greater availability of this element. Total phosphorus shows little variation between the 4 horizons of each example analysed, though there is more variation between profiles. How much of this phosphorus is available is not known. Ca/Mg ratios are rather low; C/N ratios tend to be moderately high.

The fine earth analysis of B 837 (Table 16) should be compared with the analysis of Nzima series (Table 11) which is morphologically similar. The percentage of clay rises in both profiles to a maximum in the upper subsoil, where clay is 40 - 60 per cent of the fine earth fraction, but falls rapidly in the weathered substratum. The air-dry moisture content closely reflects the clay content. In both profiles the first subsoil horizon is also the zone of maximum accumulation of coarse material. In this profile the silt fraction increases steadily from 9 per cent in the topsoil to 18 per cent at about 7 feet down, after which it decreases slightly as the fine sand percentage increases.

TABLE 15

ANALYTICAL DATA FOR BOI SERIES

Series and Profile Number	*Vegetation*	*Lower depth of horizon in inches*	*pH*	*% Fine earth*	*Exchangeable Bases (m.e. per 100 gm.)* Ca	Mg	Mn	K	S (TEB)	T (CEC)	*Ca/Mg*	*Mg/K*	*C*	*N*	*C/N*	*O.M.*	*Moistu e % Air-dry*	*Tota lP p.p.m.*
Boi																		
B 835 ...	Cultivation and Broken forest.	2	4·9	54	3·10	1·21	·13	·30	4·74	11·16 (*a*)	2·56	4·03	4·09	·340	12·03	7·03	2·60	321
		5	5·1	34	·79	·50	·03	·12	1·44	6·76	1·58	4·17	1·35	·135	10·00	2·32	1·94	258
		15	5·2	22	·64	·56	·03	·16	1·39	8·03	1·14	3·50	1·42	·121	11·74	4·44	2·78	278
		22	5·4	28	·27	·66	·01	·16	1·10	11·19	·40	4·19	·79	·124	6·37	1·36	4·51	279
Boi																		
B 836 ...	Broken forest.	2	4·1	100	·62	·69	·03	·29	1·63	15·77 (*b*)	·89	2·38	3·90	·273	14·29	6·71	2·36	174
		7	4·3	78	·18	·26	·01	·15	·60	9·55	·69	1·73	1·34	·110	12·18	2·30	2·03	142
		14	5·0	32	·17	·20	·01	·06	·44	8·42	·85	3·33	·82	·071	11·55	1·41	1·99	133
		25	4·6	23	·25	·25	·01	·06	·57	7·74	1·00	4·02	·53	·060	8·83	·91	2·36	186
Boi																		
B 837 ...	Forb regrowth	2	4·8	95	1·17	·79	·03	·22	2·46(*c*)	12·60 (*b*)	1·51	2·39	2·47	·189	13·07	4·25	1·78	174
		3	4·1	91	·30	·44	·01	·07	1·09	7·31	·79	3·90	·82	·081	10·12	1·41	1·52	123
		16	5·1	52	·31	·35	·01	·02	·96	7·83	·45	8·00	·67	·070	9·57	1·15	2·17	140
		27	4·9	93	·26	·31	·01	·04	·78	8·42	·38	2·85	·52	·059	8·81	·89	2·33	140
Boi																		
B 838 ...	Thicket	2	4·5	100	3·41	2·28	·13	·42	6·24	18·51 (*b*)	1·50	5·43	4·39	·347	12·63	7·55	3·14	311
		5	4·6	53	·80	·98	·01	·09	1·88	10·89	·82	10·70	1·69	·154	10·97	2·91	2·18	249
		12	4·8	50	·25	·51	·01	·07	·84	12·72	·51	7·29	1·05	·104	10·10	1·81	3·25	319
		28	5·0	63	·16	·46	·01	·04	·67	10·58	·35	11·50	·75	·093	8·39	1·34	3·72	325
Boi																		
B 877 ...	Broken forest.	1	3·9	100	1·64	1·12	·05	·34	3·15	15·14 (*a*)	1·46	3·29	5·15	·350	14·71	8·58	2·83	308
		6	4·0	87	·47	·32	·01	·10	·90	6·79	1·47	3·20	1·20	·110	10·91	2·06	1·84	200
		13	4·6	23	·29	·19	·01	·12	·61	6·31	1·53	1·58	·74	·078	9·49	1·27	2·17	215
		31	4·5	18	·31	·34	·01	·11	·76	6·68	·91	3·09	·58	·053	10·94	1·00	2·48	260
Boi																		
B 998 ...	Secondary forest.	2	4·9	64	2·31	1·38	·08	·42	4·19	—	1·67	3·94	3·29	·232	14·18	5·66	1·68	—
		5	4·8	60	·72	·47	·02	·14	1·35	—	1·53	3·92	1·86	·154	12·08	3·20	1·39	—
		13	4·9	37	·33	·18	·08	·11	·70	—	1·83	2·00	·86	·084	10·24	1·48	1·57	—
		26	4·9	55	·31	·23	·005	·11	·655	—	1·35	3·29	·60	·071	8·46	1·03	1·79	—
Boi																		
Average of profiles given above.	do.	1·5	4·5	85	2·05	1·25	·08	·35	3·73	—	1·64	3·57	3·88	·285	13·61	6·63	1·68	—
		5·2	4·5	67	·55	·49	·02	·12	1·18	—	1·12	4·08	1·38	·124	11·13	2·37	1·39	—
		13·3	4·9	36	·31	·34	·03	·10	·78	—	·91	3·40	·93	·088	10·57	1·93	1·57	—
		26·5	4·9	47	·24	·39	·01	·09	·72	—	·62	4·33	·63	·077	8·18	1·09	1·79	—

(*a*) As determined with ammonium acetate.
(*b*) As determined with barium acetate.
(*c*) Including Na.

TABLE 16

MECHANICAL ANALYSIS OF BOI SERIES (PROFILE NO. B837)

Lower Depth of Horizon in inches	*Cross Mechanical Analysis per cent. Air-Dry*				*Mechanical Analysis of Fine Earth per cent. Oven-Dry*								*Per cent. Oven-Dry*		Moisture per cent.
	Stones > 20*mm.*	*Coarse Gravel* 20-6·20*mm.*	*Fine Gravel* 6·05-2*mm.*	*Fine Earth* <2*mm.*	*Very Coarse Sand* 2-·625*mm.*	*Coarse Sand* ·625-·2*mm.*	*Fine Sand* ·2-·02*mm.*	*Silt* ·02-·002*mm.*	*Clay* <·002*mm.*	*CaCO3*	*Loss on Solution*	*Total*	*Ignition Loss*	*Corr. Ignition Loss*	
3	Nil	3·7	1·6	94·7	2·75	21·17	39·04	9·59	22·17	Nil	4·91	99·63	7·34	3·09	1·86
7	Nil	2·7	1·7	95·6	4·04	16·57	38·32	10·50	27·71	Nil	2·32	99·46	6·14	4.73	1·56
16	2·0	23·0	23·0	52·0	4·41	10·63	29·42	11·72	41·94	Nil	1·88	100·00	6·41	5·26	2·00
27	Nil	4·8	2·1	93·1	1·40	8·03	22·43	13·88	52·68	Nil	1·04	99·46	8·50	7·61	2·08
42	Nil	1·7	·3	98·0	·77	5·51	21·85	15·64	54·57	Nil	1·41	99·75	11·08	—	2·20
66	Nil	·8	·7	98·5	·31	5·30	27·46	17·87	47·82	Nil	1·39	100·15	8·58	—	2·10
88	Nil	·7	·6	98·7	·52	7·80	42·51	18·40	29·71	Nil	·91	99·93	7·32	—	1·56
114	Nil	Nil	Nil	100·0	·36	10·29	56·18	11·47	21·10	Nil	·51	99·91	7·19	—	1·34
138	Nil	·7	·6	98·7	·62	8·75	60·89	15·57	13·48	Nil	·55	99·86	6·67	—	1·06

TABLE 17

ANALYTICAL DATA FOR SUTRI SERIES

Series and Profile Number	*Vegetation*	*Lower depth of horizon in inches*	*pH*	*% Fine earth*	*Exchangeable Bases (m.e. per 100 gm.)* Ca	Mg	Mn	K	S (TEB)	T (CEC)	*Ca / Mg*	*Mg / K*	*C*	*N*	*C/N*	*O.M.*	*Moisture % Air-dry*	*Total P p.p.m.*
Sutri																		
B 879 ...	Broken	3	4·9	40·2	9·68	2·65	·12	·51	12·96	26·38 (*a*)	3·65	5·20	5·72	·500	11·44	9·84	6·69	—
	forest.	6	5·1	36·8	1·59	·72	·01	·27	2·59	10·58	2·67	2·67	2·44	·234	10·43	4·20	6·03	—
		16	5·0	40·1	·43	·28	·01	·13	·85	8·40	2·15	3·31	1·45	·159	9·12	2·49	6·28	—
		33	5·2	48·3	·47	·27	·005	·15	·91	9·07	1·74	1·08	·96	·111	8·73	1·65	6·23	—

(*a*) As determined with ammonium acetate.

20. Omappe series

Omappe series is the oxysol counterpart of Atonsu series (Series 6, page 141), differing from it in the greater leaching to which it has been subject and, consequently, in its more acid reaction which, in the topsoil, is pH 5·0 or below. Omappe series is usually found in areas where the annual rainfall is over 65–70 inches per annum. It is an indurated upland soil consisting essentially of a humous topsoil, sometimes thin or absent and often gravelly, overlying a highly gravelly upper subsoil which in turn overlies, usually at 4–5 feet, the mottled and indurated layer which distinguishes this series from associated sedentary soils such as Boi series. The morphology of Omappe series is very similar to Atonsu series (q.v.) and, as in the case of Atonsu series, this series is usually developed on flattish upland sites where the underlying geology is Lower Birrimian, Upper Birrimian or, occasionally granite. Since flattish upland remnants of former peneplains are commoner in the north of the basin than in the south, where most appear to have been eroded away, Omappe series is, proportionately, less common in the Boi association of the southern half of the basin than is Atonsu series in the Nzima and Nzima-Boi associations to the north.

Agricultural value

The main agricultural disadvantages of Atonsu series, namely the low fine earth fraction and consequent low moisture and nutrient-retaining capacity of the gravel layer and the poor internal drainage conditions resulting from the presence of the indurated layer, also apply to Omappe series, with the additional limitation that (as in all oxysols) most of the exchangeable bases have been leached out of the soil. This is, therefore, a soil with both a low nutrient status and unsatisfactory moisture relationships, and is one with relatively limited agricultural possibilities, though, in the wet areas where it is usually found, it is not as subject to dry season drought as is Atonsu series. Nutrient status is too low for cocoa and drainage is not rapid enough for coffee: oil palm roots would probably go through the indurated layer and oil palm would possibly be the tree crop best suited to this series. Yields from annual crops can be expected to be lower than for Boi series. Slightly indurated soils intermediate between Boi and Omappe series are often encountered, since some induration in the lower subsoil is common in upland soils within the association.

21. Sutri series

Sutri series is the oxysol equivalent of Nsuta series, a shallow soil consisting essentially of a highly concretionary layer overlying massive ironpan. The normal site of the two series is the same, i.e. flat hill-summits usually representing the remains of former peneplains, but the annual rainfall of Sutri series is greater, being 65–85 inches, though this series is thought to be very rare if not absent in the south of the basin where the rainfall approaches the higher figure.

The morphology of this series is the same as that of Nsuta series (q.v.). The topsoil pH is, by definition, below 5·0. Below the topsoil pH values usually rise slightly.

Agricultural value

Sutri series, being more acid, is lower in bases than Nsuta series, but the main agricultural limitation remains the massive ironpan layer which limits root development to the upper 30 - 50 inches of the soil and also completely impedes the internal drainage. As a result the soil is poorly drained during wet periods but is liable to dry out at other times. For this reason, this series, if cultivated at all, is best used only for shallow-rooted annuals such as cassava. Its nutrient status is limited by the very low fine earth fraction.

The following profile (B 879) has been analysed (Table 17). It was dug on a high hill near Asemkrom, in the centre of the basin, where the site is upper slope to summit and gently undulating. Vegetation was broken forest, and the rainfall is about 75 inches per annum.

Topsoil

0–3 inches: dark brown (10YR 3/3), humous silty clay, crumbly and slightly loose, containing occasional to frequent small and large irregular ironstone concretions.

3–6 inches: dark yellowish brown (10YR 4/4), silty clay, structureless and firm containing very frequent small and large irregular ironstone concretions and ferruginised rock fragments.

Subsoil

6–16 inches: yellowish brown (10YR 5/4), silty light clay, structureless and firm, containing very frequent small and large irregular ironstone concretions and rare boulders of ironpan.

16–33 inches: yellowish brown (10YR 5/6), silty clay, structureless and firm, containing very frequent small and large irregular ironstone concretions, and rare quartz gravel and stones.

33–42 inches: brownish yellow (10YR 5/8), slightly indurated clay, structureless and very firm, containing abundant ironstone concretions and rare pieces of broken ironpan.

Below 42 inches: orange-brown, mottled, hard ironpan with some embedded ironstone concretions. Too hard to be dug.

The analysis of this profile (Table 17) shows relatively high base figures for an oxysol, expressed as m.e. per 100 gm. of the fine earth fraction, but the fine earth fraction is small (being only 40·2 per cent even in the topsoil) and total nutrient reserves are therefore low. Even without the pan impeding drainage and root development this would be only a moderately fertile soil. Short-rooted annuals might give a satisfactory return on this particular example immediately after clearing, but the soil would be rapidly exhausted.

22. Totua series

Totua series is an immature soil developed on steep slopes where the parent material is phyllite and the annual rainfall is 65 - 70 inches and above. The morphology of this series is similar to that of Kobeda series (series 8, page 145) its outwardly similar but less acid equivalent, from which it differs by virtue of its highly acid topsoil (which has a pH value of below 5·0) and the lower content of exchangeable bases which this reflects. Under the high rainfall experienced by the association it is even more necessary than in the case of Kobeda series to guard against accelerated erosion. No analyses are available of this series: it is distinctly less productive than the less acid Kobeda series, but, within the association, the high fine earth fraction and the fact that decomposing phyllite is found within rooting depth probably give this series a slightly higher nutrient status than most associated upland soils. The usual steep site of this series and its good external drainage suggest its use for tree crops such as coffee and oil palm: clearing for annual crops, in view of the dangers of erosion, should be avoided.

23. Ebowu series

This is the oxysol equivalent of the Amuni series (series 9, page 149). There is little outward difference between the two soils and the detailed description of Amuni series applies equally well to Ebowu series except that the topsoil pH is usually 4·6–4·8 tending to rise to about 5·0 or a little more in the subsoil. No analyses are available, but bases and, to a lesser extent, organic matter content are probably considerably below those of Amuni series. As in the case of Totua series, the nutrient status of this soil is probably equivalent to or somewhat better than Boi series, the associated acid sedentary soil which occupies most of the upland areas of the association, but the agricultural value of this soil, which is of minor extent within the association, is limited by the usual steep and often inaccessible site and by the danger of accelerated erosion following clearing.

24. Bremang series

This is the oxysol equivalent of Kokofu series. The detailed description of Kokofu series (series 10, page 149) applies equally well to Bremang series except that the normal topsoil pH is 4·4 - 4·8 and tends to rise below this to about 5.0 in the weathered substratum. Cultivation characteristics of the two soils are the same, but yields on Bremang series will be reduced by its lower content of plant nutrients. Rainfall is heavier and more care is required to prevent erosion and topsoil removal. The nutrient status of this soil has the same relationship to that of Boi series as Kokofu series has to

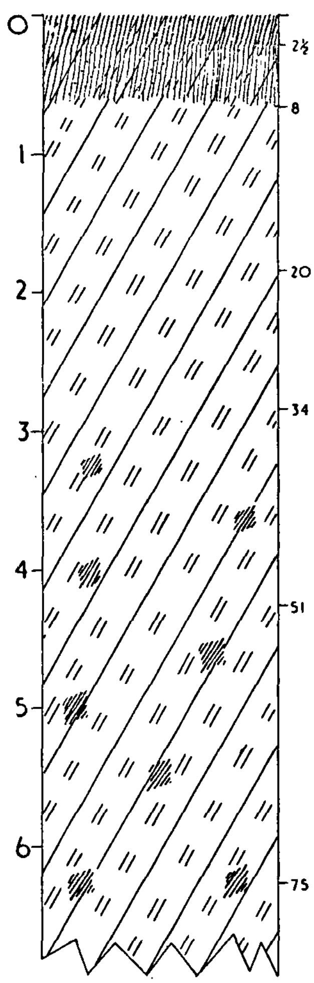
Nzima among the ochrosols, i.e. the high fine earth fraction probably ensures a nutrient status similar to or slightly higher than Boi series. The absence of included gravel suggests that this series is best used for root crops, but tree crops such as oil palm or rubber would be more satisfactory in preventing erosion. The lower-slope site of this series, which is of minor extent within the association, is probably insufficiently well drained for coffee.

25. Kwaben series

Kwaben series, a very acid gleisol, is undoubtedly the most productive and valuable soil in the Boi association, though it is far less extensive than Boi series, the associated upland oxysol. It is a yellow-brown alluvial light clay of levees and the better drained valley-bottom areas, differing from the outwardly similar Kakum series in its more acid reaction. Kwaben series is also found within the remaining associations of the southern half of the basin.

Detailed description

The general description (Fig. 45) is based on eighteen pits dug within the basin.



Topsoil

0–2½ inches: light brownish grey (10YR 6/2) humous silty fine sandy light clay, crumbly and loose. Highly acid (average pH 4.7, range 4.6 to 4.8).

2v–8 inches: pale brown (10YR 6/3) slightly humous silty fine sandy light clay, structureless and fairly firm. Highly acid (average pH. 4.7, range 4.4 to 5.0).

Subsoil

8–20 inches: light yellow brown (10YR 6/4) silty light clay, structureless and firm Highly acid (average pH 4.7, range 4.4 to 5.2).

20–34 inches: as above but with an average pH of 4.9 and a range of 4.6 to 5.4.

34–51 inches: pale brownish yellow mottled grey and orange silty light clay, structureless and firm. Highly acid (average pH 4.9, range 4.6 to 5.4).

51–75 inches: as above, but with an average pH of 5.2.

Fig. 45. Kwaben series.

Range in characteristics

Some examples go deeper than the 75 inches indicated above. Below the transported material rotting bedrock is found, but usually the water-table prevents the digging of pits to this depth. Some profiles contain scattered stream gravel. Drainage varies according to site, this series grading into the grey Oda series in the poorer drained parts, though all Kwaben series are subject to occasional flooding. A darker, more manganiferous soil otherwise similar to Kwaben series has been recognised in some areas (notably in the valley of the Ehuro, North-east of Enchi) and this has been named Ehuro series.

Agricultural value

Field observations suggest that in the southern part of the basin where nearly all the soils are oxysols, Kwaben series is the most fertile soil present. It is the only series in this area which can be recommended for cocoa, and it also gives better food crop yields than adjacent sedentary soils. It is not, however, as well suited to coconuts or oil palm as the deep soils developed over Tertiary sands, though it has been seen to support Para rubber in very good condition.

This soil is easy to work with local hand tools and is usually free of stones and gravel. Internal drainage, because of the high silt content, is moderately good, but external drainage is often slow and its position in valley bottoms and along levees means that for most of the year the water-table is not very far from the surface, though this fluctuates considerably with the season. There is a very wide range in water volume of the major rivers of the basin, and a considerable difference in height of water between their normal level and their flood level. Because of this Kwaben series is liable to occasional flooding, but as soon as the water goes down the soil becomes moderately well drained again: this is in strong contrast to the associated grey soils, Oda and Densu series. Those Kwabens on a very well developed levee site are the best drained, and these are also often a little more sandy than those further away from the river. The poorer drained Kwaben series, where these intergrade with Oda and Densu series, are distinguished by their paler colour and the presence of coarse mottles relatively near the surface, whereas the normal Kwaben series has only a few stains or slight mottles in the subsoil.

Eight examples of this series have been analysed (Table 18) and these eight profiles are described first:

B 850 *was sampled from a flat bottom site between Jemma and Abenia where the annual rainfall was about* 70 *inches or a little more: it supported very good cocoa. The analyses indicate remarkably high manganese content and manganese stains were noticed in the field. The detailed description of this profile is as follows:*

Topsoil

0–2 inches: greyish brown (10YR 5/2) humous silty clay, crumbly and loose.
2–5 inches: pale brown (10YR 6/3) slightly humous silty clay, slightly crumbly and slightly loose.

Subsoil

5–15 inches: light yellowish brown (10YR 6/4) stained orange and brown silty clay, structureless and firm, with rare MnO_2 stains.
15–28 inches: light yellowish brown stained orange and brown, silty light clay, structureless and firm, with some MnO_2 stains.
28–44 inches: brownish yellow mottled grey, yellow and brown silty light clay, structureless and firm, with some MnO_2 stains.

B 851 *also supported good cocoa: this sample was dug from a nearly flat valley bottom site along the banks of the Kusuru stream north of Seewum where the annual rainfall is about* 65 *inches. The profile morphology is very similar to B* 850 *above, except that no manganese stains were noticed.*

B 852 *supported only thicket vegetation, about four years old, and was dug on the bank of the Tano near Abenia where the annual rainfall is a little over* 70 *inches. The detailed description of this profile follows:*

TABLE 18

ANALYTICAL DATA FOR KWABEN SERIES

Series and Profile Number	*Vegetation*	*Lower depth horizon in inches*	*pH*	*% Fine earth*	*Exchangeable Bases (m.e. per 100 gm.)*						*Ca/Mg*	*Mg/K*	*C*	*N*	*C/N*	*O.M.*	*Moisture % Air-dry*	*Total P p.p.m.*
					Ca	*Mg*	*Mn*	*K*	*S (TEB)*	*T (CEC)*								
Kwaben B 850 ...	Cocoa (good condition)	2	4·3	100	1·87	·76	1·44	·28	4·35	25·01 (*b*)	2·46	2·71	3·17	·254	12·48	5·45	4·48	928
		5	4·5	100	·83	·40	·67	·18	2·08	19·06	2·08	2·22	1·58	·191	8·27	2·72	3·94	758
		15	4·9	100	·38	·26	·28	·12	1·04	13·46	1·46	2·17	·63	·090	7·00	1·08	3·50	636
		28	5·2	100	·34	·51	·16	·06	1·07	12·89	·67	8·50	·38	·063	6·03	·65	3·21	610
Kwaben B 851 ...	do.	2	5·0	100	6·93	·94	1·08	·28	9·23	24·66 (*b*)	7·37	3·36	3·92	·373	10·51	6·74	3·35	451
		7	5·3	100	1·74	·35	·40	·14	2·63	9·86	4·97	2·50	·98	·141	6·95	1·69	2·03	322
		21	5·3	100	·92	·67	·03	·11	1·73	7·61	1·37	6·09	·41	·081	5·06	·71	1·88	230
		34	5·3	100	·49	·45	·01	·06	1·01	7·62	1·09	7·50	·30	·066	4·55	·52	2·19	245
Kwaben B 852 ...	Thicket	2	5·1	100	1·73	·82	·08	·27	2·90	10·04 (*b*)	2·11	3·04	1·11	·110	10·09	1·91	1·53	146
		7	5·2	100	·51	·32	·01	·06	·90	6·91	1·59	5·33	·75	·077	9·74	1·29	1·36	134
		18	5·3	100	·54	·24	·01	·06	·85	5·69	2·25	4·00	·31	·042	7·38	·53	1·37	112
		35	5·1	100	·91	·27	·01	·10	1·29	6·35	3·37	2·70	·24	·037	6·49	·41	1·59	151
Kwaben B 873 ...	Secondary forest.	3	4·6	100	1·78	·70	·18	·18	2·84	5·68 (*a*)	2·54	3·89	1·79	·159	11·26	3·08	1·13	—
		10	5·1	100	·43	·17	·04	·08	·72	3·42	2·53	2·13	·90	·080	11·25	1·55	·93	—
		29	5·0	100	·20	·25	·01	·02	·46	3·26	·87	3·03	·22	·035	6·28	·38	·89	—
		51	5·0	100	·18	·16	·01	·05	·40	4·39	1·13	3·20	·17	·036	4·72	·29	1·23	—
Kwaben B 878 ...	Para rubber	2	4·3	100	2·25	·91	·73	·35	4·24	13·81 (*a*)	2·47	2·60	4·02	·335	12·00	6·91	3·38	—
		8	4·4	100	·44	Nil	·53	·05	1·02	6·87	—	—	1·13	·139	8·13	1·94	2·70	—
		16	4·8	100	·29	Nil	·35	·05	·69	7·23	—	—	·91	·122	7·46	1·57	3·29	—
		32	4·7	100	·30	·06	·31	·05	·72	·539	5·00	1·20	·46	·074	6·22	·79	2·87	—
Kwaben B 995 ...	Cocoa	3	4·3	100	1·43	·68	·06	·25	2·42	—	2·10	2·72	3·10	·217	14·29	5·33	1·17	—
		8	4·4	100	·44	·15	·01	·02	·62	—	2·93	7·50	·80	·077	10·39	1·38	1·07	—
		18	4·6	100	·33	·10	·005	·04	·48	—	3·30	2·50	·42	·048	8·75	·72	1·25	—
		28	4·6	100	·30	·10	·005	·02	·42	—	3·00	5·00	·38	·048	7·92	·65	1·50	—
Kwaben B 996 ...	Swamp thicket	3	4·9	100	2·55	1·38	·21	0·36	4·50	—	1·85	3·83	3·88	·278	13·96	6·67	2·34	—
		6	4·7	100	·46	·26	·03	0·12	·87	—	1·77	2·27	1·00	·103	9·71	1·72	1·21	—
		14	4·8	100	·30	·11	·02	0·06	·49	—	2·73	1·83	·46	·062	7·42	·79	·90	—
		25	4·6	100	·26	·12	·01	0·20	·59	—	2·17	·60	·34	·051	6·67	·58	·98	—
Kwaben B 997 ...	Cocoa	3	5·5	100	4·92	2·11	·39	·30	7·72	16·38 (*b*)	2·33	7·03	2·13	·197	10·81	3·71	2·23	—
		9	5·0	100	·75	·33	·06	·03	1·17	5·31	2·17	11·0	·49	·050	9·80	·84	·97	—
		23	5·1	100	·86	·33	·12	·09	1·40	8·60	2·61	3·67	·35	·051	6·86	·60	1·74	—
		44	5·0	100	·91	·57	·05	·02	1·55	8·04	1·60	28·5	·20	·044	4·55	·34	1·80	—
Kwaben Average of the 8 profiles above	do.	2·5	4·75	100	2·93	1·04	·52	·28	4·77	—	2·90	3·71	2·89	·240	12·04	4·98	—	—
		7·5	4·83	100	·70	·28	·22	·09	1·29	—	2·59	3·11	·95	·107	8·88	1·64	—	—
		19·3	4·98	100	·48	·28	·12	·07	·85	—	2·08	4·0	·46	·066	6·96	·79	—	—
		34·6	4·94	100	·46	·28	·08	·07	·89	—	2·25	4·0	·31	·052	5·96	·53	—	—

(*a*) As determined with ammonium acetate.
(*b*) As determined with barium acetate.

Topsoil

0–2 inches: light brownish grey (10YR 6/2) stained yellow and brown slightly humous silty clay, structureless and slightly loose.

2–7 inches: very pale brown (10YR 7/4) silty clay, structureless and slightly loose.

Subsoil

7–18 inches: pale yellow (2.5YR 8/4) silty light clay, structureless and fairly firm.

18–35 inches: pale yellow (2.5YR 7/4) mottled red, grey and orange silty clay, structureless and firm.

35–65 inches: pale yellow mottled grey, orange and red silty light clay, structureless and firm.

65–105 inches: brownish yellow mottled grey, orange and red silty clay, structureless and firm.

B 873 *is an example of Kwaben series under secondary forest vegetation, from a very gently undulating lower-slope site in the valley of the Suraw, north-west of Sefwi-Bekwai where the annual rainfall is about* 65 *inches. The profile morphology is very similar to B* 852, *described immediately above.*

B 878 *is from Boinso, and is an example of Kwaben series found along the river Boin supporting a mature rubber plantation. The profile is very similar to B* 850, *described above, and this example also has manganese stains.*

B 995 *and B* 997 *were sampled from the banks of the Tano near Cocoatown, both of them supporting cocoa. Cocoa is very extensive on Kwaben series in this area. B* 997 *was slightly stained with manganese, B* 995 *was not. Both were fairly typical examples of the series. The rainfall here is about* 75 *inches per annum.*

B 996 *is from the south of the basin and was sampled from a flat, bottom site on Sample strip* 16, *near Ebowu. Vegetation was swamp thicket and the annual rainfall approaches* 85 *inches.*

An examination of the analyses for the eight profiles described above (Table 18) shows that the main variations in total base content are due to the differences in the amount of calcium present. Potash figures are relatively constant, as they are in most soils of the basin, with approximately ·2 to ·3 m.e. per 100 gm. in the upper topsoil, falling rapidly in the subsoil. The most striking feature of these analyses is the relatively high amount of manganese present, compared with most acid upland soils of the basin (Table 5). Only two of the eight pits have less than ·1 m.e. of manganese in the upper topsoil, while two examples selected for analysis because of the good quality cocoa they supported (B 850 and B 851) both have over ten times this quantity. Profile B 878, supporting excellent Para rubber, is remarkable for the large amounts of manganese in the subsoil. The importance of this is not yet known.

The total exchangeable bases in the series vary from 2·42 to 9·23 m.e. in the topsoil. Three profiles fall into a lower group with totals of below 3 m.e. in the topsoil, three more have between 4 and 5 m.e. in the topsoil, while the remaining two have 7·72 and 9·23 m.e. in the topsoil. Of the three poorer examples in the first group, one (B 995) supported moderately good cocoa, while the other two were under regrowth vegetation. All except one of the remaining examples in the better groups supported cocoa or rubber.

In all the examples, bases fell off fairly rapidly below the topsoil though in five of the examples total exchangeable bases for the second sampling horizon in the subsoil were slightly higher than those for the first subsoil horizon.

Nitrogen figures (available for five profiles only) are somewhat similar to the averages of acid upland soils within the basin (Table 5). No phosphorus figures are available. Carbon and organic matter are low in B 852, under thicket, and the average for all eight profiles is a little lower than the average for oxysols, though figures are relatively high in the two examples supporting good cocoa and in a third (B 996) under swamp thicket, where drainage is slower than normal for the series.

The main characteristics of this soil are best brought out, however, by a comparison between the analyses available with those available for Boi series, the associated, and distinctly less productive, upland soil. Whereas the fine earth fraction of Kwaben series is 100 per cent in all horizons of all eight profiles analysed, the gravel content of Boi series reduces these figures, in the six profiles analysed, to an average, in the first four sampling horizons, of 85, 67, 36 and 47 per cent. In the following table, the average base figures for each series have been multiplied by the fine earth fraction to give an indication of reserves for the whole soil:

	Depth of Horizon (inches)	% Fine Earth	Exchangeable Bases in m.e. per 100 gm. of Total Soil					Ca/Mg	Mg/K
			Ca	Mg	Mn	K	S(Teb)		
Boi Series—Average of six profiles	1·7	85	1·74	1·06	·07	·30	3·17	1·64	3·57
	5·0	67	·36	·32	·01	·08	·78	1·12	4·08
	14·1	36	·11	·12	·01	·04	·28	·91	3·40
	27·4	47	·12	·19	·005	·04	·35	·62	4·33
Kwaben Series—Average of eight profiles	2·5	100	2·93	1·04	·52	·28	4·77	2·90	3·71
	7·5	100	·70	·28	·22	·09	1·29	2·59	3·11
	19·3	100	·48	·28	·12	·07	·85	2·08	4·0
	34·6	100	·46	·28	·08	·07	·89	2·25	4·0

This table shows clearly the effect of the greater fine earth percentage: base reserves, particularly in the subsoil, are distinctly higher in Kwaben series. Although subsoil figures are much lower than those for the topsoil, the thickness of these horizons is much greater, so that the figures given represent considerable differences in total reserves.

The 7–35 inch layer of the average Kwaben series has nearly twice the exchangeable potash, per 100 gm. of total soil, than the 5–27 inch layer of the average Boi series. Differences in average exchangeable manganese content between the two series are also very striking, the totals for the average Boi series representing amounts, in the first 27 inches, 15 times as great as those of the average Boi series to the same depth. In Boi series there is more magnesium than calcium in the subsoil, but in Kwaben series this proportion is reversed and almost nowhere does the ratio fall to less than unity, while it is usually above two. The major apparent differences between Kwaben and the less productive Boi series can therefore be summarised as follows:

1. The average Kwaben series has about ten times as much manganese as the average Boi series analysed.

2. Total exchangeable bases do not differ greatly in the topsoil, but the average Kwaben series has about three times the total exchangeable bases in the first two subsoil horizons than the average Boi series. Moreover, these two horizons are deeper in Kwaben series than in Boi series.

3. Whereas Mg/K ratios are about the same, Ca/Mg ratios are higher in Kwaben series (between 2 and 3 throughout) than in Boi series, where they fall to below unity in the subsoil.

4. Although no cation exchange capacity figures are available, the base exchange capacity of Kwaben series is probably significantly higher, possibly due to the presence of some illite.

These differences are partly the result of the greater fine earth fraction of Kwaben series.

26. Samreboi series

Samreboi series is an oxysol developed in terrace deposits (Page 157). It is the more acid counterpart of Birim series and usually occurs where the annual rainfall is 65–70 inches, or more. This series is found most frequently, though nevertheless somewhat irregularly, in the valleys of the larger rivers such as the Boin and Tano. The morphology is essentially similar to Birim series (Series 16, page 157), consisting of a humous topsoil overlying a considerable depth of yellow-brown light clay, with or without pebble beds, the difference between the two series being one of topsoil reaction and the different base status this represents.

The nutrient status of this soil is probably somewhat similar to that of Kwaben series, of which it can best be regarded as an older and better drained version. This is, therefore, one of the less infertile soils of the association, which has the further advantage of occurring in relatively flat expanses, though it is scattered in distribution and minor in extent. Like Kwaben series, Samreboi series can be expected to support cocoa, rubber and a range of foodcrops. Only the relatively infrequent higher, older examples are usually sufficiently well drained for coffee.

27. Amoku series

Amoku series is very similar to Samreboi series above, except that pebble beds, either deep or absent in Samreboi series, occur here within 30 inches of the surface. They reduce the fine earth fraction of these horizons and may interfere with cultivation, particularly if they occur at or near the surface. In other respects this minor soil is very similar to Samreboi series.

SOILS DEVELOPED OVER UPPER BIRRIMIAN ROCKS (GROUP 2)

2A. THE ATUKROM ASSOCIATION

28. Atukrom series

Atukrom series is a reddish brown sedentary forest ochrosol developed over Upper Birrimain rocks (mostly greenstones, schists and tuffs) under annual rainfalls of up to about 65 inches, It is found on upper-slope and summit sites and has the usual sedentary morphology i.e. a humous topsoil, a gravelly subsoil, reddish brown in colour, and a weathered substratum consisting of loam derived from the weathered parent rocks.

Detailed description

The example described (Fig. 46) is typical of the series. This was dug in the Bibiani range, on a strongly rolling upper slope site north of Apiakrom where the annual rainfall is about 65 inches.

Range in characteristics

The topsoil pH is within the range 5·5 to 7·2, but acidity increases with depth, usually falling below pH 5·0 at 5–8 feet. Texture is usually light clay, becoming loam in the weathered substratum.

In some examples only moderate amounts of concretions are found, in others there are abundant irregular or flattish concretions. Quartz gravel and stones in this and associated soils are present in smaller quantities than in soils developed over Lower Birrimian phyllites.

Agricultural value

This is a moderately fertile to fertile soil, depending on acidity, organic matter content and on variations in parent rock.

Drainage, both internal and external, is fairly rapid, as is suggested by the subsoil colour. Cultivation of the topsoil is easy, though many examples on steeper sites have thin topsoils or are liable to erosion on cultivation if the ground is left without adequate vegetation cover. Atukrom series when newly cleared from original forest is sometimes a good cocoa soil, but, particularly when once cultivated, is more often better suited to coffee. Some of the lighter textured examples, especially those developed over tuffs, may dry out dangerously in particularly severe dry seasons.

Analyses for B 839 described above (Table 19), show it to be unusually well supplied with bases and nitrogen, though potash is relatively low; the pH of this example is higher than normal and this profile must be taken to represent the better examples of Atukrom series and not the average. Those with a topsoil of 5·5 to 6·0 would be considerably less fertile.

29. Asikuma series

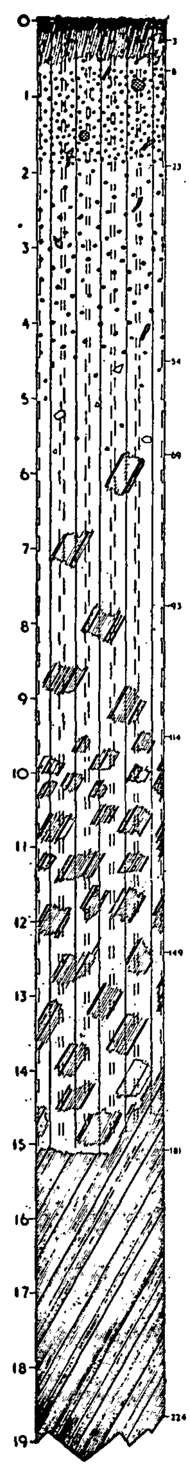
Asikuma series is a brown forest ochrosol, a slightly less well drained associate of Atukrom series. It has an orange-brown to yellow-brown subsoil, whereas that of Atukrom series is reddish brown. Asikuma series is sometimes found on lower sites than Atukrom series, but in many cases Atukrom series is absent from the catena and Asikuma series is then found on all sites from summit to lower slope.

Detailed description

The morphology of Asikuma series is similar to that of Atukrom series except that the subsoil is strong brown in colour (about 7·5YR 5/7).

Range in characteristics

As in the case of Atukrom, concretions may be either relatively few in number, or fairly abundant, and sometimes irregular or flattish in shape.



Topsoil

0–3 inches: brown (7.5YR 5/4) slightly humous silty light clay, crumbly and loose. pH 7.1.

3–8 inches: dark reddish brown (5YR 5/4) very slightly humous silty clay, slightly crumbly and slightly loose, containing occasional irregular ironstone concretions. pH 6.5.

Subsoil

8–23 inches: reddish brown (5YR 5/6) silty clay, structureless and firm, containing very frequent to abundant irregular ironstone concretions, occasional ferruginised rock brash and rare pieces of ironpan. pH 4.9.

23–54 inches: brownish red (5YR 5/6) silty clay, structureless and firm, containing very frequent ironstone concretions and occasional ferruginised rock brash. pH 4.8.

54–69 inches: brownish red (5YR 6/6) silty heavy loam, structureless and very firm, with rare to occasional ironstone concretions, and occasional quartz gravel and stones. pH 5.0.

Weathered substratum

69–93 inches: brownish red (5YR 6/6) silty heavy loam, structureless and firm, with rare patches of weathered roack pH 5.0.

93–114 inches: reddish brown (5YR 6/6) silty heavy loam, structureless and very firm, with occasional yellow and white patches of decomposing rock. p H4.9.

114–149 inches: reddish brown (5YR 6/6) silty light clay, structureless and somewhat friable, with abundant patches of decomposing rock. pH 4.7.

149–181 inches: purplish, mottled red and yellow, silty light clay of decomposing rock, structureless and friable. pH 4.4.

181–224 inches: yellow, mottled white and red, silty light clay of decomposing rock, structureless and friable. pH 4.6.

Fig. 46. Atukrom series.

TABLE 19

ANALYTICAL DATA FOR ATUKROM AND ASIKUMA SERIES

Series and Profile Number	*Vegetation*	*Lower depth of horizon in inches*	*pH*	*% Fine earth*	*Exchangeable Bases (m.e. per 100 gm.)* Ca	Mg	Mn	K	S (TEB)	T (CEC)	*Ca/Mg*	*Mg/K*	*C*	*N*	*C/N*	*O.M.*	*Moisture % Air-dry*	*Total P p.p.m.*
Atukrom																		
B 839 ...	Broken forest.	3	7·1	85	41·32	10·73	·43	·49	52·97	60·44 (*b*)	3·85	21·90	8·04	·753	10·68	13·83	6·69	—
		8	6·5	53	12·67	5·07	·18	·18	18·10	26·14	2·50	28·17	2·68	·300	8·93	4·61	4·49	—
		23	4·9	24	1·99	2·07	·07	·08	4·21	19·36	·96	25·88	1·34	·128	10·47	2·30	3·71	—
		54	4·8	27	·63	1·56	·01	·04	2·24	17·89	·40	39·00	·70	·072	9·72	1·20	4·19	—
Asikuma																		
B 843 ...	Broken forest.	2	6·0	18	20·48	8·71	·63	·63	30·45	41·82 (*a*)	2·35	13·83	7·43	·633	11·74	12·78	6·05	—
		8	5·2	25	·85	1·45	·03	·10	2·43	17·58	·59	14·50	1·66	·164	10·12	2·86	4·04	—
		28	5·1	32	·47	·53	·01	·09	1·10	12·06	·89	5·89	·98	·099	9·90	1·69	4·37	—
		68	5·2	59	·47	·52	·005	·04	1·03	9·03	·90	13·00	·42	·051	8·24	·72	3·87	—

(*a*) As determined with ammonium acetate.
(*b*) As determined with barium acetate.

Agricultural value

This series has a somewhat similar nutrient status to Atukrom series, but there is a considerable variation between individual examples depending, as in the case of Atukrom, on reaction, organic matter content, content of coarse material, and (to a lesser extent) on minor variations in parent rock.

The following example (B 843) has been analysed. This is eroded, as shown by the shallow concretionary topsoil, and was sampled on a steep upper-slope site on Sample strip 6, near Tanokrom, a village 15 miles north of Enchi, where the rainfall is about 65 inches per annum.

Topsoil

0–2 inches: dark greyish brown (10YR 5/2) humous silty clay, structureless and loose, containing very frequent to abundant ironstone concretions and rare ferruginised rock brash.

Subsoil

2–8 inches: yellowish red (5YR 5/6) silty clay, structureless and loose, containing very frequent to abundant irregular ironstone concretions and rare ferruginised rock brash.

8–28 inches: yellowish red (5YR 5/8) silty clay, structureless and slightly firm, containing very frequent irregular ironstone concretions and rare ferruginised rock brash.

28–68 inches: reddish yellow (YR 6/8) stained red and yellow silty light clay, structureless and fairly firm, with occasional ironstone concretions and very rare ferruginised rock brash.

Weathered

68–100 inches: brown mottled orange and yellow heavy loam of decomposing greenstone or schist.

Analysis of this profile (Table 19) shows a base status which is not as high as that of the Atukrom discussed above, which has a higher pH and a higher fine earth fraction. In this example of Asikuma series the fine earth fraction of the topsoil is only 18 per cent, so that despite the fairly high figure for total bases of 30·45 m.e. per 100 gm. of the fine earth fraction, the actual base reserves are quite low, and potash, in particular, is in poor supply. This reflects the effect of topsoil removal on steep slopes. Carbon and nitrogen figures, as well as those for bases, suggest that the topsoil is only 2 inches thick. In the first 28 inches of soil, over two-thirds consists of coarse material, i.e. mostly of concretions and small stones, and this eroded gravelly example could be expected to give lower yields than associated soils with a higher fine earth fraction.

Generally speaking, Asikuma series has a similar or slightly higher nutrient status than Nzima series, the corresponding soil developed over Lower Birrimian phyllites and associated rocks, since Upper Birrimian greenstones liberate more minerals on weathering than metamorphosed clay deposits such as phyllite. On the other hand, Asikuma series is less fertile than soils developed over the more resistant crystalline rocks, e.g. epidiorite, and these shallower and stonier soils are included under Wiawso and Shi series (Series 30 and 31, below). Asikuma series is characterised by the very deep weathered substratum so that, even in pits dug to 20 – 30 feet, the soft weathered parent material cannot usually be identified with certainty.

30. Wiawso series

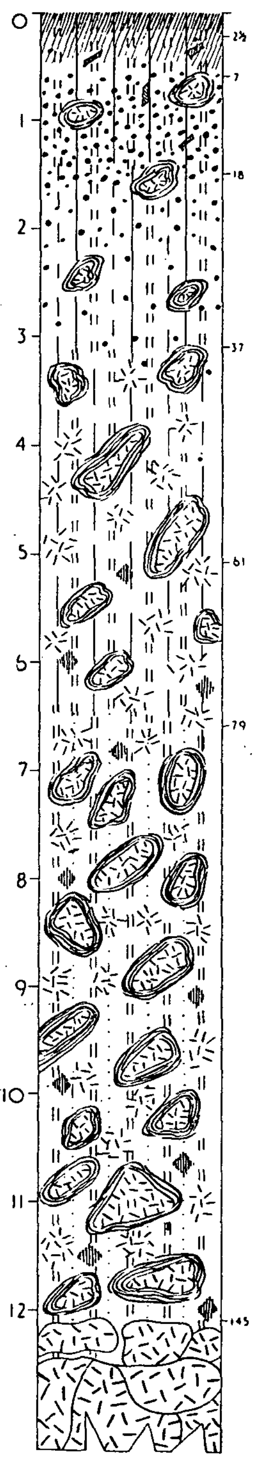
Wiawso series is the red, very well drained associate of Shi series, series 31, described immediately below. Although this series is assumed to occur within the association, it was not actually recorded. Apart from its slightly better drainage, and somewhat redder subsoil colour, Wiawso series is very similar to Shi series: cultivation characteristics, nutrient status and agricultural value of the two series can be assumed to be the same.

31. Shi series

Shi series is a fertile brown sedentary forest ochrosol developed over Upper Birrimian rocks. It is found on a range of sites from middle slope to summit, usually on relatively high and steep hills, and is distinguished from associated sedentary soils developed over less resistant Upper Birrimian rocks by the presence of slightly weathered pieces of greenstones (particularly epidiorite) in the profile. These often weather on the outside to a characteristic dull yellow colour. Shi series is sometimes associated with a redder, better drained, but otherwise similar soil, Wiawso series.

Detailed description

The description (Fig. 47) is an average one based on all pits sampled within the basin.



Topsoil

0–2½ inches: dark brown to brown (7.5YR 4/3) humous silty clay, crumbly and loose. Moderately acid (average pH 5.9).

2½–7 inches: reddish brown (5YR 4/3) silty light clay, structureless and slightly loose, containing occasional ironstone concretions and rare ferruginised rock brash. Moderately acid (average pH 5.6–5.7).

Subsoil

7–18 inches: reddish brown (5YR 4/4) silty light clay, structureless and moderately firm, containing frequent ironstone concretions and occasional stones and small boulders of parent rock, often weathered yellowish on the outside, and rare ferruginised rock brash. Moderately acid (average pH 5.5).

18–37 inches: reddish brown to yellowish red (5YR 4/5) silty heavy loam, structureless and moderately firm, containing frequent to occasional ironstone concretions and occasional traces and boulders of decomposing parent rock. Highly acid (average pH 5.3).

37–61 inches: yellowish red (5YR 4/6) silty loam, structureless and moderately firm, containing frequent traces and pieces of decomposing parent rock and occasional ironstone concretions. Highly acid (average pH 5.2).

Weathered substratum

61–79 inches: yellowish red (5YR 4/6) mottled brown silty light loam, structureless and friable, with frequent traces of decomposing parent rock. Highly acid (average pH 5.0).

79–145 inches: yellowish red mottled red, grey, and yellow light loam, structureless and friable, with very frequent patches and boulders of decomposing greenstone. Highly acid (average pH 5.0). This merges, at 12–20 feet, into weathered greenstone.

Fig. 47. Shi series.

Range in characteristics

Traces of manganese dioxide and brown manganese stains are present in the subsoil of some profiles. Ironstone concretions vary in number and size, occasionally becoming abundant and irregular or flattish, while in other examples (particularly those on steep slopes) they are fewer and more spherical. This series grades into the less fertile Asikuma series which lacks the greenstone brash of Shi series.

Agricultural value

Drainage, both internal and external, is good. The soil is found both on flattish summits and on very steep slopes of high hills: on the latter site there is danger of accelerated erosion if the surface soil is left unprotected.

The nutrient status of this soil is high, with a good base status which is being replenished by the weathering fragments of greenstone and epidiorite which are characteristically scattered through the subsoil. At Tanokrom, 15 miles north of Enchi, soils of Shi and Tanokrom series, its more skeletal associate, gave very high food crop yields, while old cocoa was producing well and new cocoa was being successfully established even on land previously cultivated. These field observations suggest that this is one of the most fertile soils in the basin, almost as good as the very inextensive Anum series. Unfortunately, Shi series is itself not very extensive, being confined to certain steep high Upper Birrimian hills, many of which are inaccessible or in forest reserves. The acid equivalent of this series has not been recorded, and probably does not occur since the bases released from the parent rock are sufficient to keep the reaction within the ochrosol range.

32. Atewa series

Atewa series is a deep, light-textured, non-concretionary red or brown sedentary forest ochrosol developed over Upper Birrimian rocks, usually schists, under a rainfall of 60-65 inches per annum or a little less. It is found on lower slopes to summits, usually on very steep sites.

Detailed description

The general description (*see* Fig. 48) is based on five examples dug in the basin.

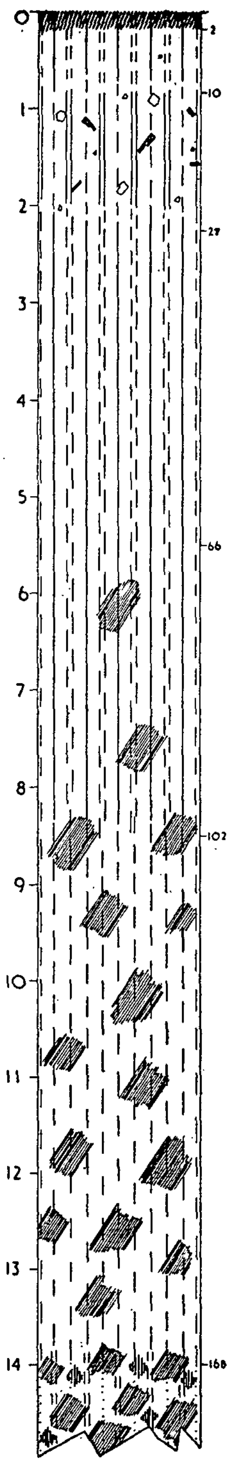
Range in characteristics

The colour of some profiles is duller than that of the average profile described above, becoming brown rather than reddish brown. The normal profile has little or no coarse material. The parent rock is deeply weathered and is thought to be similar to that of Atukrom and Asikuma series, i.e. a schist or tuff.

Agricultural value

This soil is well drained, both internally and externally. Because of the relatively light texture, water retention in the dry season is probably only just adequate. Atewa series is deep, soft and easily worked but, because of the normal steep site, is subject to rapid erosion if left unprotected.

No analyses are available for this series. The topsoil is not well marked and is low in nitrogen and organic matter, though the fine earth fraction is high and approaches 100 per cent in most horizons and the base status is probably relatively good. Field observations suggest that this is in some cases a better soil than Atukrom series, though the steep site calls for very careful exploitation. Occasional cocoa failures on this relatively inextensive series are due perhaps to drought and die-back in particularly severe dry seasons.



Topsoil

0–2 inches: reddish brown (5YR 5/4) slightly humous silty clay, crumbly and slightly loose. Moderately acid (average pH 6.0).

2–10 inches: reddish brown (5RY 5/4) silty light clay, slightly crumbly and porous. Very acid (average pH 5.5).

Subsoil

10–27 inches: yellowish red (5YR 4/6) light clay, structureless and slightly loose, containing occasional quartz gravel and stones and a little scattered ferruginised rock brash. Very acid (average pH 5.2).

27–66 inches: yellowish red (5YR 5/8) heavy loam, structureless and slightly loose. Very acid (average pH 5.1).

Weathered substratum

66–102 inches: yellowish red (5YR 5/8) heavy loam, structureless and firm, with rare traces of decomposing rock. Highly acid (average pH 5.0).

102–168 inches: yellowish red (5YR 5/6) loam, structureless and firm, with frequent patches of decomposing rock. Highly acid (average pH 4.9).

Below 168 inches: pale reddish brown, mottled red, purple and yellow, light loam, structureless and friable, with frequent patches of decomposing rock. This grades into a light loam of decomposed rock (usually schist). Highly acid (average pH 4.9).

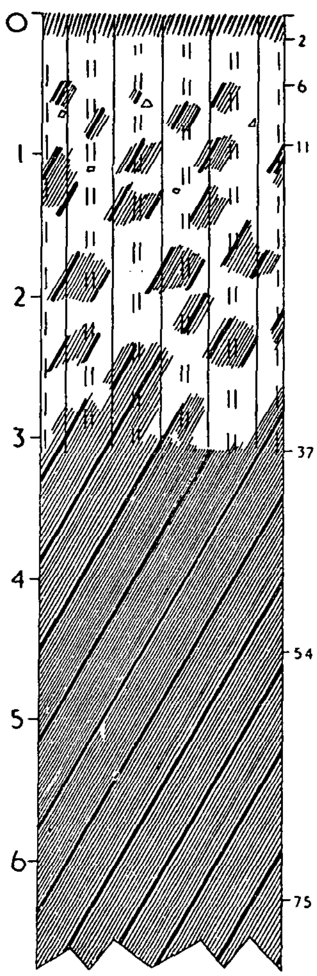
Fig.. 48 Atewa series.

33. Piki series

Piki series is an immature soil found on steep slopes in areas of Upper Birrimian geology. It is very similar to Kobeda series except that instead of Lower Birrimian phyllite, the parent rock is an Upper Birrimian schist or greenstone. This series should be distinguished from Tanokrom series (page 185) which is a stonier and more skeletal lithosol found over resistant greenstones.

Detailed description

The following example (Fig. 49) is fairly typical of the series. It occurred on an extremely steep middle-slope site north of Enchi where the vegetation was original high forest.



Topsoil

0–2 inches: light brown (10YR 6/4) humous silty clay, crumbly and porous pH 4.8.

2–6 inches: light reddish brown (5YR 6/4) silty clay, crumbly and slightly porous. pH 4.6.

Weathered substratum

6–11 inches: reddish yellow (7.5YR 7/6) silty clay, structureless and fairly loose, with rare quartz gravel and occasional traces of decomposing parent rock. pH 4.8.

11–37 inches: reddish yellow (7.5YR 6/6) silty light clay, structureless and fairly loose, with very frequent traces and small pieces of weathered parent rock. pH 5.0.

37–54 inches: brownish yellow, fairly easily broken, weathered parent rock (schist). pH 5.0.

54–75 inches: as above but dull brownish orange and somewhat mottled. Structureless and firm. pH 5.0.

Fig. 49. Piki series.

Range in characteristics

This series always lacks a subsoil, and consists of a topsoil overlying the weathered substratum: it lacks therefore the gravel characteristic of the subsoil of most upland soils. The weathered substratum contains frequent traces of parent rock and merges into the weathered rock itself at shallow depths. Topsoil reaction is within the range pH 4·5–6·5.

Agricultural value

The external drainage of this series is usually rapid. Internal drainage is good, but less rapid than that of upland soils with a gravelly subsoil. Moisture retention in the dry season, on the other hand, is probably better than that of associated gravelly soils such as Asikuma series.

The soil is easy to cultivate with local hand implements, being free of gravel and stones, but the normal steep site and liability to accelerated erosion requires that cultivation and topsoil disturbance be kept to a minimum and that a good plant cover be maintained. Despite the fact that this is a relatively shallow soil there is adequate rooting depth for both tree crops and annuals since the parent material is usually softened for many feet below the surface.

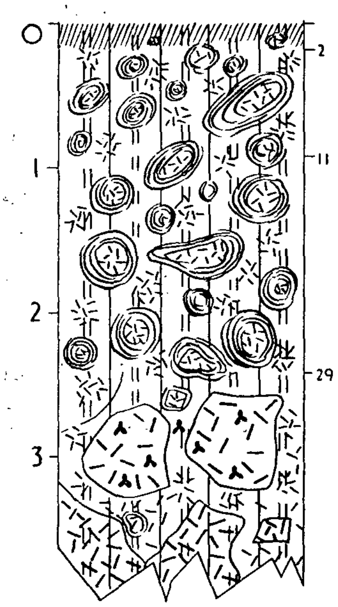
The high fine earth fraction and presence of decomposing rock within easy reach of plant roots suggests that the soil might be more fertile than sedentary soils such as Atukrom and Asikuma series developed over the same parent materials (mostly schists and tuffs), though variations in topsoil thickness and reaction will be responsible for considerable differences in nutrient status from profile to profile. The steep site, irregular occurrence, small total extent and relative inaccessibility of this series, however, serve to limit its agricultural value.

34. Tanokrom series

Tanokrom series is a forest lithosol found on steep sites in areas of Upper Birrimian geology. It differs from Piki series in that the parent material is a fairly resistant greenstone, hard pieces of which are found throughout the profile. Piki series is associated with Atukrom, Asikuma, Elibo and Yakasi series, all of which have the same group of relatively easily weathered parent rocks. Tanokrom series, on the other hand, is associated with Shi series, both these soils being developed over relatively resistant greenstones.

Detailed description

The following example (B 840) is typical of the series. It was sampled on a middle-slope site just north of Yankomam, where it supported good cocoa. Rainfall here is about 65 inches per annum.



Topsoil

0–2 inches: brown (10YR 5/3) humous silty clay, crumbly and loose, containing a little rock brash. pH 5.4.

Weathered substratum

2–11 inches: strong brown (7.5YR 5/6) silty clay, brashy and loose, containing frequent fragments of decomposing greenstone. pH 5.4.

11–29 inches: reddish brown (7.5YR 6/6) silty light clay containing abundant irregular angular pieces of greenstone, slightly weathered on the outside but fresh when broken. Stony and fairly firm. pH 5.8.

Below 29 inches: as above with large boulders as well as smaller angular pieces of slightly decomposed greenstone, often manganese stained.

Fig. 50. Tanokrom series.

Range in characteristics

Topsoil acidity is thought to range from pH 5·0 to 7·0, this series being a little less acid than Piki series.

Agricultural value

Internal and external drainage are good. The soil is shallow and stony, and not easy to cultivate, especially as it is also often found on a steep slope. Nevertheless it is one of the more fertile soils of the basin, because of the nutients released by the decomposing greenstone, particularly if the topsoil is not eroded.

Table 20 gives analytical results for B 840, described above. In the partly eroded topsoil, nitrogen, organic matter (as might be expected) and potash are relatively low, and total bases are considerably less than the average for Lower Tano Basin ochrosols given in Table 5. The most striking feature of this soil is, however, the relatively high base content in the subsoil, which is about four times that of the average ochrosol subsoil, though this is due mainly to calcium, potash being only a little higher than the ochrosol average. These figures and the reaction reflect the effect of the weathering rock brash in the profile.

35. Ansum series

Ansum series is a yellow-brown ochrosol found on lower, often concave, slopes of Upper Birrimian areas. It is developed in colluvial material ultimately derived from soils up-slope. The associated upper-slope sedentary soils are usually Atukrom and Asikuma series, occasionally Atewa, Piki or Tanokrom, though Ansum series is not extensive and may, locally, be absent from the catena. Down-slope it grades into alluvial soils, principally Kwaben series. The equivalent and outwardly similar soil developed in areas of Lower Birrimian geology is Kokofu series (Series 10, page 149).

Detailed description

The average profile (Fig. 51) is based on all pits dug within the area.

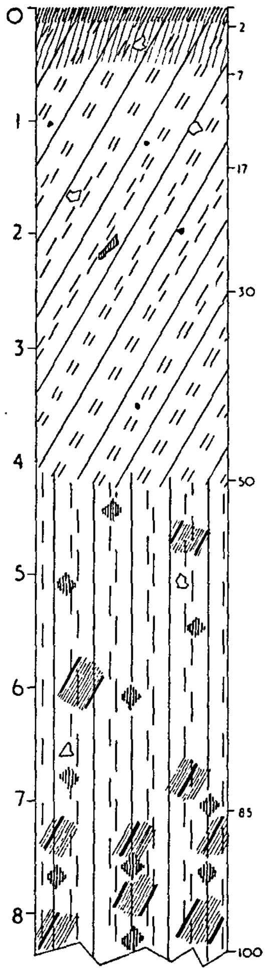
Range in characteristics

Depth of transported material varies, and in some cases the lower subsoil and upper weathered substratum are slightly indurated. Occasional profiles have slight dark brown manganese staining in the subsoil.

Agricultural value

External drainage is fairly rapid: internal drainage is somewhat slower, particularly in the substratum, and the lower slope position probably ensures a water supply seeping down-slope; for this reason this series, under the relatively high rainfalls of the basin, has satisfactory dry season moisture relationships. Physically, the soil is easy to cultivate, the colluvial material being a relatively light silty clay similar to Kakum series, and free, or nearly so, of stones. On the steeper sites, the gradient requires care against erosion and, as in most upland soils within the basin, soil disturbance is best kept to a minimum.

This series has a high fine earth fraction and total nutrient reserves may be expected to compare favourably with associated gravelly soils such as Asikuma series but to be less than that of the better examples of Wiawso, Shi and Tanokrom series. Variations between individual examples will depend primarily on differences between topsoil reaction and state of preservation, but partly on the fertility and parent rock of the associated upland soil.



Topsoil

0–2 inches: brown (10YR 5/3) humous silty light clay, crumbly and loose. PH 5.6.

2–7 inches: pale brown (10YR 6/3) very slightly humous silty light clay, structureless and firm, containing very rare scattered subangular quartz stones. pH 5.4.

Subsoil

7–17 inches: light brown to reddish yellow (7.5YR 6/5) silty light clay, structureless and firm. Rare scattered gravel and quartz stones are present in some profiles. pH 5.4.

17–30 inches: strong brown (7.5YR 5/6) silty heavy loam, structureless and firm, sometimes containing scattered subangular quartz stones and gravel. pH 5.2.

30–50 inches: light yellowish brown to brownish yellow (10YR 5/4) silty light clay, structureless and firm, occasionally with rare small ironstone concretions and quartz stones. pH 5.2.

Weathered substratum

50–85 inches: yellow-brown, mottled orange and red silty heavy loam, structureless and firm, containing very rare scattered subangular quartz stones and traces of decomposing parent rock. pH 5.0.

85–100 inches: brown, mottled grey orange and red silty heavy loam, structureless and friable, with traces of decomposing parent rock. pH 5.0.

Fig. 51. Ansum series.

The relatively wide range of variation in the nutrient status of this series is illustrated by Table 20 giving analytical results for the following two profiles.

B 883 *was sampled in the Upper Birrimain hills between Mawchikrom and the Boin River forest reserve, on a steeply sloping middle-slope site where the vegetation was original forest. The rainfall here is about* 65 *inches per annum. Profile morphology is similar to the average example described above.*

B 884 *was sampled* 30 *chains west of B* 883 *above, where the site and vegetation were similar. The soil, however, was much shallower, with yellowish brown silty light clay to* 19 *inches and a horizon containing some rock brash separating this transported material from a slightly indurated layer beginning at* 35 *inches.*

Both of these examples, because of their topsoil reaction, are intergrades between Ansum series and Disue series, the oxysol counterpart (Series 42, page 197). Of these, the less acid B 883 has a relatively good total base status, particularly in the subsoil, where the most important base, potash, is higher than in most upland soils of the basin while nitrogen and organic matter are about average. The second, more acid, example (B 884) has a distinctly lower nutrient status though, as in B 883, the bases in the lower subsoil are relatively high. This pattern reflects the presence of rock fragments

TABLE 20

ANALYTICAL DATA FOR TANOKROM AND ANSUM SERIES

Series and Profile Number	Vegetation	Lower depth of horizon in inches	pH	% Fine earth	Exchangeable Bases (m.e. per 100 gm.) Ca	Mg	Mn	K	S (TEB)	T (CEC)	Ca/Mg	Mg/K	C	N	C/N	O.M.	Moisture % Air-dry	Total P p.p.m.
Tanokrom																		
B 840 ...	Thicket	2	5·9	41	4·20	2·17	·70	·23	7·30	12·76 (*a*)	1·94	9·43	2·39	·243	9·84	4·11	2·44	—
	and	11	5·4	48	1·20	·77	·36	·07	2·40	5·66	1·56	11·00	·56	·080	7·00	·96	2·05	—
	cocoa.	29	5·7	18	2·60	1·52	·10	·11	4·33	7·32	1·71	13·82	·46	·069	6·67	·79	3·50	—
		46	5·7	16	2·90	1·70	·05	·17	4·82	7·31	1·71	10·00	·43	·058	7·41	·74	3·43	—
Ansum-Disue Intergrade																		
B 883 ...	Broken	2	5·2	81	7·34	2·21	1·07	·39	11·01	14·50 (*a*)	3·32	5·67	3·00	·260	11·54	5·16	4·16	—
	forest.	12	5·5	89	3·33	1·39	·55	·15	5·42	9·57	2·40	9·27	·86	·068	12·65	1·46	3·33	—
		21	5·5	87	2·07	·96	·31	·74	4·08	7·86	2·16	1·30	·49	·064	7·66	·85	3·16	—
		32	5·3	81	1·33	1·30	·28	·50	3·41	7·37	1·02	2·60	·41	·045	9·11	·70	3·18	—
Ansum-Disue Intergrade																		
B 884 ...	do.	2	5·0	100	1·33	·45	·96	·12	2·86	8·12 (*a*)	2·96	3·75	2·08	·200	10·40	3·58	2·75	—
		5	5·1	100	·61	·71	·59	·12	2·03	6·63	·86	5·91	1·10	·128	8·59	1·89	2·58	—
		19	5·2	100	·31	·39	·52	·09	1·31	6·98	·79	4·33	·79	·093	8·49	1·34	2·87	—
		35	5·3	30	1·03	·73	1·05	·27	3·08	6·94	1·41	2·70	·61	·065	9·88	1·05	3·08	—

(*a*) As determined with ammonium acetate.

in this horizon. Normal examples of Ansum series with a topsoil reaction of more than pH 5·5 may be expected to resemble B 883, or be somewhat better, while B 884 is probably more typical of Disue series.

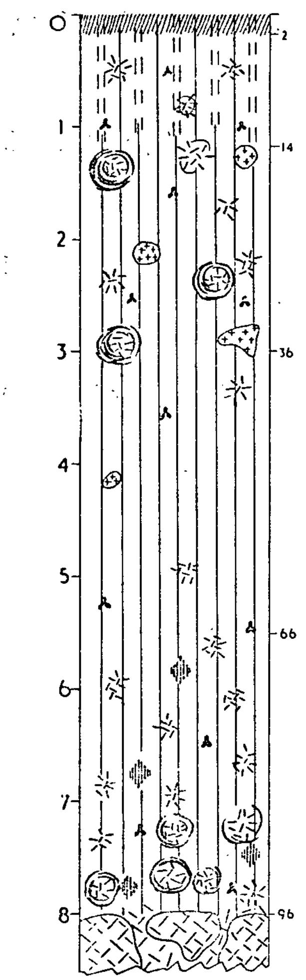
Ansum series supports a range of food crops and is also a cocoa soil. Only the better drained examples can be recommended for coffee. The main agricultural limitation of this series is its relatively limited extent and somewhat irregular occurrence.

36. Anum series

Anum series is a distinctive, fertile, but inextensive forest brunosol developed over certain basic rocks rich in hornblende. It is nearly neutral in reaction, and the series is further distinguished by its fairly dark colour and heavy texture, suggesting the presence of montmorillonite. It is one of the few soils in the basin in which the subsoil has a definite structure. This series is found on a range of sites from summit to lower slope, and is associated downslope with Abu and Rubi series.

Detailed description

The following typical example was sampled south of Efwhia, in the north of the basin, on a broad gently undulating upland site supporting excellent cocoa. Rainfall here is about 65 inches per annum.



Topsoil

0–2 inches: dark greyish brown (10YR 4/2) humous silty clay, nutty or coarsely granular, and slightly plastic. pH 6.8.

2–14 inches: dark yellowish brown (10YR 4/4) silty clay, plastic and medium angular blocky, slightly manganese stained and containing occasional small fragments of rock. pH 6.4.

Subsoil

14–36 inches: dark brown (10YR 4/3) clay, blocky and plastic, containing occasional manganese concretions and small and large rounded boulders of rock, slightly weathered and yellow on the outside. Some of these are a manganiferous greenstone, others a fine-grained hornblende granite (probably not related to the parent material). pH 6.4.

36–66 inches: yellowish brown (10YR 5/6) heavy clay, medium angular blocky, with rare manganese stains. Boulders, as above, are rare or absent. pH 6.4.

Weathered substratum

66–96 inches: pale brown mottled orange and dark brown heavy clay, blocky, plastic when moist and very hard when dry, containing frequent patches of a more friable decomposing manganiferous basic igneous parent rock. pH 6.0.

Below 96: as above, with increasing proportions of decomposing parent material. pH 6.0.

Fig. 52. Anum series.

Range in characteristics

This series may vary slightly in its parent material, but the main characteristics of dark colour, cloddy structure, heavy texture and near-neutral reaction are always the same.

Agricultural value

This series is somewhat less well drained internally than most sedentary soils because of the heavy texture, which also makes the series heavy to work. External drainage depends on the site, which is often relatively flat or only gently undulating.

The nutrient status of this soil is undoubtedly very high and it appears to be the most fertile soil in the basin. The fine earth fraction, except in the upper subsoil, is usually high and the presence of montmorillonitic clay which gives the series its characteristic structure and texture also ensures a high base exchange capacity, as well as an exceptional water-retaining capacity, though some of this water is not available to plants. Base status is high, though potash may form a lower percentage of the total than in more acid soils. This soil has consistently shown itself capable of supporting excellent cocoa. Drainage is too slow for coffee. The main disadvantage of this series is its scattered distribution and small total area.

37. Abu series

Abu series is the colluvial soil associated with Anum series, which it resembles in its dark colour, heavy texture, and neutral or near-neutral reaction.

Detailed description

The typical example described in Fig. 53 was sampled on a gently undulating middle-slope site south of Efwhia, near the profile of Anum series described above.

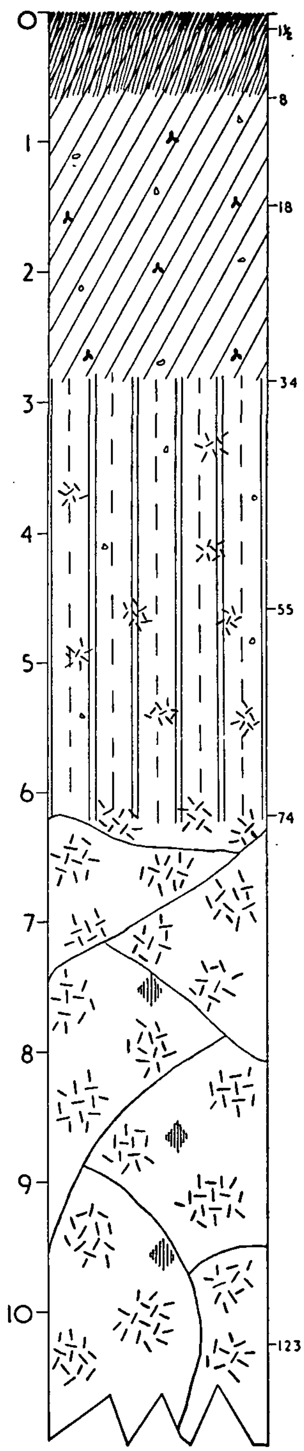
Range in characteristics

As in many colluvial soils, the depth of the subsoil varies, usually between 15 and 50 inches. The soil grades into Anum series up-slope, and into Rubi series in the valley bottoms.

Agricultural value

External drainage is usually moderate, but internal drainage is slow and the soil is rather heavy to work, though it has a very good water retention capacity in the dry season.

Base exchange capacity is high because of the high clay fraction which is thought to include some montmorillonite, and nutrient status is also unusually good. This is a fertile soil which, like Anum series, can, with correct management, be relied upon to support excellent cocoa.



Topsoil

0–1½ inches: very dark greyish brown (2.5Y 3/2) humous heavy clay, coarsely granular, slightly plastic when wet, loose when dry. pH 7.0.

1½–8 inches: olive brown (2.5Y 4/4) slightly humous heavy clay, nutty, plastic when wet, fairly hard when dry. pH 6.8.

Subsoil

8–18 inches: dark yellowish brown (10YR 4/4) heavy clay, nutty and plastic, with rare minute feldspar particles and small MnO_2 concretions. pH 6.6

18–34 inches: brownish yellow (10YR 6/6) heavy clay, as above. pH 6.4.

Weathered substratum

34–55 inches: yellow (10YR 8/6) light clay, slightly nutty and slightly plastic, with small specks of feldspar and patches of decomposing rock. pH 6.6.

55–74 inches: as above, but a little darker in colour and with more frequent patches of decomposing rock. pH 6.6.

74–123 inches: pale yellow, speckled white, orange and green, decomposing rock; this has the structure of the original rock, but is fairly soft and easily broken.

Fig. 53. Abu series.

38. Rubi series

Rubi series is a very dark, almost black, plastic heavy clay bottom soil associated with Anum and Abu series. The dark colour is due to the presence of manganese and, possibly, of calcium humate, and the heavy texture suggests the presence of some montmorillonite.

Detailed description

A very dark greyish brown, humous topsoil, 6–8 inches thick, overlies a very dark greyish black heavy clay subsoil, plastic when wet, hard and blocky when dry. The reaction of the profile is nearly neutral, being pH 6–7 throughout. As in the case of all valley bottom alluvial soils the depth of the subsoil varies and the soil may contain gravel or stone beds: the usual subsoil depth is 30–40 inches, below which weathered rock is found.

Range in characteristics

Those examples which contain a few calcium carbonate concretions are separated, and are known as Aprutu series, though these have not been found within the Lower Tano Basin.

Agricultural value

Drainage, both internal and external, is very slow, and during the wet season this soil is liable to be waterlogged for considerable periods. It is nevertheless a productive and highly fertile soil, with a high base exchange capacity and nutrient status, which is capable of giving very good yields of crops such as rice and sugarcane adapted to damp conditions. It is, however, found in very minor quantities indeed.

2B. THE YAKASI-SHI ASSOCIATION

This association consists of all the soils included in Group 2A (i.e. series numbers 28–38, 6, 7 and 12–18) together with acid alluvial and indurated soils numbers 20–21 and 25–27, and the following oxysol counterparts of soils described under 2A.

39. Elibo series

Elibo series is the oxysol counterpart of Atukrom series, an upland red sedentary forest soil developed over Upper Birrimian rocks.

Detailed description

The morphology of this series is similar to that of Atukrom series, described above (Series 28, page 177) from which this series differs mainly by virtue of its more acid topsoil. This is, by definition, pH 5·0 or below, though the profile usually becomes slightly less acid with depth.

Range in characteristics

Topsoil reaction is in the range pH 4·0–5·0.

Agricultural value

This series is well drained, both internally and externally, as is suggested by the reddish colour of the subsoil. It is, however, of only low fertility and it has a much lower content of exchangeable bases than its ochrosol equivalent, Atukrom series. This is brought out by a comparison of the analyses of an example of this series, described below, given in Table 21, with the analyses for an example of Atukrom series given in Table 19.

The following very concretionary and somewhat eroded example (B 845) was dug on a fairly steep upper-slope site on the western boundary of the Sui River forest reserve, where the rainfall is about 65 inches, per annum.

Topsoil

0–2 inches: dark brown (10YR 5/3) humous silty clay, slightly crumbly and loose, containing frequent ironstone concretions.

2–8 inches: brown (7.5YR 5/4) slightly humous silty clay, structureless and fairly loose, containing abundant small and large ironstone concretions and occasional ferruginised rock brash.

Subsoil

8–20 inches: reddish brown (5YR 5/3) silty light clay, structureless and firm, containing abundant ironstone concretions and ferruginised rock brash.

20–42 inches: reddish brown (5YR 5/4) silty clay, structureless and firm, containing very frequent to abundant small and large ironstone concretions and ferruginised rock brash.

42–62 inches: reddish brown (5YR 4/4) silty light clay, structureless and firm, containing very frequent large and small irregular ironstone concretions and occasional ferruginised rock brash.

62–90 inches: yellowish red (5YR 5/6) silty light clay, structureless and firm, containing frequent pieces of flattish, angular and somewhat ferruginised pieces of rock, and rare ironstone concretions.

Weathered substratum

90–118 inches: yellowish red (5YR 5/6) stained yellow silty heavy loam, structureless and very slightly indurated, with occasional small ferruginised rock fragments.

118–146 inches: as above, but with fewer ferruginised rock fragments.

146–200 inches: reddish yellow, mottled yellow and orange, silty loam, somewhat crumbly when dry, with traces and small patches of decomposing parent rock.

The analyses of this example (Table 21) show a total content of exchangeable bases which, in terms of m.e. per 100 gm. of the fine earth fraction, is higher than the oxysol average, but the fine earth fractions are so small even in the topsoil that the actual reserves in this highly concretionary soil are, as would be expected, very low.

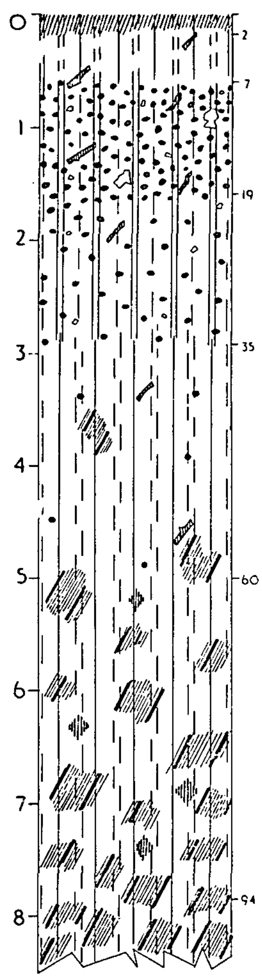
Normally, examples of this series could be expected to have a slightly higher nutrient status than Boi series. There is probably little or no difference in fertility between this series and Yakasi series, described immediately below, for which more analyses are available.

40. Yakasi series

Yakasi series is the oxysol equivalent of Asikuma series, a brown sedentary forest soil developed over Upper Birrimian rocks.

Detailed description

The morphology of this series is similar to that of Asikuma series, but the pH values are lower: the topsoil of Yakasi series is always below pH 5·0 and is usually in the range 4·2-4·6. The following general description is based on seven pits dug in the Enchi area, five of which have been analysed and are further discussed below.



Topsoil

0–2 inches: dark brown (7.5YR 4/3) humous silty clay, crumbly and loose. Very highly acid (average pH 4.5, usual range 4.2 to 5.0).

2–7 inches: brown (7.5YR 5/4) silty light clay, slightly crumbly and porous, containing occasional to frequent ironstone concretions and sometimes rare ferruginised rock brash. Very highly acid (average pH 4.5, range 4.2 to 4.6).

Subsoil

7–19 inches: strong brown (7.5YR 5/6) light clay, structureless and fairly firm, containing very frequent ironstone concretions, occasional quartz gravel and ferruginised rock brash and rare quartz stones. Highly acid (average pH 4.6, range 4.4 to 5.0).

19–35 inches: yellowish red (5YR 4/6) light clay, structureless and firm, containing frequent ironstone concretions, occasional ferruginised rock brash and rare quartz gravel. Highly acid (average pH 4.8, range 4.6 to 5.0).

35–60 inches: yellowish red (5YR 5/7) heavy loam, structureless and firm, containing rare ironstone concretions and ferruginised rock brash, and very rare scattered traces of decomposing parent rock. Highly acid (average pH 4.9, range 4.8 to 5.0).

Weathered substratum

60–94 inches: yellowish red mottled yellow heavy loam, structureless and fairly firm, with occasional to frequent traces of decomposing rock. Highly acid (average pH 5.0., range 4.8 to 5.2).

Below 94 inches: yellowish red mottled grey heavy loam with frequent patches of decomposing rock (schist or tuff), structureless but friable. This merges into soft decomposing parent rock. The pH in this zone is usually between 5.0 and 5.6.

Fig. 54. Yakasi series.

TABLE 21

ANALYTICAL DATA FOR ELIBO AND YAKASI SERIES

Series and Profile Number	*Vegetation*	*Lower depth of horizon in inches*	*pH*	*% Fine earth*	*Exchangeable Bases (m.e. per 100 gm.)* Ca	Mg	Mn	K	S (TEB)	T (CEC)	*Ca/Mg*	*Mg/K*	*C*	*N*	*C/N*	*O.M.*	*Moisture % Air-dry*	*Total P p.p.m.*
Elibo																		
B 845 ...	Broken Forest	2	4·1	27	4·01	2·09	·10	·96	7·16	—	1·92	2·18	5·99	·469	12·77	10·30	6·58	
		8	4·4	22	2·33	1·26	·06	·26	3·91	—	1·85	4·85	3·51	·276	12·72	6·04	6·13	
		20	4·7	32	·74	·55	·01	·10	1·40	—	1·35	5·5	1·60	·161	9·94	2·75	5.03	
		42	4·9	38	·30	·38	·01	·09	·78	—	·79	4·2	1·00	·112	8·93	1·72	5.09	
Yakasi B 841 ...	Broken Forest	1½	4·7	80	5·25	1·55	·12	·38	7·30	25·64 (*b*)	3·39	4·08	4·94	·363	13·61	8·50	3·33	
		5	4·5	80	1·31	·62	·03	·29	2·25	16·64	2·11	2·14	2·24	·193	11·61	3·85	2.28	
		15	4·7	62	·93	·35	·01	·11	1·40	14·60	2·66	3·18	1·15	·110	10·45	1·98	2·79	
		29	4·7	43	·60	·19	·005	·07	·86	13·81	3·16	2·71	·69	·076	9·08	1·31	3·22	
Yakasi B 842 ...	Secondary Forest	2	5·1	52	5·09	3·48	·80	·69	10·06	19·46 (*a*)	1·46	5·04	4·95	·417	11·87	8·51	4·33	
		6	4·4	48	·53	·96	·05	·13	1·67	7·20	·55	7·38	1·42	·154	9·22	2·44	3·57	
		16	4·5	28	·47	·51	·03	·08	1·09	9·68	·92	6·38	·88	·102	8·63	1·51	3.66	
		32	5·0	38	·47	·46	·06	·09	1·08	6·45	1·02	5·11	·57	·075	7·60	·98	3·58	
Yakasi B 880 ...	Broken Forest	2	4·4	100	2·16	1·22	1·76	·52	5·66	11·86 (*a*)	1·77	2·35	3·26	·327	9·97	5·61	3·45	
		9	4·6	89	1·03	·23	·81	·16	2·23	8·21	4·48	1·44	1·14	·129	8·84	1·96	3·03	
		23	5·0	28	·40	·20	·10	·16	·86	7·88	2·00	1·25	·73	·087	8·39	1·26	3·03	
		35	5·0	85	·44	·25	·03	·08	·80	7·00	1·76	3·12	·54	·069	7·83	·93	3·10	
Yakasi																		
B 881 ...	Broken Forest	2	4·4	100	·75	·28	·01	·39	1·43	14·24 (*a*)	2·68	·72	3·95	.303	13·04	6·79	3·31	
		5	4·5	33	·32	·16	·01	·19	·68	10·19	2·00	·84	1·73	·153	11·31	2·98	3·30	
		24	4·5	61	·37	·16	·005	·19	·72	10·44	2·31	·84	1·18	·114	10·35	2·03	3·61	
		50	4·8	42	·21	·09	·005	·09	·39	8·96	2·33	1·00	·72	·081	8·89	1·24	3·74	
Yakasi																		
B 882	Broken Forest	1	5·1	76	8·71	2·68	·11	·88	12·38	23·17 (*a*)	3·25	3·04	6·04	·543	11·12	10·39		
		4	4·8	82	2·63	·61	·07	·27	3·58	9·64	4·31	2·26	2·04	·221	9·23	3·51		
		16	4·9	14	·43	·33	·04	·19	·99	9·14	1·30	1·74	1·28	·148	8·65	2·20		
		33	5·0	12	·35	·38	·01	·19	·93	9·55	·92	2·50	·98	·115	8·50	1·58		

(*a*) As determined with ammonium acetate.

(*b*) As determined with barium acetate.

Range in characteristics

The amount, size and shape of the concretions vary within considerable limits but, as with most Upper Birrimian soils, there is relatively little quartz gravel.

Agricultural value

This series is well drained, both internally and externally. Cultivation characteristics are typical of upland forest soils, with a thin humous topsoil which is crumbly and easy to work, and a deep, gravelly, heavier-textured subsoil, dug less easily.

Nutrient status is low, as would be expected of an acid soil with a low fine earth fraction. Analytical data for five profiles are given in Table 21. These profiles are briefly described first.

B 841 *was sampled north-west of Enchi on a gently undulating upper slope site where the vegetation was original forest. Morphologically this profile was very similar to the average profile described above except that it was somewhat indurated below* 50 *inches.*

B 842 *was sampled in Sample strip* 5, *on the northern boundary of the Boin River forest reserve, just south of Enchi, on a very steep middle-slope site where the vegetation was secondary forest. This example was similar to the average described above except that it had frequent concretions in the topsoil.*

B 880 *was sampled on a steep upper-slope site, under original forest, along the south-eastern boundary of the Yoyo River forest reserve. This example had fewer concretions than the average, but had frequent ferruginised rock brash in the upper subsoil.*

B 881 *is a highly concretionary example of the series dug from a steep upper-slope site under original forest along the northern boundary of the Yoyo River forest reserve. It is the most acid of the four examples analysed.*

B 882 *was sampled along the eastern boundary of the Boin River forest reserve, from a gently undulating upper-middle slope site where the annual rainfall is about* 65 *inches. The morphology of this example is typical of the series and is similar to the average description given above.*

These analyses show that total reserves of exchangeable bases, after correction for the fine earth percentage, though moderately low are nevertheless above the averages for Lower Tano Basin Oxysols given in Table 5. This reflects the fact that Upper Birrimian rocks are a better source of plant nutrients than most of the remaining soil parent materials of the basin.

Though total exchangeable bases vary, in the five profiles, between rather wide limits, the most important of these, potash, is in relatively steady supply. Potash reserves are similar to the ochrosol averages given in Table 5 and somewhat above the oxysol figures. Carbon and nitrogen totals are also nearer the ochrosol averages than those for oxysols. It will be recalled that all the samples analysed are from the Enchi area, where the annual rainfall is 65 inches, the normal lower limit for oxysols. No phosphorus figures are available.

These figures confirm field observations that the Upper Birrimian soils of the Enchi area are potentially a little more fertile than the Lower Birrimian soils of the Asankrangwa area, in the same latitude and with a similar rainfall. While the better examples of this series, when newly cleared, may support cocoa, for most of the better drained sites coffee is probably preferable. Food crop yields can be expected to be slightly higher than those for Boi series, the corresponding oxysol developed over phyllite. Oil palm and, on the flatter lower sites, rubber can be expected to grow successfully.

41. Enchi series

Enchi series is the acid counterpart of Atewa series described above (series 32, page 182). It is a non-concretionary sedentary forest oxysol developed over Upper Birrimian parent rocks. It occurs only on very steep upland sites.

Detailed description

Morphologically this series is very similar to Atewa series (q.v.), though Enchi series appears to be somewhat less deep than Atewa series, and is also relatively much less common. Enchi differs from Atewa series mainly in its more acid topsoil, which usually has a reaction of pH 4·4 to 4·8, rising to pH 5·0 and above in the lower subsoil.

Range in characteristics

The depth of this series varies considerably: the more shallow examples grade into eroded versions of associated sedentary soils (Shi, Elibo and Yakasi series) from which the concretionary layers have been removed. Subsoil colour may be red or brown.

Agricultural value

The series is very well drained both internally and externally, soft and easy to work, but its steep site is a disadvantage and it is liable to rapid erosion and topsoil removal if carelessly cleared and exposed. No analyses are available but, provided that the topsoil has not been eroded, this series is thought to be slightly better than associated acid sedentary soils, mainly because of the high fine earth fraction. It is, however, found very seldom within the basin, being confined to the steep flanks of certain high hills where Piki and Tanokrom series also occur.

42. Disue series

Disue series is the oxysol equivalent of Ansum series (series 35, page 186), from which it is distinguished by its more acid topsoil reaction. The profile morphology and cultivation characteristics of the two series are very similar, but the agricultural potential of Disue series is limited by its lower nutrient status. This is probably somewhat similar to that of profile B 884, analytical data for which are given in Table 20.

2C. THE YAKASI ASSOCIATION

This is similar to 2B above, except that the relief is generally lower, so that certain upland soils (particularly series 30, 31, 34, 6, 7 and 21) are either absent or proportionately less extensive, while alluvial soils are relatively more extensive.

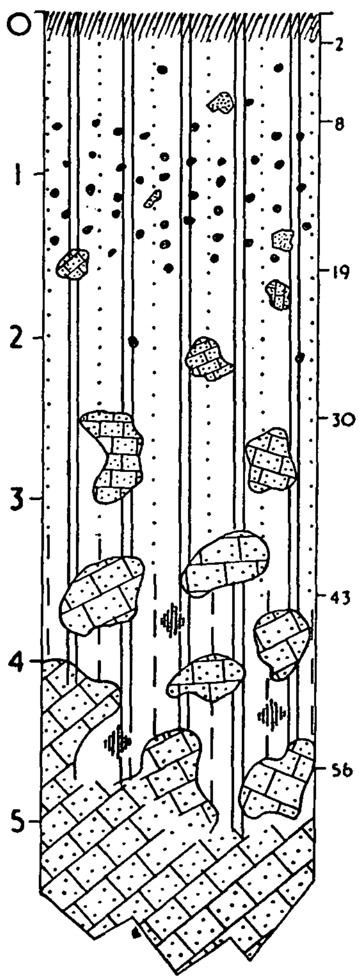
2D. THE SEFWI ASSOCIATION

43. Sefwi series

Sefwi series is a very minor oxysol developed over an arenaceous facies of the metamorphic rocks of the Bibiani range.

Detailed description

The following example was dug on the eastern boundary of the Tano Suraw forest reserve on a very steeply sloping upper-slope site where the vegetation was original forest.



Topsoil

0–2 inches: dark brown (10YR 4/3) humous sandy light clay, structureless and loose. pH 5.0.

2–8 inches: brown (7.5YR 5/4) sandy light clay, structureless and loose, with rare ironstone concretions. pH 5.4.

Subsoil

8–19 inches: reddish yellow (7.5YR 6/6) sandy clay, structureless and firm, containing frequent ironstone concretions and occasional brash of a sandy rock. pH 4.8.

19–30 inches: yellowish red (5YR 5/8) sandy clay, structureless and firm, with occasional small pieces of slightly weathered sandy rock and scattered ironstone concretions. pH 4.8.

30–43 inches: yellowish red (5YR 5/8) slightly gritty sandy clay, structureless and firm, with occasional boulders of slightly weathered sandy parent rock. pH 4.6.

Weathered substratum

43–56 inches: reddish yellow slightly mottled light clay, structureless and firm, with frequent boulders and friable patches of weathered sandy rock. pH 5.0.

Below 56 inches: sandy bedrock.

Fig. 55. Sefwi series.

Range in characteristics

Parent material includes a range of sandy metamorphic rocks including sandstone, quartzites, quartzitic greywackes and sandy conglomerates. Pieces of these rocks are always found in the profile, which is usually sandy clay in texture.

Agricultural value

This soil is relatively acid for the rainfall, and low in nutrients. The usual site on the flanks of the Bibiani range is steep and inaccessible. Because of its low fertility and liability to erosion this inextensive series is best left under forest.

This soil is associated with a colluvial soil similar to series 47, page 204.

SOILS DEVELOPED OVER GRANITES (GROUP 3)

3A. THE ANKASA ASSOCIATION

44. Abenia series

Abenia series is the normal upland sedentary forest oxysol developed over biotite granite in areas where the annual rainfall is above 65–70 inches. It is however less extensive proportionately than the sedentary soils of most forest catenas since most of the upland sites are occupied by Ankasa series (series 47, page 204). Abenia series has relatively few concretions compared with most upland sedentary soils of the basin, and is usually found on upper slopes and summits.

Detailed description

The average description (Fig. 56) is based on fourteen profiles sampled within the basin.

Range in characteristics

This soil is usually deep, the depth at which soft granite is found often reaching 16–18 feet, though in some shallow examples this is found at 5–10 feet. On steep slopes this series grades into the shallow, immature soil, Adiembra series. Texture is usually sandy or gritty, and this distinguishes the series from the silty Ninisu series developed over biotite schist. Large mica flakes are present in some profiles. A number of examples were found to be slightly indurated in the lower subsoil.

Agricultural value

External drainage is rapid; internal drainage is somewhat slower. Dry season moisture-retention capacity is only moderate, but because of the high total rainfall and short dry seasons of the southern half of the basin, this factor is not critical.

The nutrient status of this series, as shown by analyses of four profiles (Table 22), is very low, and this confirms field observations which indicate that this is an infertile soil.

The four profiles analysed are the following:—

B 855 *was sampled between Samreboi and Abenia on a gently rolling upper-slope site where the vegetation was original forest and the annual rainfall is about* 70 *inches. The morphology is very similar to the average example described above.*

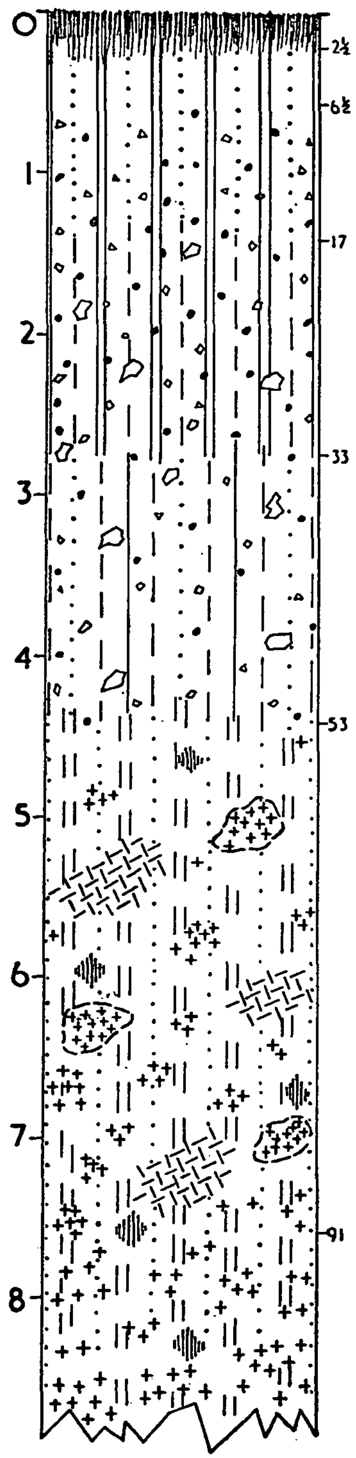
B 858 *was sampled on Sample strip* 9, *at Abenia, on a gently rolling upper slope site under original forest. The morphology closely resembles the average example already described.*

B 859 *is from a similar site, also on Sample strip* 9. *This example is slightly indurated below* 50 *inches but is otherwise typical.*

B 862 *was sampled on a gently undulating upper-slope site under original forest north of Ebowu, in the south of the basin. Its morphology is very similar to B* 859.

Analyses of these four profiles show that total exchangeable bases are only about 2–3 m.e. in each case, which is below the average for all oxysols within the basin (Table 5). Calcium, magnesium and manganese are present in quantities which are below the oxysol averages, though potassium figures are similar to the oxysol average. These figures are further reduced by the moderately low fine earth fraction which, in the four profiles analysed, averages 34 and 40 per cent in the upper layers of the subsoil. Carbon/nitrogen ratios for this series and the associated Abenia series are particularly high.

This is a highly leached soil with very poor nutrient reserves and a very low agricultural value. Cocoa does not grow on this series and coffee yields can be expected to be low: oil palm is probably the most suitable tree crop.



Topsoil

0–2½ inches: greyish brown (10YR 5/2) humous light clay, slightly crumbly and slightly loose. Very highly acid (average pH 4.4, range 4.0 to 5.0).

2½–6½ inches: light yellowish brown (10YR 6/4) slightly humous fine sandy light clay to clay, slightly crumbly and slightly loose. Highly acid (average pH 4.6, range 4.0 to 5.2).

Subsoil

6½–17 inches: light yellowish brown (10YR 6/4) slightly gritty and slightly micaceous light clay to clay, structureless and firm, containing rare ironstone concretions. Highly acid (average pH 4.7, range 4.4 to 5.2).

17–33 inches: reddish yellow (7.5YR 6/6) slightly micaceous light clay, structureless and firm, containing occasional ironstained quartz gravel (easily mistaken for concretions), ironstone concretions, and quartz stones. Highly acid (average pH 4.8, range 4.6 to 5.4).

33–53 inches: strong brown (7.5YR 5/6) slightly gritty and slightly micaceous heavy loam, structureless and firm containing occasional quartz gravel and stones and rare ironstone concretions. Highly acid (average pH 4.9, range 4.6 to 5.2).

Weathered substratum

53–91 inches: yellow brown gritty loam, with orange and red stains and mottles, structureless and firm, and with occasional indurated patches. This horizon contains occasional to frequent traces of decomposing granite, and pieces of slightly weathered granite. Highly acid (average pH 4.9 to 5.0, range 4.6 to 5.2).

Below 91 inches: as above with increasing amounts of weathered granite, merging into soft weathered granite below. This zone of decomposing rock usually has a pH of 4.9 to 5.0.

Fig. 56. Abenia series.

TABLE 22

ANALYTICAL DATA FOR ABENIA AND NINISU SERIES

Series and Profile Number	*Vege-tation*	*Lower depth of horizon in inches*	*pH*	*% Fine earth*	*Exchangeable Bases (m.e. per 100 gm.)* Ca	Mg	Mn	K	S (TEB)	T (CEC)	*Ca/Mg*	*Mg/K*	*C*	*N*	*C/N*	*O.M.*	*Moisture % Air-dry*	*Total P p.p.m.*
Abenia																		
B 855 ..	Broken Forest	3	4·1	87	1·80	1·01	·10	·44	3·26		1·78	2·30	5·39	·378	14·26	9·27	3·29	385
		7	4·2	47	·41	·54	·02	·29	1·26		·76	1·86	2·27	·186	12·20	3·90	2·47	355
		20	4·7	24	·15	·25	·01	·07	·48		·60	3·57	·85	·089	9·55	1·46	2·88	427
		39	4·9	31	·20	·20	·01	·03	·44		1·00	6·67	·65	·073	8·90	1·12	2·95	453
Abenia																		
B 858 ..	Broken Forest	2	4·3	70	·91	·70	·03	·35	1·99		1·30	2·00	3·13	·220	14·23	5·38	2·09	
		7	4·55	62	·41	·49	·01	·14	1·05		·84	3·50	1·26	1·05	12·00	2·17	1·66	
		13	4·8	40	·62	·49	·01	·07	1·19		1·27	7·00	·77	·072	10·69	1·32	1·88	
		22	4·8	34	·41	·30	·01	·05	·77		1·37	6·00	·60	·064	9·38	1·03	2·15	
Abenia																		
B 859 ..	Broken Forest	3	4·1	100	1·85	1·01	·03	·15	3·08		1·83	5·32	4·24	·245	17·31	7·29	2·64	
		6	4·4	66	·42	·47	·02	·18	1·09		·89	2·61	1·42	·099	14·34	2·44	1·84	
		19	4·5	24	·80	·31	·01	·18	1·30		2·58	1·72	·54	·061	8·85	·93	2·22	
		37	4·6	34	·30	·28	·01	·07	·67		1·03	4·14	·28	·048	5·83	·48	3·33	
Abenia																		
B 862 ..	Broken Forest	2	4·3	67	1·34	·78	·03	·26	2·41	7·70 (*a*)	1·72	3·00	2·41	·166	14·52	4·15	1·77	
		6	4·3	51	·40	·21	·01	·05	·67	5·37	1·90	4·20	1·56	·110	14·18	2·68	1·63	
		20	4·6	47	·18	·18	·1	·07	·43	4·02	1·06	2·43	·74	·068	10·88	1·27	1·87	
		36	4·8	59	·22	·38	·005	·11	·71	4·04	·58	3·46	·55	·056	9·82	·95	2·35	
Abenia: Average of Profiles, Above	Broken Forest	2·5	4·2	81	1·47	·88	·048	·31	2·69		1·67	2·87	3·79	·252	15·04	6·52		
		6·5	4·36	57	·41	·43	·015	·17	1·03		·95	2·53	1·63	·125	13·04	2·80		
		18·0	4·65	34	·44	·31	·01	·10	·86		1·42	3·10	·73	·073	10·00	1·25		
		33·5	4·77	40	·29	·29	·01	·07	·65		·97	4·14	·52	·060	89·67	·90		
Ninisu																		
B 854 ..	Broken Forest	2	4·5	96	·41	·36	·09	·13	·98		1·17	2·69	1·83	·140	13·07	3·15	1·80	199
		7	4·8	92	·36	·36	·01	·05	·78		1·00	7·20	1·27	·102	12·45	2·18	1·68	218
		19	5·0	45	·37	·39	·02	·03	·81		·95	13·00	·76	·069	11·01	1·31	2·11	300
		41	5·1	47	·37	·32	·01	·05	·75		1·16	6·40	·57	·064	8·91	·98	2·47	351
Ninisu																		
B 861 ..	Broken Forest	2	5·0	62	·43	·38	·01	·15	·97	6·88 (*a*)	1·13	2·53	1·24	·097	12·78	2·13	1·47	
		8	5·3	33	·25	·20	·01	·04	·50	4·34	1·25	5·00	·82	·081	10·12	1·41	2·26	
		17	5·3	41	·16	·08	·01	·01	·26	6·19	2·00	8·00	·68	·070	9·71	1·17	2·51	
		42	5·4	40	·19	·10	·01	·07	·37		1·90	1·43	·47	·058	8·10	·81	2·88	

(*a*) As determined with ammonium acetate.

45. Ninisu series

Ninisu series, the acid equivalent of Nsaba series, is a yellow to orange-brown sedentary upland forest oxysol developed over biotite schist in areas where the rainfall is 65–70 inches and above. It is found on a range of sites from lower slope to summit, and occurs most frequently in partially granitised zones near the margins of the main granite areas, so that it often occurs with soils such as Abenia series developed over biotite granite. It has a normal concretionary forest profile which is distinguished from Abenia series by its lack of grit. The weathered parent rock has a distinctive purplish colour.

Detailed description

The description given in Fig. 57 is based on eight profiles sampled in the basin.

Range in characteristics

Topsoil and subsoil are occasionally fine sandy. In rare cases the lower part of the subsoil is indurated.

Agricultural value

This soil is fairly well drained both internally and externally. Cultivation characteristics are similar to those of most gravelly forest soils.

Only two examples have been analysed (Table 22).

These are described below:

B 854 *was sampled from a gently rolling upper middle slope site on the western boundary of the Fure Headwaters Forest Reserve where the rainfall is about* 65 *inches per annum. It has a morphology similar to the average example described above.*

B 861 *with a similar morphology and site to B* 854, *was sampled further south between Jemma and Abenia, where the rainfall is about* 70 *inches per annum.*

Analyses of both of these examples show unusually low base reserves for a sedentary soil, the totals being as low as those for Ankasa series, the associated colluvial soil, so that this is a very highly leached soil from which the bases have been almost completely removed. Even potash is outstandingly low and both profiles also have an unusually low carbon and nitrogen content, with high carbon/nitrogen ratios indicating a relative nitrogen deficiency. If the two examples analysed are typical of the series, this is undoubtedly an exceptionally poor soil which, even when newly cleared, can give only very low returns.

46. Adiembra series

Adiembra series is an immature soil, usually found on relatively steep slopes, consisting essentially of a humous topsoil overlying a weathered substratum of the products of the decomposition of the granite parent material. This series is equivalent to Piki and Kobeda series in Upper and Lower Birrimian areas respectively.

Detailed description

The following example, sampled on Sample strip 9, at Abenia, is typical of the series.

Topsoil

0–2 inches: greyish brown (10YR 5/2) slightly humous, slightly gritty light clay, with a weak crumb structure and fairly loose. pH 4.6.

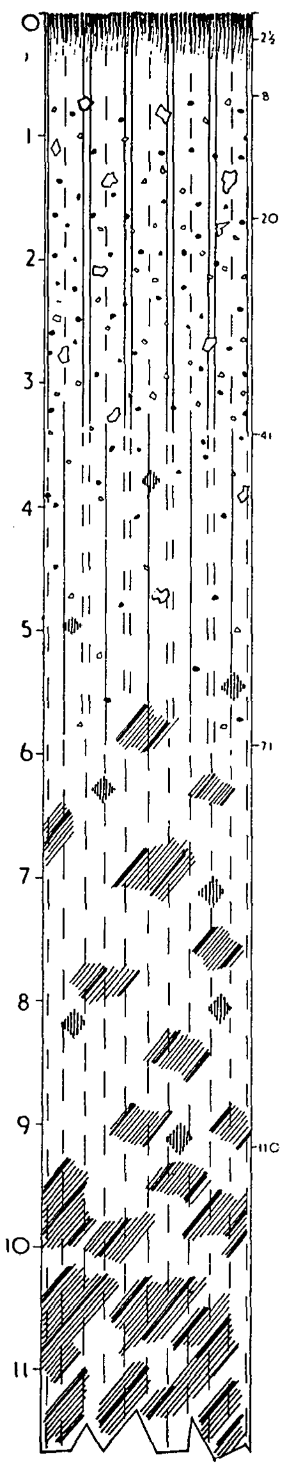
2–5 inches: dark brown (10YR 4/3) very slightly humous gritty light clay, structureless and slightly loose, with frequent quartz gravel. pH 4.4.

Weathered substratum

5–27 inches: light yellowish brown (10YR 6/4) slightly gritty light clay, structureless and firm, with frequent quartz gravel, mica flakes and traces of decomposing granite. pH 4.6.

27–62 inches: pale yellowish brown, mottled orange and yellow, structureless heavy loam of decomposed granite, containing frequent quartz gravel, feldspar particles, mica flakes and traces of partly decomposed granite. pH 4.6.

Below 62 inches: pale yellowish brown loam, mottled orange, red and yellow, with rare fine quartz gravel and mica specks, and frequent patches of partially decomposed fine-grained biotite granite. pH 4.6.



Topsoil

0–2½ inches: brown (10YR 5/3) humous loam to light clay, crumbly and loose. Highly acid (average pH 4.6, range 4.4 to 4.8).

2½–8 inches: light yellowish brown (10YR 6/4) slightly humous light clay, structureless and slightly loose. Highly acid (average pH 4.7 to 4.8, range 4.6 to 5.0).

Subsoil

8–20 inches: reddish yellow (7.5YR 6/6) light clay, structureless and firm, containing occasional quartz gravel, ironstone concretions, and quartz stones. Highly acid (average pH 4.75, range 4.6 to 5.0).

20–41 inches: strong brown to reddish yellow (7·5YR 5/6–6/6) light clay, structureless and firm, containing frequent quartz gravel and occasional ironstone concretions and quartz stones. Highly acid (average pH 5.0, range 4.9 to 5.2).

41–71 inches: yellowish red (5YR 5/8) sometimes stained or mottled light clay, structureless and firm, containing very rare ironstone concretions, quartz gravel and stones. Highly acid (average pH 5.0, range 4.8 to 5.2).

Weathered substratum

71–110 inches: yellowish red loam, mottled red and yellow, with purple patches of decomposing biotite schist. Structureless and fairly firm. Highly acid (average pH 5.0). Below this the proportion of friable decomposing biotite schist increases until the profile merges into weathered rock at about 15 feet.

Fig. 57. Ninisu series.

Range in characteristics

Adiembra series, within the basin, usually has a topsoil reaction within the range pH 4.4–4.8, the weathered substratum having a similar or slightly less acid reaction.

Agricultural value

The shallowness of this soil, so that decomposing rock occurs immediately below the topsoil, probably gives it a better nutrient status than the remaining soils of the association, though the steep site calls for care in cultivation to prevent loss of the thin and generally poorly humous topsoil. External drainage is good; internal drainage moderately so. Coffee and oil palm are probably the tree crops best adapted to this series.

47. Ankasa series

Ankasa series is a yellow-brown part-colluvial part-sedentary forest oxysol developed over biotite granite. It is found on upper to lower slopes of gently undulating to strongly rolling granite areas and forms the most extensive series in the association. Ankasa series is associated with sedentary soils above it, both Ninisu and Abenia series, and with colluvial and alluvial soils below. Although undoubtedly partly colluvial there is often no marked transition in this extensive series between transported material and that formed in situ.

Detailed description

The general description given in Fig. 58 is based on thirteen pits dug within the basin.

Range in characteristics

The subsoil depth varies between 20 and 60 inches: below this the granite is often fairly deeply weathered, though in some cases fresh granite may begin at 3–4 feet below the surface. Topsoil pH is below 4·0 in some examples, and this is one of the most acid soils in the basin. Some of the profile are sandy rather than gritty as described above.

Agricultural value

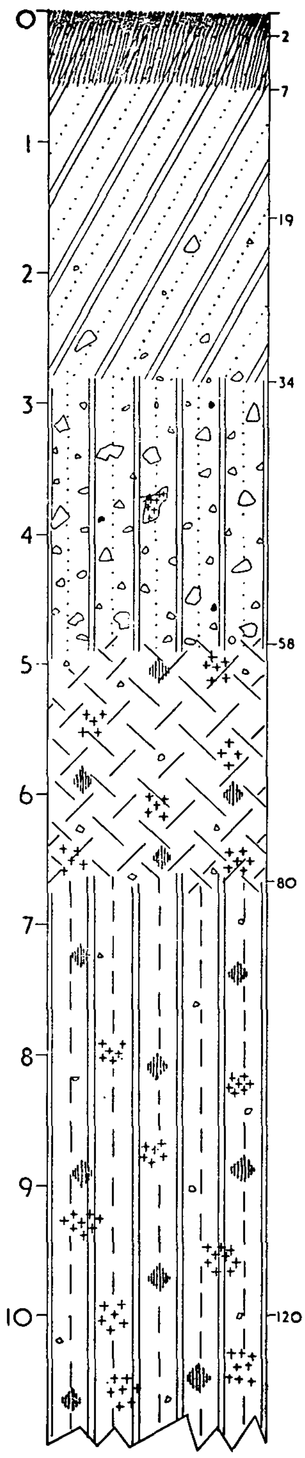
Ankasa series is moderately easy to work, particularly in the topsoil, well drained externally and moderately drained internally. Its main agricultural limitation is its very low nutrient status. Despite a high fine earth fraction, this series is so highly leached that the total nutrient supply is extremely low. The topsoil is also very poor in organic matter: nitrogen and, presumably, phosphorus are low, Field observations suggest that this soil is unsuited to cocoa, which often dies while still young, and that food crop yields are also disappointing. Pineapples, cassava and oil palm are possibly the plants best adapted to this series and coconut palms grow moderately well, though with all of these yields can be expected to be low without fertilisers.

Three examples of this series have been analysed. These are the following:

B 856 *was sampled on a gently rolling middle slope under broken forest south-east of Samreboi where the annual rainfall is* 65–70 *inches. Its morphology is very similar to the average example described above.*

B 857 *is from a gently rolling upper slope site in Sample strip* 9 *at Abenia. The vegetation was original forest and the rainfall is about* 70 *inches per annum. The morphology is typical of the series.*

B 860 *is from a rolling middle-slope site in Sample strip* 8 *on the Prestea road south-east of Samreboi. Vegetation was original high forest, rainfall is* 65–70 *inches per annum, and the morphology of this profile is also typical.*



Topsoil

0–2 inches: greyish brown (10YR 5/2) slightly humous slightly gritty light clay, crumbly and loose. Highly acid (average pH 4.6, range 3.8 to 4.8).

2–7 inches: pale brown (10YR 6/3) slightly humous gritty light clay, structureless and porous. Highly acid (average pH 4.6, range 4.2 to 4.8).

Subsoil

7–19 inches: light yellowish brown (10YR 6/4) gritty clay, structureless and firm. Highly acid (average pH 4.6, range 4.2 to 4.8).

19–34 inches: light yellowish brown (10YR 6/4) gritty light clay, structureless and firm, containing occasional quartz gravel and very rare angular and subangular quartz stones. Highly acid (average pH 4.7, range 4.6 to 5.0).

34–58 inches: light yellowish brown (10YR 6/4) gritty light clay, structureless and firm, containing occasional to frequent fine and coarse quartz gravel, occasional angular quartz stones, frequent subangular small quartz stones, and rare ironstone concretions. Highly acid (average pH 4.8, range 4.6 to 5.2).

Weathered substratum

58–80 inches: light yellowish brown (10YR 6/4) mottled grey and red light clay, structureless and often slightly indurated, containing occasional fine and coarse quartz gravel and occasional to frequent traces of decomposing granite. Highly acid (average pH 4.9, range 4.6 to 5.2).

80–120 inches: yellowish brown mottled red and grey light clay, structureless and firm, containing frequent fine quartz gravel and patches of soft decomposing granite. Highly acid (average pH 4.9, range 4.8 to 5.2) This merges below into a gritty loam of decomposing granite.

Fig. 58. Ankasa series.

TABLE 23

ANALYTICAL DATA FOR ANKASA SERIES

Series and Profile Number	*Vegetation*	*Lower depth of horizon in inches*	*pH*	*% Fine earth*	*Exchangeable Bases (m.e. per 100 gm.)* Ca	Mg	Mn	K	S (TEB)	T (CEC)	Ca/Mg	Mg/K	C	N	C/N	O.M.	*Moisture % Air-dry*	*Total P p.p.m.*
Ankasa B 856 ...	Broken forest.	2	4·4	83	·41	·30	·01	·14	·86	—	1·37	2·14	1·52	·115	13·22	2·61	1·28	—
		7	4·4	90	·22	·19	·01	·04	·46	—	1·16	4·75	·74	·061	12·13	1·27	1·50	—
		28	4·6	89	·24	·19	·01	·05	·49	—	1·26	3·80	·54	·055	9·82	·93	1·83	—
		48	5·0	86	·29	·28	·01	·05	·63	—	1·04	3·60	·43	·053	8·11	·74	2·21	—
Ankasa B 857 ...	do.	2	4·2	100	·72	·60	·04	·16	1·52	—	1·20	3·75	1·98	·129	15·35	3·41	1·30	—
		4	4·6	100	·36	·21	·01	·02	·60	—	1·71	10·50	·86	·067	12·83	1·48	1·46	—
		12	4·8	100	·41	·14	·01	·03	·59	—	2·93	4·67	·48	·045	10·67	·83	1·52	—
		26	4·7	94	·31	·10	·01	·03	·45	—	3·10	3·33	·35	·040	8·75	·60	1·76	—
Ankasa B 860 ...	do.	2	4·3	97	·73	·51	·01	·26	1·51	—	1·43	1·96	1·92	·110	17·45	3·30	1·32	—
		8	4·4	95	·23	·18	01	·19	·61	—	1·28	·95	·72	.061	11·80	1·24	1·56	—
		19	4·8	97	·24	·21	·01	·06	·52	—	1·14	3·50	·46	·047	9·79	·79	·69	—
		33	4·7	97	·22	·20	·01	·04	·47	—	1·10	5·00	·35	·403	8·14	·60	1·78	—
Ankasa Average of 3 profiles above.	do.	2·0	4·3	93	·62	·47	·02	·19	1·29	—	1·32	2·47	1·81	·118	15·52	3·11	—	—
		6·3	4·46	95	·27	·19	·01	·08	·55	—	1·42	2·37	·77	·063	12·22	1·33	—	—
		17·0	4·73	95	·29	·18	·01	·05	·53	—	1·50	3·60	·49	·049	10·00	·85	—	—
		35·6	4·38	92	·27	·19	·01	·04	·42	—	1·42	4·75	·38	·045	8·44	·65	—	—

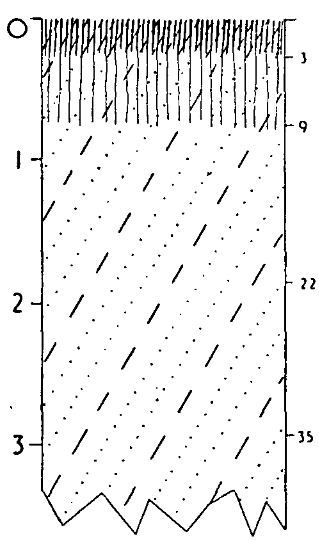
Analytical data for these three profiles (Table 23) indicate that exchangeable bases are lower than for many sandy soils, being lower than for soils developed over Tertiary sands and as low as the poorest soils in the coastal sands group. These figures suggest a leaching so complete that very little remains. In all three profiles calcium is well below even 1 m.e. per 100 gm. of the fine earth fraction throughout, manganese is almost absent, and total exchangeable bases are correspondingly low. Despite the presence of mica in the parent rock, potash figures are about half the oxysol average (Table 5). Carbon and nitrogen figures, compared with the oxysol average, are relatively even poorer, while the air-dry moisture figures suggest a low clay content and, under less heavy rainfalls, a tendency to droughtiness. These figures confirm field observations which indicated that Ankasa series is the poorest major soil in the basin.

48. Nta series

Nta series is an acid, pale yellow sandy soil of lower slopes, developed in sandy colluvium washed out of soils higher up the catena. It is not extensive within the basin, though it is more common in some granite areas outside it.

Detailed description

The following average description is based on numerous chisel holes dug within the basin.



Topsoil

0–3 inches: dark greyish brown humous loam, crumbly and loose. Highly acid.

3–9 inches: greyish brown loamy sand, with little or no visible humous, structureless and loose. Highly acid.

Subsoil

9–22 inches: pale yellow to pale yellowish brown sand or loamy sand, structureless and loose. Highly acid.

22–35 inches: as above, often a little paler in colour. Below this a stone-line (sometimes absent) separates the transported material above it from weathered rock below.

Fig. 59. Nta series.

Range in characteristics

Depth and development of the stone-line varies. Texture is usually sand to loamy sand. Topsoil pH is within the range 4·0 to 5·0.

Agricultural value

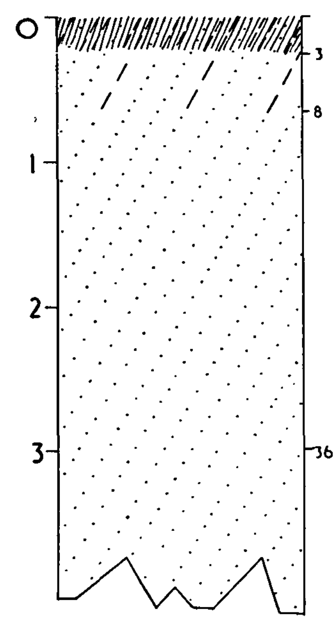
External drainage is good: internal drainage is very rapid to excessive and the soil dries out rapidly during dry spells. This series is very loose, light textured and easy to cultivate but it is also easily eroded. The nutrient status is very low, being similar to or lower than Ankasa series, and the agricultural value of this series is limited accordingly. Almost all the nutrients are stored in the topsoil. The sandy subsoil has a very low base exchange capacity and is nearly sterile.

49. Ofin series

Ofin series is a pale grey to white alluvial sand of valley bottoms, classified as an acid to very acid gleisol. It occurs in association with granite upland soils.

Detailed description

The following average profile is based on all pits and chisel holes dug within the basin.



Topsoil

0–3 inches: brownish grey (10YR 5/2) humous sandy loam, slightly crumbly and loose. Highly acid.

3–8 inches: light brownish grey (10YR 6/2) slightly humous loamy sand, structureless and loose. Highly acid.

Subsoil

8–36 or more inches: light grey (10YR 7/1) sand, becoming paler with depth, structureless and loose. Highly acid. Below this stones or gravel may be present and the subsoil overlies weathered rock at between 3 and 6 feet, or more.

Fig. 60. Ofin series.

Range in characteristics

The texture of the subsoil is usually sand or loamy sand, but occasional horizons are heavier in texture. The topsoil reaction is usually between pH 4·0 to 5·0, with a slightly less acid subsoil.

Agricultural value

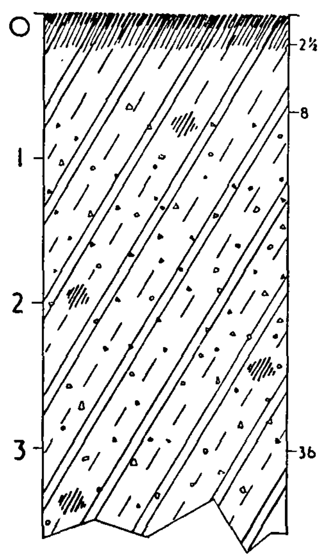
The moisture relationships of this series fluctuate considerably during the year. Internally it is very free-draining with a very low water-retaining capacity, so that it is liable to dry out during dry spells. Because of its low site, however, it is flooded and waterlogged after heavy rains and has a water-table near the surface during the wet season. The nutrient status and base exchange capacity are very low indeed, and the soil is highly leached, as is suggested by its near-white colour. Despite the ease with which this soil can be worked, its agricultural value is usually very low. The sand of the subsoil is often used for making concrete blocks.

50. Firam series

Firam series is a grey, ill-drained gritty valley-bottom clay of granite areas. It is an acid to very acid gleisol transitional in character between Ofin and Oda series (series 49 and 14, above and page 155).

Detailed description

The average description (Fig. 61) is based on chisel hole samples dug within the basin.



Topsoil

0–2½ inches: dark greyish brown humous light clay, slightly crumbly but fairly firm, containing rare quartz grit. Highly acid.

2½–8 inches: dark grey slightly humous light clay, structureless and firm, containing occasional quartz grit. Highly acid.

Subsoil

8–36 inches or more: pale bluish grey to grey light clay to clay, slightly stained or mottled, structureless and firm, containing frequent quartz grit. Highly acid. The mottles become better developed towards the lower part of the subsoil, which may be underlain by gravel or pebbles, or overlie directly the weathered granite below.

Fig. 61. Firam series.

Range in characteristics

The depth of the subsoil may reach 6 or more feet, and there is a considerable variation in the amount of quartz grit, gravel and stones present. The reaction is always highly acid, being below pH 5·0 throughout the profile.

Agricultural value

Both internal and external drainage are very slow, as is suggested by the grey colour, and the soil is liable to be waterlogged at times of heavy rain. The water-table is always fairly near the surface and the soil remains moist throughout the dry season. Although organic matter content in the topsoil is sometimes moderately good, total nutrient reserves are low. The soil is, however, more productive than Ofin series and, because of the poor drainage, is best planted to chewing cane or rice, though yields without fertilisers will not be high.

3B. THE NSABA ASSOCIATION

In addition to the two series described below, this association includes alluvial soils numbers 13, 14 and 25–27.

51. Nsaba series

Nsaba series is a yellow-brown to orange-brown sedentary forest ochrosol developed over biotite schist, a partially granitised rock intermediate between phyllite and biotite granite. Nsaba series is found on a variety of sites, from lower slope to summit, under rainfalls of 60–65 inches per annum. Under a higher rainfall than this it grades into Ninisu series, its acid equivalent. It has a normal sedentary profile with a moderately well developed gravel layer.

Detailed description

The morphology of this series and its range in characteristics are very similar to those of Ninisu series (series 45, page 202) except that the topsoil has a pH value of 5·5 to 6·5 or more, though most examples within the basin have topsoil pH values within the lower part of this range. Below the topsoil, the soil becomes a little more acid, dropping to about pH 5·0 in the lower subsoil.

Agricultural value

Nsaba series is fairly well drained, both internally and externally, and does not appear to dry out dangerously during the short dry seasons experienced in the basin. The nutrient status of the series is probably similar to examples of Nzima series of the same acidity. In both cases the degree of acidity and the thickness of the topsoil are responsible for considerable variations between individual profiles. With a topsoil reaction of pH 6·0 and above, Nsaba series is a productive soil with a fair reserve of potash and nitrogen, and possibly phosphorus too. Examples with topsoil pH values between 5·5 and 6·0 and Nsaba-Ninisu intergrades with topsoil reactions between pH 5·0 and 5·5 are relatively moderate to poor soils.

52. Akroso series

Akroso series is a yellow-brown sandy or gritty forest ochrosol, associated with granite sedentary soils, developed in light clay colluvium of middle and lower slopes. It is very widespread in the forest area of Ghana, but uncommon in the Lower Tano Basin where its oxysol equivalent, Ankasa series, is usually found instead.

Detailed description

Relatively few examples occur within the basin: the average description (Fig. 62) is based therefore on thirty-four pits sampled elsewhere in the forest areas of Ghana, mainly in the Kumasi Region.

Range in characteristics

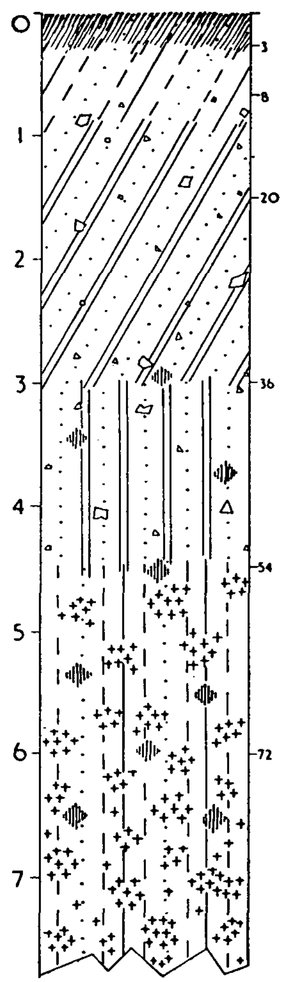
The depth of transported material varies between about 30 and 70 inches. A stone-line is sometimes found at the base of this but it may be poorly developed or absent entirely. Topsoil reaction is within the range pH 5·5–6·5.

Agricultural value

External drainage is good, and internal drainage is moderate to fairly good. Dry season moisture retention, under rainfalls experienced in the basin, is usually satisfactory.

The nutrient status of the series is similar or slightly inferior to the normal sedentary soils with which the series is associated. Analyses of eight profiles outside the basin show that the content of bases is slightly less than the Lower Tano Basin ochrosol averages given in Table 5, while organic matter is distinctly lower. Both potash and nitrogen fall off very sharply below the topsoil. These soils are therefore of moderate fertility, distinctly better than most acid soils of the basin, but inferior to the better sedentary ochrosols.

Physically the soil is fairly easy to work and free of stones, though it is liable to erosion if left unprotected.



Topsoil

0–3 inches: greyish brown (10YR 5/2) humous light loam, structureless and loose. Moderately acid (average pH 5.9).

3–8 inches: light yellowish brown (10YR 6/4) very slightly humous sandy or gritty heavy loam, structureless and loose. Moderately acid (average pH 5.5 to 5.6).

Subsoil

8–20 inches: light yellowish brown (10YR 6/4) sandy or gritty light clay, structureless and slightly firm, containing rare quartz gravel and stones. Very acid (average pH 5.4).

20–36 inches: yellow-brown (10YR 6/5) sandy or gritty light clay, structureless and firm, containing rare quartz gravel and stones. Very acid (average pH 5.3).

36–54 inches: strong brown (7.5YR 5/6) sandy or gritty light clay, structureless and firm, containing rare quartz gravel and occasional quartz stones. Very acid (average pH 5.2).

Weathered substratum

54–72 inches: light brown (7.5YR 6/4) gritty, heavy loam, somewhat stained or mottled, with frequent traces of decomposing granite. Very acid (average pH 5.1).

Below 72 inches: as above, but with increasing amounts of decomposing granite merging into weathered rock at about 12 feet.

Fig. 62. Akroso series.

3C. THE NINISU ASSOCIATION

This association includes series 44 and 46, associated with soils of the Nzima-Boi association, association 1C.

3D. THE ADUJANSU ASSOCIATION

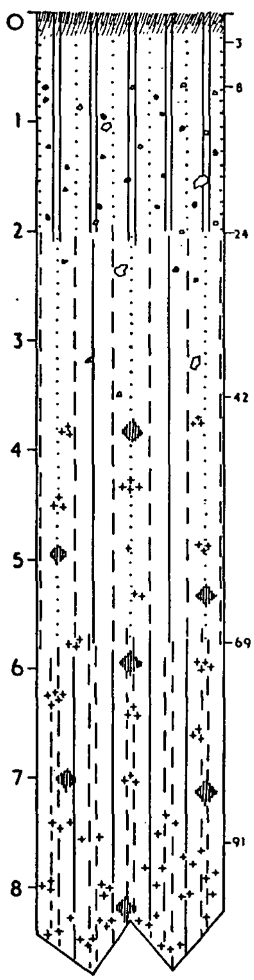
The two series described below are associated with series 52 and with alluvial soils numbers 12–18 and 48–50.

53. Adujansu series

Adujansu series is a red sedentary forest ochrosol developed over hornblende granite containing little or no visible mica. Within the Lower Tano Basin it is very inextensive, and occurs only over small granite patches found in the Upper Birrimian areas, north and south of Enchi and in the Bibiani range, where the rainfall is about 65 inches per annum.

Detailed description

The average description (Fig. 63) is based on pits dug both within the basin and in similar forest areas, particularly in the Kumasi Region.



Topsoil

0–3 inches: dark brown (7.5YR 4/2) humous fine sandy loam to light clay, crumbly, loose and porous. Moderately acid to slightly acid (average pH 6.3, range 5.5 to 7.0).

3–8 inches: dark brown to brown (7.5YR 4/4) slightly humous fine sandy heavy loam to light clay, weakly crumbly, firm and slightly porous. Slightly acid (average pH 6.3).

Subsoil

8–24 inches: red to reddish brown (2.5YR 6/5) sandy light clay, structureless and firm, containing frequent quartz gravel and rare to occasional ironstone concretions and quartz stones. Moderately acid (average pH 5.9).

24–42 inches: red (2.5YR 5/6) sandy heavy loam, structureless and firm, containing rare ironstone concretions and occasional quartz gravel and stones. Moderately acid (average pH 5.7).

Weathered substratum

42–69 inches: yellowish red (5YR 5/6) mottled sandy heavy loam, structureless and firm, containing frequent traces of decomposing rock. Moderately acid (average pH 5.7).

69–91 inches: light red, mottled red yellow and grey heavy loam, structureless and friable, containing frequent traces of decomposing granite. Moderately acid (average pH 5·6).

Below 91 inches: highly mottled red, yellow, grey and white loam of soft weathered granite, structureless and friable.

Fig. 63. Adujansu series.

Range in characteristics

Examples within the Lower Tano Basin are usually a little more acid than the average described above.

Agricultural value

Adujansu series absorbs rainfall readily at the surface, is fairly porous in the upper part of the profile and well drained, though it is liable to dry out during prolonged dry spells. This is particularly true of examples with a high content of quartz grit and gravel.

The topsoil and upper subsoil are relatively easy to work, but liable to erosion if exposed.

Nutrient status depends largely on the reaction and on the thickness and state of preservation of the topsoil. The better examples of this series, with a topsoil reaction above 6·0 and a good humous topsoil, have, by local standards, a fairly good supply of potash, nitrogen and phosphorus, and often support good cocoa provided that they do not dry out in the dry season, those on some upper slopes and summits being rather prone to drought. The relatively very small expanses of this series found in the Lower Tano Basin occur towards the southern limit for ochrosols: the rainfall is relatively high and there is less fear of dry-season drought, but leaching, on the other hand, is higher, reaction is more acid, and nutrient reserves lower. Adujansu series within the basin is a moderately good cocoa soil, particularly if not previously cultivated, and, because of its rapid drainage, also supports coffee.

54. Bechem series

Bechem series, the paler less well drained drainage associate of Adujansu series, is a sedentary forest ochrosol developed over non-micaceous hornblende granite. It differs from Adujansu series mainly in the colour of the subsoil. It occurs on lower slopes to summits and, within the basin, is relatively more extensive than Adujansu series.

Profile morphology is the same as that of Adujansu series except that the subsoil colour is yellow-brown to orange-brown. Internal drainage is a little slower than in Adujansu series, but otherwise the agricultural value of the two series is somewhat similar.

3E. THE YOYO ASSOCIATION

In addition to the two series described below, this association includes series numbers 25 and 47–50.

55. Santomang series

Santomang series is the acid (oxysol) equivalent of Adujansu series. This soil is rare in the basin and may be absent altogether from some granite areas since the usual soil found is its yellow-brown associate, Yoyo series (q.v.). Apart from the redder colour and slightly better drainage of Santomang series, Santomang and Yoyo series are very similar, and for most agricultural purposes may be considered together.

56. Yoyo series

Yoyo series, a yellow-brown sedentary forest oxysol developed over non-micaceous hornblende granite, is the acid equivalent of Bechem series (series 54, page 213). It is usually found in areas where the annual rainfall is 65 inches and upwards, and is not normally associated with a red soil, as Bechem is with the red Adujansu series, so that it is found on all sites from lower slope to summit.

Detailed description

Profile morphology and range in characteristics are similar to Bechem series, except that the pH of the topsoil is below 5·0. The subsoil is slightly less acid than the topsoil. Many examples in the Enchi area are intergrades between Bechem and Yoyo series.

Agricultural value

Drainage, both internal and external, is good and the dry season within the basin is probably not long enough for this somewhat porous soil to dry out, except perhaps in the upper layers. The gravel content is fairly low for a sedentary forest soil, but examples on steep sites need very careful protection to prevent accelerated erosion.

The nutrient status of this oxysol is undoubtedly low compared with Bechem series, its ochrosol counterpart, though the presence of hornblende in the parent material suggests it might not be quite so low as that of Abenia series (series 44, page 199), an otherwise similar granite oxysol. Yoyo series is very inextensive and often inaccessible, and there has been little opportunity of assessing its agricultural potential in the field.

3F. THE PEPRI ASSOCIATION

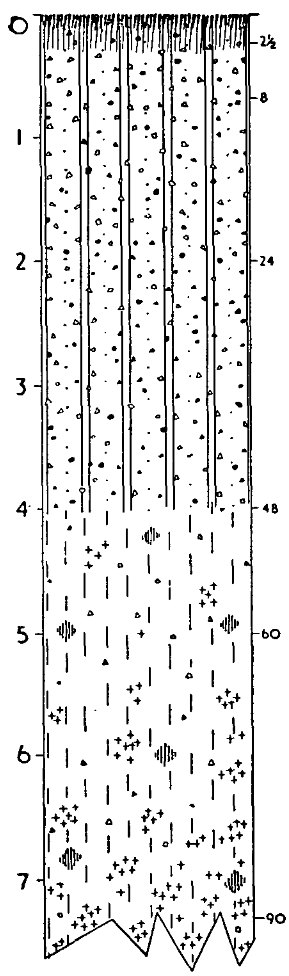
In addition to the two soils described below, this association includes series 12–18 and 47–50.

57. Kobo series

Kobo series is an orange-red, deeply weathered forest ochrosol developed over coarse-grained non-micaceous hornblende granite, distinguished by the abundant coarse grit always present. It occurs on the summits and upper slopes of rolling hills, but is far less extensive than its brown associate, Pepri series.

Detailed description

The following average profile is based on several pits sampled in the Upper Tano Basin, in the Sefwi-Wiawso area. Reaction is discussed below.



Topsoil

0–2½ inches: grey-brown humous gritty light clay, crumbly, loose and porous, with occasional coarse quartz gravel.

2½–8 inches: grey-brown slightly humous gritty light clay, slightly crumbly, loose and porous, with occasional to frequent coarse quartz gravel and odd ironstone concretions.

Subsoil

8–48 inches: pale reddish yellow gritty light clay, structureless and firm but porous, containing frequent coarse quartz gravel and occasional to frequent ironstone concretions.

Weathered substratum

48–90 inches: reddish brown loam, slightly stained and mottled yellow, grey and brown, structureless and friable, containing rare quartz gravel and frequent traces of weathered rock which become more abundant with depth.

Fig. 64. Kobo series.

Range in characteristics

Recognisable weathered granite may not occur within 12–15 feet of the surface. The coarse quartz grit which is so typical of the subsoil often almost disappears in the weathered substratum. Topsoil pH is usually above 5·5 and sometimes above 6·0, but the subsoil is more acid.

Agricultural value

Under a normal vegetation cover, rainfall is absorbed rapidly at the surface and percolates fairly rapidly through the somewhat porous subsoil. Because of this, and its poor water-retaining capacity, this series is liable to dry out during the dry season, particularly in the upper layers. The topsoil is loose, erodes rapidly and is often gravelly, so that it has to be handled with care. Nutrient status is usually low for a soil in this acidity group because of the low fine earth fraction and the nature of the parent material. Cocoa usually fails on this series, largely due to dry-season drying out.

58. Pepri series

Pepri series is the brown, less well drained associate of Kobo series, found on lower slopes to summits of hills. The morphology of this soil is the same as for Kobo series above, except that the subsoil is strong brown to yellow-brown rather than reddish yellow in colour. The low nutrient status and liability to erosion of this series are also the same as those of Kobo series, and its agricultural value is similar except that those examples on lower-slope sites do not dry out as rapidly as otherwise similar soils on upper slopes and summits, so that they may be a little more productive.

SOILS DEVELOPED OVER TERTIARY SANDS
(Group 4)

4A. THE TIKOBO ASSOCIATION

59 and 60. Tikobo series and Nuba subseries

Tikobo series is an important and extensive deep sandy-clay oxysol developed in the Tertiary deposits of Nzima. It is characterised by the uniform appearance of both the subsoil and the parent material below, which may continue downward for 30–50 feet or more.

This series is found on all sites except valley bottoms. The Tertiary deposits in which it is developed have a distinctive relief consisting of flattish or gently undulating summit areas separated by deep, steep-sided valleys.

Detailed description

The average description (Fig. 65) is based on twenty-two pits dug: this series occurs in Ghana only within the Lower Tano Basin.

Range in characteristics

Because of the low buffer capacity of this soil and its low cation exchange capacity, relatively small differences in base content cause considerable variations in the pH of the topsoil which may be as low as 3·4 but also sometimes reaches 6·0. The subsoil, on the other hand, shows relatively little variation in acidity. A slight textural subsoil is often noticeable, as indicated in the average description above, where the texture is light clay from 8 to 58 inches, but a little lighter both above and below.

Subseries

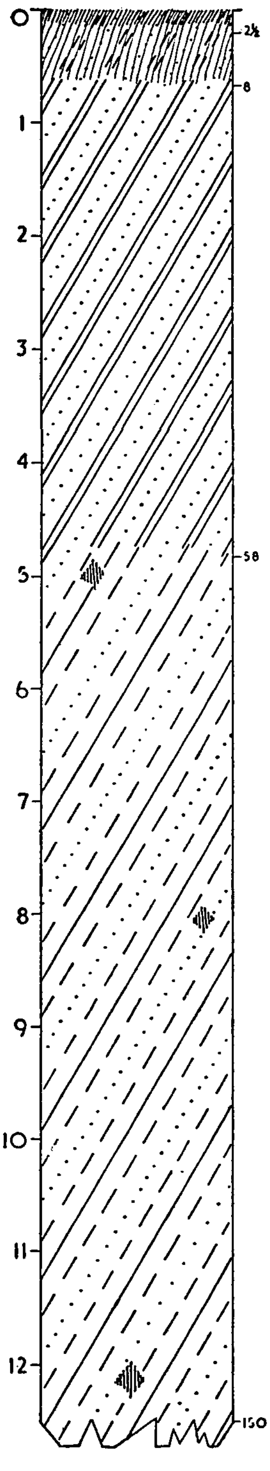
Nuba is the only subseries and is almost as common as Tikobo series itself. It is distinguished from Tikobo series by being lighter textured in the upper part of the subsoil. The normal Tikobo series is loam in texture to at least 8 inches, and sometimes to 15–20 inches, before the texture becomes clay or light clay, but when the texture is loam for more than the first 30 inches the soil is distinguished as Nuba subseries. Occasional examples are loam in texture throughout the profile. Nuba subseries merges into Tikobo series on all sites. On upland sites the lighter texture of Nuba series appears to be due to downward leaching of the clay fraction: on lower-slope sites it may be due to the fact that the upper part of the profile is re-sorted colluvial material.

Agricultural value

Tikobo series is remarkable for its free drainage. The surface is so receptive of rainfall that there is not usually any runoff and even water poured onto a sloping surface will travel only a few feet before it is all absorbed. The lack of runoff reduces the danger of surface erosion and explains the distinctive relief associated with this series. Internal drainage is extremely rapid and water quickly percolates downwards to the water table which is at very great depths: one pit dug to over 60 feet did not tap the water table.

The series is light textured and usually easy to work, the loamy topsoil being very easily cultivated with simple hand tools. There are no concretions or gravel, and the normal profile consists entirely of fine earth i.e. material passing a 2 mm. sieve. The depth of the soil and the light texture make it easy for roots to penetrate to great depths and physical conditions such as these are ideal for oil and coconut palms.

Mechanical analysis of B 863 (Table 25) shows that in the first 17 inches of the profile, which is loam in texture, the clay fraction is only 5–8 per cent, though this increases rapidly in the subsoil and reaches 45 per cent below 70 inches. Throughout the profile the sand fraction is dominant, being 50 per cent to over 90 percent: of this, most is coarse sand. Silt is only 2–3 per cent in most of the profile. This analysis explains the very rapid drainage observed in the field, and suggests that the exchange capacity of the light textured upper part of the profile is very low.



Topsoil

0–2½ inches: dark greyish brown (10YR 4/2) humous sandy loam, structureless and loose. Highly acid (average pH 5.0, range 3.4 to 6.0).

2½–8 inches: greyish brown (10YR 5/2) slightly humous sandy loam, structureless and fairly loose. Highly acid (average pH 4.8).

Subsoil

8–58 inches: brown to yellow brown (10YR 5/3 to 10YR 5/4) sandy light clay to clay, structureless and increasingly firm with depth. Highly acid (average pH 4.7, increasing with depth to 4·8).

Parent material

58–150 inches and more: yellowish brown sandy light clay to heavy loam with occasional slight orange-brown stains, structureless and firm, but easily dug. Highly acid (average pH 4.8 to 4.9). Similar material continues downward to 30–50 feet or more.

Fig. 65. Tikobo series.

The nutrient status of Tikobo series is subject to fairly wide local variations, depending principally on topsoil reaction and organic matter content. Nine profiles of Tikobo series (including three of Nuba subseries) have been analysed: brief notes on these are given first. In all cases the rainfall is about 85 inches per annum.

B 863 *is a normal example of Tikobo series, loamy to* 17 *inches, sampled on a flat summit site near the main road between Tikobo* 2 *and Mpataba, where the ground had been newly cleared prior to cultivation.*

B 864 *was dug on a gently sloping middle slope site, under current cultivation, near Amishible Bokaso. This is a normal profile, loam in texture to* 26 *inches.*

B 866 *is from a gentle undulating middle slope site on Sample strip* 11, *very near to Mpataba. This was under thicket regrowth, and the profile is typical of the series.*

B 868 *was sampled about* 1 *mile north of Tikobo* 2, *on a gentle undulating upper slope site newly cleared for cultivation. The profile is typical of the series.*

B 885 *was dug close to the main road near to the village of Nvelenu from a nearly flat middle slope site under young cocoa. Mature cocoa nearby was in poor condition. The profile is typical of the series, except that terrace gravel was encountered at* 12 *feet.*

B 869 *was extended to* 60 *feet in order to examine the underlying material, but only the first four horizons to* 31 *inches are included in the analysis. This is an example of Nuba subseries, with loam to* 53 *inches, sampled from a flat summit site* 1½ *miles north of Nuba. Below* 16 *feet the texture reverts to loam and continues with little or no change to the bottom, which remained dry. Vegetation was broken forest.*

B 871 *is also an example of Nuba subseries, with loam to* 48 *inches. This was sampled from an upper middle slope site on the rolling Bonyere ridge near the junction between the main road and a minor road to Alawuli, a mile west of Tikobo* 1. *Vegetation was thicket regrowth.*

B 991 *and* 1,000 *were both sampled on Sample strip* 13, 4 *miles north of Nuba. The vegetation on the strip is original forest, but of a rather poor and pole-like character and the topsoils in this area were unusually thin. B* 991 *is Nuba subseries, and was sampled from a flattish summit site: B* 1,000 *is the normal series, and was sampled on a steep upper slope site.*

It is to be expected that an acid sandy soil under 85 inches of rainfall per annum would have a very low nutrient status. Analyses of the above profiles (Table 24) show the average content of total exchangeable bases in the topsoil to be similar to or slightly above the average for all Lower Tano Basin oxysols, due partly to a higher fine earth fraction than the average (Table 5) but this average hides considerable variations between individual profiles. Two profiles, B 863 and B 885, with relatively high base reserves, are less acid than the normal. On the other end of the scale are three profiles (B 869, B 991 and B 1,000), all sampled from an area north of Nuba where the original forest is particularly thin and poor, which have topsoil pH values of 4·4 or less and correspondingly low base reserves.

Of the individual bases, calcium shows the greatest fluctuations. In profiles with a high total base content, there is three of four times as much calcium in the topsoil as magnesium: in the poorer examples the ration approaches unity, while in B 1,000 there is more magnesium than calcium and B 991 is remarkable for the absence of magnesium in the subsoil. Manganese is low throughout, being ·01 or ·005 m.e. in all the subsoils. Potash, the most important base, is well below the oxysol average, particularly in the subsoil. Carbon and nitrogen, as is suggested by the thin low-humous topsoils, are also present in quantities very much below the average for oxysols within the basin. Carbon/nitrogen ratios, particularly below the topsoils, are fairly high.

These analyses suggest, therefore, that despite occasional moderately fertile examples with a higher topsoil pH than normal, the nutrient status of this highly leached sandy soil is, generally speaking, very low. Nevertheless, the very favourable physical qualities of this soil makes it agriculturally of much greater value than many associated acid soils, and sandy soils of this nature suggest themselves for manuring. Many of the world's most productive soils are in fact poor soils with a good texture which have been heavily manured. Preliminary results of fertiliser experiments at Atuabo on the somewhat similar Fredericksburg series (series 68, page 230) have shown very promising results (Gordon, 1956). It is thought likely that the manuring of the already large acreage of established coconut palms in Nzima would give a large and immediate increase in yields and a good return for

TABLE 24

ANALYTICAL DATA FOR TIKOBO SERIES

Series or sub-series and Profile Number	*Vegetation*	*Lower depth of horizon in inches*	*pH*	*% Fine earth*	*Exchangeable Bases (m.e. per 100 gm)* Ca	Mg	Mn	K	S (TEB)	T (CEC)	Ca/Mg	Mg/K	C	N	C/N	O.M.	Moisture % Air-dry	Total P p.p.m.
Tikobo B 863 ...	Newly cultivated	2	6·0	100	5·38	2·07	·04	·15	7·64	11·60 (*b*)	2·60	13·80	2·11	·163	12·94	3·63	1·54	164
		7	5·6	100	1·96	·82	·02	·10	2·90	6·12	2·39	8·20	·88	·070	12·57	1·51	·84	111
		17	5·2	100	·36	·27	·01	·05	·68	5·70	1·33	5·40	·52	·037	14·32	·89	·88	96
		43	4·8	100	·30	·23	·01	·09	·62	7·59	1·30	2·56	·43	·048	8·96	·74	1·94	197
Tikobo B 864 ...	Cultivation	3	5·4	100	1·00	·58	·04	·15	1·77	3·29 (*a*)	1·72	3·87	·89	·073	12·19	1·53	·66	99
		8	4·6	100	·20	·24	·01	·07	·52	5·10	·83	3·43	·64	·051	12·55	1·10	·81	83
		15	4·8	100	·19	·15	·01	·25	·59	2·59	1·27	·60	·32	·028	11·43	·55	·45	64
		26	5·0	100	·28	·32	·01	·25	·85	2·76	·88	1·28	·22	·024	9·17	·38	·59	81
Tikobo B 866 ...	Thicket	3	5·2	100	2·15	·83	·08	·08	3·14	4·68 (*a*)	2·59	10·38	1·34	·107	12·52	2·30	1·08	110
		8	4·8	100	·76	·47	·03	·03	1·29	3·18	1·62	15·67	·63	·053	11·89	1·08	·90	76
		20	4·8	100	·25	·20	·01	·01	·47	3·60	1·25	20·00	·50	·044	11·36	·86	1·24	100
		36	4·6	100	·23	.24	·01	·01	·49	4·26	·96	24·00	·42	·053	9·77	·72	1·51	138
Tikobo B 868 ...	Newly cultivated	2	5·4	100	1·45	·41	·04	·28	2·18	3·20 (*a*)	3·54	1·46	·73	·069	10·58	1·26	·58	73
		7	5·2	100	·70	·30	·02	·10	1·12	2·87	2·33	3·00	·50	·049	10·20	·86	·54	65
		23	5·0	100	·63	·27	·01	·05	·96	2·56	2·33	5·40	·34	·039	8·72	·58	·93	94
		66	4·8	100	·34	·21	·01	·05	·61	6·25	1·62	4·20	·33	·045	7·33	·57	1·79	172
Tikobo B 885 ...	Cocoa	2	5·8	100	6·56	1·48	·07	·21	8·32	9·46 (*a*)	4·43	7·04	2·70	·189	14·28	4·64	1·53	—
		7	5·5	100	2·37	·68	·04	·08	3·17	5·03	3·49	8·50	1·05	·080	13·13	1·81	·94	—
		18	5·2	100	·72	·49	·02	·08	1·31	5·51	1·47	6·01	·98	·089	11·01	1·69	1·12	—
		25	4·8	100	·41	·40	·01	·08	·90	5·06	1·02	5·00	·63	·056	11·25	1·08	1·51	—
Nuba B 869 ...	Secondary forest.	3	4·4	100	·43	·35	·02	·18	·98	4·06 (*a*)	1·23	1·94	1·36	·099	13·74	2·34	·97	190
		9	4·6	100	·26	·20	·01	·10	·57	4·07	1·30	2·00	·965	·0675	14·30	1·66	1·15	256
		17	4·4	100	·18	·16	·01	·05	·40	2·96	1·13	3·20	·57	·044	12·95	·98	1·11	276
		31	4·6	100	·13	·10	·01	·03	·26	2·89	1·30	3·33	·36	·036	11·25	·62	1·04	262
Nuba B 871 ...	Thicket	3	5·2	100	·79	·60	·02	·16	1·57	3·42 (*a*)	1·32	3·75	·92	·075	12·27	1·58	·90	171
		10	4·9	100	·27	·19	·01	·04	·51	3·00	1·42	4·75	·60	·048	12·50	1·03	·89	165
		27	4·8	100	·15	·11	·01	·06	·32	2·67	1·36	1·83	·38	·034	11·18	·65	·89	186
		48	4·6	100	·10	·19	·01	·004	·29	3·13	·53	47·50	·26	·031	8·39	·45	1·20	234
Nuba B 991 ...	Broken forest.	1	4·2	100	·70	·67	·02	·13	1·52	—	1·04	5·15	2·62	·223	11·75	4·51	1·10	—
		6	4·4	100	·19	·03	·005	·01	·23	—	6·33	3·00	·64	·092	6·96	1·10	·65	—
		19	4·6	100	·17	Nil	·005	·01	·18	—	—	—	·56	·037	15·14	·96	·72	—
		30	4·8	100	·14	Nil	·005	·16	·30	—	—	—	·34	·028	12·14	·58	·73	—

TABLE 24—contd.

ANALYTICAL DATA FOR TIKOBO SERIES—*contd.*

Series or sub-series and Profile Number	*Vegetation*	*Lower depth of horizon in inches*	*pH*	*% Fine earth*	*Exchangeable Bases (m.e. per 100 gm.)* Ca	Mg	Mn	K	S (TEB)	T (CEC)	*Ca/Mg*	*Mg/K*	*C*	*N*	*C/N*	*O.M.*	*Moisture % Air-dry*	*Total P p.p.m.*
Tikobo																		
1000 ...	Broken forest.	2	3·8	100	·66	1·06	·12	·38	2·22	—	·62	2·79	4·10	—	—	7·05	1·79	—
		8	4·0	100	·25	·27	·005	·04	·56	—	·93	6·75	1·22	—	—	2·10	·81	—
		18	4·4	100	·18	·06	·005	·02	·26	—	3·00	3·00	·57	—	—	·98	·82	—
		31	4·6	100	·12	·18	·005	·21	·51	—	·67	—	·28	—	—	·48	·89	—
Average of 9 profiles above.	do.	2·3	5·0	100	2·12	·89	·05	·19	3·25	—	2·38	4·68	1·86	—	—	3·20	1·13	—
		7·9	4·8	100	·77	·36	·02	·06	1·21	—	2·14	6·00	·79	—	—	1·36	·84	—
		19·3	4·8	100	·31	·21	·01	·06	·59	—	1·48	3·50	·53	—	—	·91	·91	—
		37·3	4·7	100	·23	·23	·01	·01	·57	—	1·00	2·30	·36	—	—	·62	1·24	—

(*a*) As determined with ammonium acetate.
(*b*) As determined with barium acetate.

TABLE 25

MECHANICAL ANALYSIS OF TIKOBO SERIES (PROFILE B 863)

Lower Depth of Horizon in inches	*Gross Mechanical Analysis per cent. Air-dry* Stones >20mm.	Coarse Gravel 20-6·25mm.	Fine Gravel 6·25-2mm.	Fine Earth <2mm.	*Mechanical Analysis of Fine Earth per cent. Oven-dry* Very Coarse Sand 2-·625mm.	Coarse Sand ·625-·2mm.	Fine Sand ·2-·02mm.	Silt ·02-·002mm.	Clay <·002mm.	CaCO3	Loss on Solution	Total	*Per cent. Oven-dry* Ignition Loss	Corr. Ignition Loss	*Moisture per cent Air-dry*
2	Nil	Nil	Nil	100·0	14·73	41·07	30·98	2·83	5·76	Nil	4·10	99·47	4·51	·98	1·54
7	Nil	Nil	Nil	100·0	18·19	39·85	30·78	3·23	5·59	Nil	1·17	98·81	2·26	·75	·84
17	Nil	Nil	Nil	100·0	13·38	43·20	30·50	3·41	7·84	Nil	1·63	99·96	1·94	1·03	·88
43	Nil	Nil	Nil	100·0	14·46	32·38	21·07	2·40	27·97	Nil	1·92	100·17	4·49	3·75	1·94
70	Nil	Nil	Nil	100·0	9·56	27·81	20·31	2·77	38·77	Nil	1·47	100·69	5·38	4·72	2·30
113	Nil	Nil	Nil	100·0	7·63	24·71	19·83	2·44	44·76	Nil	·62	99·99	6·19	5·73	2·72
183	Nil	·6	·5	98·9	7·69	23·19	23·51	3·57	41·06	Nil	·96	99·98	5·40	5·19	2·22
230	Nil	·5	·4	99·1	7·18	19·77	32·67	5·07	34·78	Nil	·59	100·06	4·62	4·50	2·08
247	Nil	Nil	Nil	100·0	18·48	34·80	14·09	3·20	28·83	Nil	·77	100·17	3·78	3·71	1·74
265	Nil	Nil	Nil	100·0	3·78	13·55	22·44	10·52	49·24	Nil	·36	99·89	6·49	6·40	4·44
276	10·6	8·0	7·9	73·5	—	—	—	—	—	—	—	—	—	—	—
313	Nil	8·5	7·7	83·8	—	—	—	—	—	—	—	—	—	—	—
338	8·5	12·4	6·7	72·4	—	—	—	—	—	—	—	—	—	—	—
352	Nil	·5	·3	99·2	—	—	—	—	—	—	—	—	—	—	—
370	Nil	Nil	Nil	100·0	—	—	—	—	—	—	—	—	—	—	—

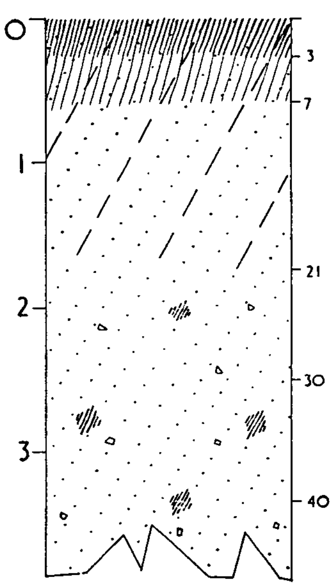
the capital invested, though the heavy rainfall of this area requires measures to be taken to reduce the percentage of fertiliser washed out of the soil before it can be taken up by plants. Even without manuring, however, coconut and oil palms are well adapted to this series and coconuts in particular have proved very profitable, so that considerable new areas are now being planted. The light texture is ideal for groundnuts, though manuring would be necessary for high yields, and tea, tobacco and a range of other crops not normally associated with Ghana forest soils might also prove to be suited to this soil.

61. Aiyinasi series

Aiyinasi series is a relatively inextensive grey sandy bottom soil confined to poorly drained sites near streams. It is developed in local alluvium derived from Tikobo series, the associated upland soil, and is classified as a very acid gleisol.

Detailed description

The following average description is based on three pits and numerous chisel holes dug in the Tertiary sand area of the basin.



Topsoil

0–3 inches: dark grey (10YR 4/1) humous loamy sand, structureless and loose. Highly acid (average pH 4.7).

3–7 inches: greyish brown (10YR 5/2) slightly humous loamy sand, structureless and loose. Highly acid (average pH 4.8).

Subsoil

7–21 inches: greyish brown (10YR 5/2) loamy sand, structureless and loose. Highly acid (average pH 4.9).

21–40 inches: brown to greyish brown sand (sometimes loamy sand), stained yellow and grey, structureless and loose. This may contain a little fine quartz gravel. Highly acid (about pH 5.0) becoming a little less acid with depth.

Fig. 66. Aiyinasi series.

Range in characteristics

As with many similar sandy alluvial soils, texture varies somewhat and the series may include occasional light clay horizons.

Agricultural value

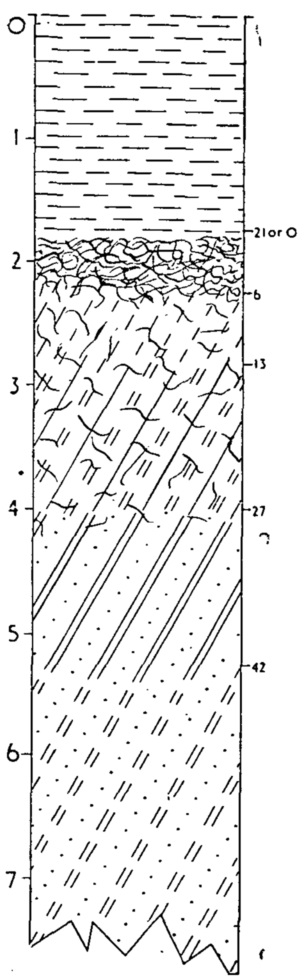
This soil is free-draining internally, but because of the site is subject to occasional flooding in May and June, when rainfall is at its heaviest, and may have the water-table near the surface for much of the rest of the year. The nutrient status is very low, being inferior to that of Tikobo series, while the drainage limits the possible range of crops to chewing cane and rice, though damp sites occupied by Aiyinasi series are often used as coconut nurseries.

62. Mpataba series

Mpataba series is a black acid peaty soil formed under waterlogged conditions where the accumulated organic matter cannot decompose rapidly. It is classified as a very acid cumulosol and occurs in swampy areas of the low-lying Lake Amansuri area where direct drainage to the sea is impeded by the slightly higher line of dune sands behind the coast.

Detailed description

As this series is usually under at least a few inches of water, normal pit digging is impossible. The following profile was obtained by using augers and is thought to be typical. The soil was sampled under 21 inches of water: pH figures are for the air-dried samples.



21–0 inches: fresh water.

0–6 inches: blackish grey (10YR 3/2) stained rusty brown mat of partly decayed leaves and roots. pH 4.8.

6–13 inches: very dark grey (10YR 3/1) loam containing abundant organic matter and roots. pH 4.8.

13–27 inches: dark grey (10YR 4/1) silty light clay containing abundant root material and leaves. pH 4.8.

27–42 inches: dark grey (10YR 4/1) sandy light clay containing frequent roots. pH 4.8.

Below 42 inches: greyish brown (10YR 5/2) sandy light loam. pH 5.0.

Fig. 67. Mpataba series.

Range in characteristics

The thickness and character of the accumulated organic matter varies, while some examples are underlain by clay.

Agricultural value

This series is waterlogged for most of the year. Marginal soils between Aiyinasi and Mpataba series in character might possibly have some limited potential as rice soils but the normal Mpataba series has no agricultural value unless drained. Drainage would certainly not be economic on poor acid soils of this nature and the organic matter would rapidly decompose and disappear if exposed to the air, while compounds toxic to plants may also be produced.

63. Menzezo series

Menzezo series is a minor variant of Tikobo series. It contains scattered through the profile frequent fragments of a sandy ferruginous pan. Sometimes this occurs as large boulders, but usually as pieces 2–3 inches across or even as small gravel-like fragments. The amount of this included material varies, being locally frequent, though this series is absent from most of the area. In all other respects the soil is similar to Tikobo series. The pan fragments are an inherited feature, consisting of the broken-up remains of what was possibly an extensive sandy ironpan sheet: they are certainly not developed *in situ*. When frequent, they may interfere with cultivation, and reduce the fine earth fraction of the soil.

64. Mpem series

Mpem series forms a second variant of Tikobo series in which frequent water-worn stream pebbles and, occasionally, stream gravel are found in the profile, either scattered or in well defined beds. These occasional stream deposits were laid down at the same time as the Tertiary sands, and are not the result of contemporary stream activity. In many profiles, especially those at Aiyinasi Agricultural Station, this series is also distinctly gritty, suggesting a granitic origin of the water-borne material. As in the case of Menzezo series, the included material lowers the fine earth fraction and so reduces the content of nutrients.

65. Basachia series

Basachia series is a relatively inextensive sedentary forest oxysol developed over Tertiary sands. It is distinguished from the major soils of the Tikobo-Aiyinasi association by the presence of an indurated layer in the lower subsoil which completely alters the rapid internal drainage of the normal soils of the association. The upper subsoil above the indurated horizons contains numerous fragments of ferruginised sandstone. Basachia series is found on certain fairly flat summit areas, particularly towards the edges of the Tertiary sand areas. It is well developed at Aiyinasi Agricultural Station, but is uncommon elsewhere.

Detailed description

The average description (Fig. 68) is based on ten pits dug within the basin.

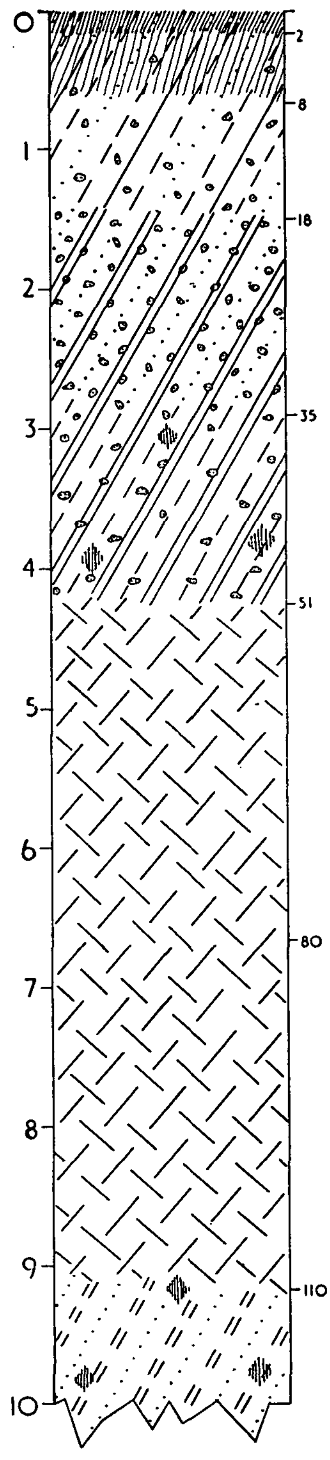
Range in characteristics

The depth at which the indurated material begins varies. In most examples it is between 4 and 5 feet, but a deep subseries is recognised in which the indurated layer begins at about twice this depth. There is also some variation in the amount and size of the included sandstone brash.

Agricultural value

The normal site is flattish and rainfall is usually absorbed immediately without runoff. Internal drainage is free above the indurated layer, but is probably impeded within it. After heavy rains there may be a perched water-table above the induration.

The indurated layer will have the effect of making root penetration difficult: this is discussed further in the report on the soils of Aiyinasi Agricultural Station (Ahn, 1957) in which it was suggested that oil palms on an indurated soil of this type might have to be spaced more widely than usual. Experiments now started at Aiyinasi should show in due course to what extent root penetration is affected by the indurated layer and how palms on this series compare with those on normal free-draining soils.



Topsoil

0–2 inches: dark greyish brown (10YR 4/2) humous sandy loam to heavy loam, structureless and loose. Highly acid (average pH 5.0).

2–8 inches: greyish brown (10YR 5/2) slightly humous sandy heavy loam, structureless and loose, containing rare nodules of ferruginised sandstone. Highly acid (average pH 4.7).

Subsoil

8–18 inches: dark brown (10YR 4/2) sandy heavy loam, structureless and loose, containing occasional concretion-like nodules of ferruginised sandstone. Highly acid (average pH 4.7).

18–35 inches: brown (7.5YR 5/4) sandy light clay, structureless and slightly firm, containing frequent concretion-like nodules of ferruginised sandstone. Highly acid (average pH 4.7).

35–51 inches: yellowish brown usually mottled red light clay, structureless and fairly firm, containing frequent nodules of ferruginised sandstone. Highly acid (average pH 4.8).

51–80 inches: orange-brown mottled yellow and red indurated material, structureless, and dug only with difficulty. Highly acid (average pH 4.9).

80–110 inches: as above. Highly acid (average pH 5.0).

Parent material

Below 110 inches: mottled sandy loam to heavy loam, structureless and firm. Highly acid (average pH 5.0).

Fig. 68. Basachia series.

Only two profiles of Basachia series have been analysed (Table 26): these suggest that the nutrient status of this series is very low indeed, and poorer than Tikobo series, the normal Tertiary sand soil, mainly because of the lower fine earth fraction. The profiles analysed are the following:

B 992 *is from an upper-slope, gently sloping site under secondary forest in the northern part of Aiyinasi Agricultural Station. This example has a normal profile with induration beginning at* 55 *inches.*

B 993 *is also from Aiyinasi Agricultural Station from a gently rolling upper middle-slope site in the north-west of the station where the vegetation is secondary forest. Induration begins at* 54 *inches.*

A striking feature of these two analyses is the absence of potash from two horizons in each of the two soils and the very minute amounts of both exchangeable potash and manganese present. Organic matter in both cases in very low, being considerably less than the oxysol average for the basin. The fine earth fraction falls to 22 per cent in one of the subsoil horizons of B 992.

These analyses indicate an extremely low nutrient reserve. Many of the manurial experiments at Aiyinasi Agricultural Station are on this soil and the effects which manuring has on the growth of oil palms and other crops on sandy soils with a low nutrient status will obviously be of importance to the future development of the area. The responses on an indurated soil such as Basachia series, however, are not necessarily indicative of what might be expected from free-draining soils, such as Tikobo series, which cover most of the Tertiary sand area, even though the nutrient status of both soils before manuring is similar.

66. Mambuen series

Mambuen series is a minor variant of Basachia series, differing from it only in the amount of ferruginised sandstone included in the subsoil. In Basachia series the subsoil above the indurated layer contains frequent sandstone fragments: in Mambuen series these are few or absent, so that the soil consists simply of a sandy light clay subsoil above the indurated layer. Moisture relationships are the same as for Basachia series, while nutrient status is similar or very slightly higher. The main reason for separating the two soils is that cultivation characteristics will differ slightly. In the report on Aiyinasi Agricultural Station (Ahn, 1957) Basachia and Mambuen series were mapped together.

4B. SWAMPY AREAS ASSOCIATED WITH 4A

The main soils here are series 61 and 62

TABLE 26

ANALYTICAL DATA FOR TWO EXAMPLES OF BASACHIA SERIES FROM AIYINASI AGRICULTURAL STATION

Series and Profile Number	*Vegetation*	*Lower depth of horizon in inches*	*pH*	*% Fine earth*	*Exchangeable Bases (m.e. per 100 gm.)* Ca	Mg	Mn	K	S (TEB)	T (CEC)	*Ca/Mg*	*Mg/K*	*C*	*N*	*C/N*	*O.M.*	*Moisture % Air-dry*	*Total P p.p.m.*
Basachia B 992 ...	Secondary forest.	2	5·0	100	2·10	·90	·04	·25	3·29	—	2·33	3·60	2·21	·164	13·48	3·80	1·37	150
		6	4·8	95	·64	·40	·01	·15	1·20	—	1·60	2·67	·92	·077	11·95	1·58	·91	102
		13	4·8	97	·57	·57	·005	Nil	1·14	—	1·00	—	·50	·039	12·82	·86	·64	87
		24	4·6	53	·31	·31	·005	Nil	·62	—	1·00	—	·32	·028	11·43	·55	·71	99
		42	4·5	22	·43	·43	·005	·01	·87	—	1·00	43·0	—	—	—	—	—	—
		55	4·8	32	·40	·40	·005	·09	·89	—	1·00	4·44	—	—	—	—	—	—
Basachia B 993 ...	do.	3	4·6	100	1·11	·81	·01	·22	2·15	—	1·37	3·68	1·69	·145	11·66	2·91	1·22	150
		8	4·4	51	·34	·33	·01	·07	·75	—	1·03	4·71	1·12	·090	12·44	1·93	1·39	120
		18	4·6	37	·36	·26	·01	Nil	·63	—	1·38	—	·88	·071	12·39	1·51	1·59	140
		33	4·6	37	·36	·34	0·005	·01	·71	—	1·06	34·0	·44	·071	6·20	·76	2·89	261
		54	4·8	71	·32	.34	0·005	Nil	·66	—	·94	—	—	—	—	—	—	—
		84	4·8	69	·26	·25	0·005	·01	·52	—	1·04	25·0	—	—	—	—	—	—

5. THE FREDERICKSBURG ASSOCIATION

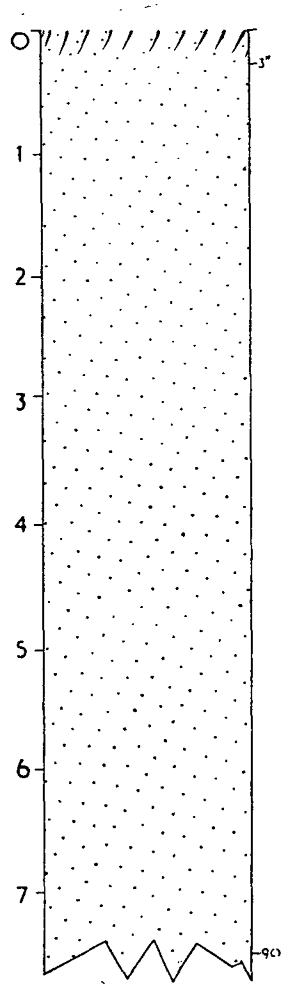
In addition to the soils described below, this association includes series 61 and 62.

67. Krisin series

Krisin series is a regosol developed in recent beach sand a little above the present high water mark. A high CaCO content from included shell fragments gives it a neutral or even slightly alkaline reaction, so differentiating it from other series in the association. It consists simply of pale coarse beach sand which has begun to be colonised by coastal thicket and beach vegetation. In many cases it is now under coconuts.

Detailed description

Figure 69 is based on five profiles sampled along the shore within the basin.



Topsoil

0–3 inches: greyish brown (10YR 5/2) coarse beach sand, structureless and very loose: there may be a little humous staining but sometimes this is absent completely. Neutral in reaction.

Parent material

3–90 inches or more: light brownish grey to very pale brown (10YR 6/2 to 10YR 7/3) coarse beach sand, single grained and very loose, containing small shell fragments. Neutral in reaction.

Fig. 69. Krisin series.

Range in characteristics

This is a series in which soil-forming processes have only just begun to operate. Older examples with a better developed vegetation cover contain a more humous topsoil than the average profile described above.

Agricultural value

The rainfall is absorbed immediately at the surface and there is no runoff. Internal drainage is excessively rapid. There is a water-table at about 10–15 feet, as fresh water seeps seawards from inland, and this supply is thought to be tapped by coconut palms.

The reaction of the series is neutral, but there is no clay in the soil and little or no organic matter, so that the base exchange capacity is extremely low. Relatively little can be grown on this series, but it supports coconuts.

68. Fredericksburg series

Fredericksburg series is a brown sandy oxysol (or oxysol-regosol intergrade) developed over marine sands of coastal dunes and raised beaches, under a rainfall of about 85 inches per annum. This is the most extensive series of the coastal sands group. Princes and Assini series are relatively minor bleached associates of this series.

Detailed description

The average description (Fig. 70) is based on nineteen pits sampled within the basin. This series has also been found at Princes Coconut Station (Purnell, 1957).

Range in characteristics

There is a slight textural range from sand to sandy light loam. An uncommon variant also occurs, transitional between this series and Princes series, in which the upper subsoil is paler than usual but is underlain by a horizon slightly darker and/or heavier in texture, thus indicating the first stages of slight podsolisation. A very rare variant found only to the west of Esiama contains frequent shells in the subsoil which raise the pH to neutral.

Agricultural value

The rainfall sinks into the surface immediately, so that there is no run-off. Internal drainage is excessively rapid. The upper parts of the profile are liable to dry out fairly rapidly, though for most of the year rain falls at such frequent intervals that even short-rooted annuals are not likely to suffer from water shortage. As in the case of Krisin series, groundwater seeps seawards, probably within root depth of coconuts. Wells at Bonyere dug in this series had water at between 6 and 12 feet in the wet season.

The four profiles analysed (Table 27) are briefly described below:

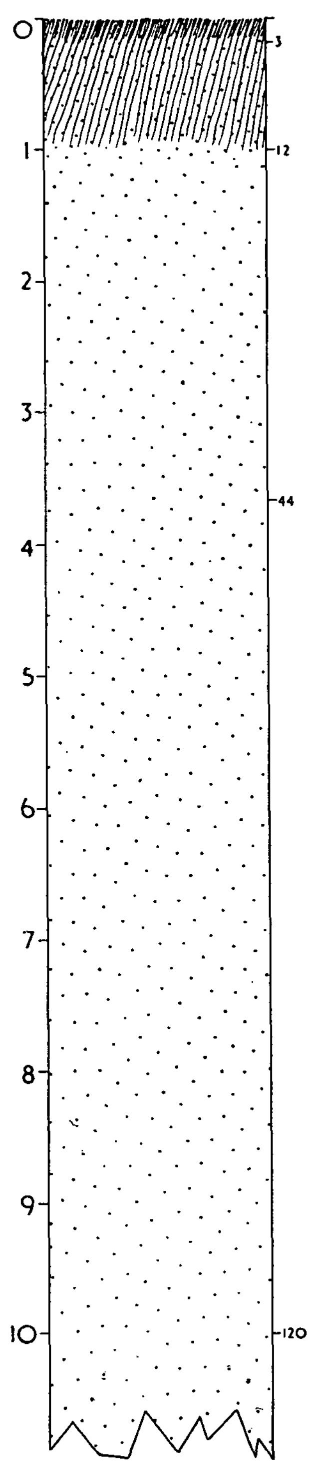
B 870 *from a gently sloping middle-slope coconut plantation just outside Bonyere, is typical of the series except that the texture is loamy sand.*

B 886 *and* B 888 *are normal examples of the series from gently sloping lower to middle-slope sites near Krisin and Esiama:* B 886 *is under coconuts,* B 888 *is under forb regrowth.*

B 990 *is an example of the slightly leached variant of the series in which there has been some accumulation of organic matter, particularly in the 27–47 inch horizon. This was sampled ½ a mile to the west of Bonyere, near to the shore, and was from a nearly flat summit site under coconuts.*

These analyses indicate that the nutrient status of the series is extremely low, being far lower than the average for twenty-two oxysols within the basin, both in bases and in organic matter. Organic matter in particular is present in extremely low quantities (·5–1 per cent in the topsoil) while nitrogen figures, also extremely low, reflect this low organic matter content. Calcium, manganese and potash are all present in quantities which are only a fraction of the oxysol average for the basin, while magnesium is virtually absent from the subsoil of B 888. The low clay and humous content give a very low exchange capacity, and, as would be expected from a sandy soil, the air-dry moisture percentages are extremely low, too. Profile B 990 shows a rise in carbon and total exchangeable base content in the fourth horizon, which is slightly indurated.

Despite the low nutrient status, this series is capable of supporting coconut and oil palms and a range of food crops, particularly cassava and groundnuts, though food crop yields are poor. Extensive areas of mature coconuts have been established on this soil, including the original demonstration



Topsoil

0–12 inches: greyish brown (10YR 5/2) humous to slightly humous medium sand, structureless and loose. Highly acid (average pH 4.9).

Subsoil

12–44 inches: greyish brown to brown (10YR 5/2 to 10YR 5/3) medium sand, structureless and loose. Highly acid (average pH 4.9 to 5.0).

44–120 inches: as above, but light yellowish brown (10YR 6/4). The pH rises with depth to an average of 5.1.

Fig. 70. Fredericksburg series.

TABLE 27

ANALYTICAL DATA FOR FREDERICKSBURG SERIES

Series and Profile Number	Vegetation	Lower depth of horizon in inches	pH	% Fine earth	Exchangeable Bases (m.e. per 100 gm.) Ca	Mg	Mn	K	S (TEB)	T (CEC)	Ca/Mg	Mg/K	C	N	C/N	O.M.	Moisture % Air-dry	Total P: p.p.m.
Fredericks-burg B 870	Coconut	4	6·5	100	·56	·91	·02	·10	1·59		·62	9·10	·68	·053	12·83	1·17	·43	155
		12	6·4	100	·42	·41	·01	·05	·89		1·02	8·20	·36	·037	9·73	·62	·43	132
		33	6·3	100	·20	·26	<·005	·08	·54		·77	3·25	·25	·023	10·87	·43	·53	151
		60	6·1	100	·13	·21	<·005	·05	·39		·62	4·20	·30	·033	9·07	·52	1·04	268
Fredericks-burg B 886	do.	4	5·3	100	·60	·77	·02	·11	1·50	2·29 (*a*)	·78	7·00	·57	·107	5·33	·98	·28	
		9	5·8	100	·30	·22	·01	·05	·58	1·75	1·36	4·40	·24	·049	4·90	·41	·24	
		19	5·8	100	·41	·23	·01	·04	·69	1·85	1·78	5·75	·23	·041	5·61	·40	·22	
		36	5·9	100	·22	·18	<·005	·02	·42	2·23	1·22	9·00	·18	·040	4·50	·31	·34	
Fredericks-burg B 888	Forb Regrowth	3	6·3	100	·80	·38	·01	·04	1·22	2·39 (*a*)	2·11	9·50	·30	·029	10.34	·52	·35	
		10	6·2	100	·29	Nil	·01	·01	·31	2·13	0	0	·24	·021	12.07	·41	·28	
		26	6·4	100	·26	Nil	<·005	·06	·32	3·56	0	0	·18	·017	10.59	·31	·31	
		52	6·0	100	·23	Nil	<·005	·04	·27	2·55	0	0	·15	·014	10.71	·26	·44	
Fredericks-burg B 990	Coconut	1	6·1	100	1·61	1·69	·03	·18	3·51		·95	9·39	1·18	·080	14·75	2·03	·79	
		11	6·3	100	·55	·28	<·005	·36	1·19		1·96	·78	·26	·018	14·44	·45	·22	
		27	6·3	100	·62	·49	·01	·07	1·19		1·27	7·00	·15	·011	13·64	·26	·16	
		47	5·7	100	·73	1·04	<·005	·03	1·80		·70	34·67	·65	·045	14·44	1·12	1·57	
Fredericks-burg Average of 4 profiles above ...	do.	3	6·1	100	·89	·94	·02	·11	1·96		·95	8·55	·68	·067	10·10	1·17	·46	
		10·5	6·2	100	·39	·30	·01	·12	·82		1·30	2·50	·28	·031	9·03	·48	·29	
		26·3	6·2	100	·37	·33		·06	·76		1·12	5·50	·20	·023	8·70	·34	·31	
		48·8	5·9	100	·33	·48		·04	·85		·69	12·00	·32	·033	9·70	·55	·85	

(*a*) As determined with ammonium acetate.

plantation at Atuabo planted by the Department of Agriculture in the 1920's. Recent fertiliser trials on this plot have given encouraging yield increases with a complete NPK dressing and other increases were obtained with potash with either nitrogen or phosphorus (Gordon, 1956) (*see* also page 122).

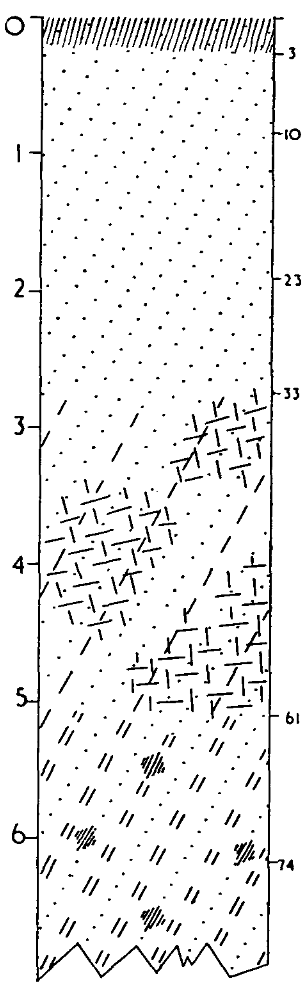
69. Princes series

Princes series is a groundwater podsol developed over recent marine sands of raised beaches, dunes and sandspits. The profile consists of a thin, slightly humous topsoil overlying 2 - 4 or more feet of white or pale grey leached sand. This in turn overlies brown less-leached sand below, the junction between the two sometimes being marked by a thin layer of dark organic pan.

This series is a podsolised associate of the more common Fredericksburg series, which consists of uniform brown sand throughout. In Princes series the upper horizons have been leached white and organic material deposited below in the organic pan layer. A completely leached soil, white throughout, is also found: this is Assini series (series 70, page 234).

Detailed description

The average description Fig. 71 is based on four pits dug within the basin. Similar pits have been sampled at Princes Coconut Station (Purnell, 1957).



Topsoil

0–3 inches: grey (2.5Y 5/1) humous fine to medium sand, structureless and loose. Highly acid (range 4.6 to 5.0).

3–10 inches: grey (10YR 6/1) fine to medium sand, structureless and loose: little or no humus. Highly acid.

10–23 inches: light grey (10YR 7/1) fine to medium sand, structureless and very loose. Highly acid.

23–33 inches: as above, but greyish brown (10YR 5/2).

Subsoil

33–61 inches: greyish brown to brown (10YR 5/2 to 10YR 5/3) loamy sand, slightly indurated to form very weak organic pan which breaks easily into small crumbs and pieces. Highly acid.

61–74 inches: greyish brown, somewhat mottled, loamy sand to sandy light loam, structureless and loose. Highly acid.

Fig. 71. Princes series.

Range in characteristics

Slightly leached examples are found intermediate between this series and Fredericksburg series. The pan is patchy and irregular, not thick and continuous as in Atuabo series.

Agricultural value

The normal very free drainage of associated sandy soils is only slightly impeded by the weak organic pan of Princes series and it is not sufficiently hard to hinder the penetration of plant roots.

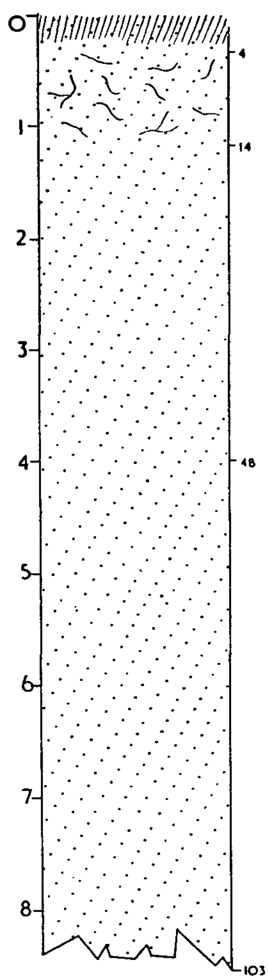
The soil, as indicated by the pale colour, is so highly leached that it is almost sterile, what little nutrients are available being concentrated in the topsoil. The weak organic pan is thought not to be a source of plant food; it may increase the acidity of the soil, which is pH 4·6–5·0 throughout the profile. Coconuts and cassava have been observed to grow in this series, but yields are likely to be low.

70. Assini series

Assini series is a highly leached soil consisting of a thin topsoil over white or nearly white quartz sand. It is developed under a rainfall of 85 inches per annum in recent marine sands of raised beaches, dunes and sandspits. The usual topography of these areas is gently undulating: Assini series appears to be commonest on the flattish summit areas. The natural vegetation is poor coastal thicket: the series appears too poor to support forest.

Detailed description

A pit sampled near Newtown, in the extreme west of Nzima, is given as a representative example (Fig. 72).



Topsoil

0–4 inches: light grey (10YR 7/1) fine sand, structureless and loose, containing almost no visible humus, and occasional roots. pH 5.0.

Subsoil

4–14 inches: light grey (10YR 7/2) fine sand, structureless and very loose, with frequent roots. pH 5.0.

14–48 inches: light grey to white (10YR 7/2–10YR 8/2) fine sand, structureless and very loose, with occasional roots. pH 5.4.

48–103 inches and below: white (10YR 8/1) fine sand, structureless and very loose. pH 5.6.

Fig. 72. Assini series.

Agricultural value

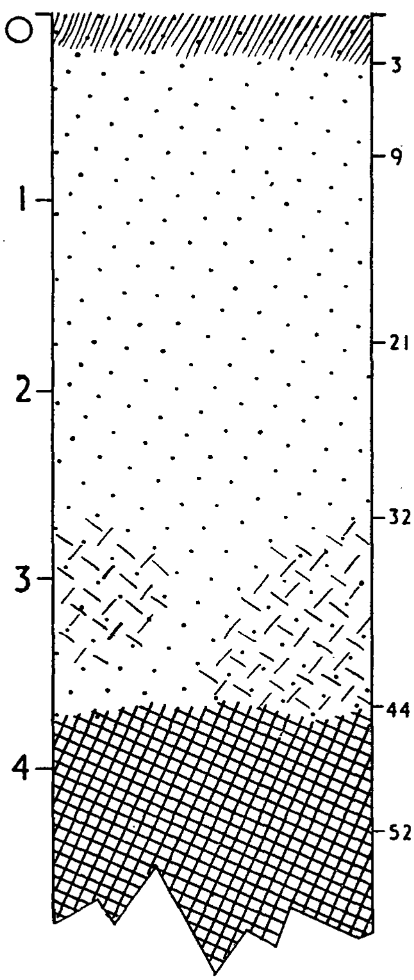
This series is extremely free draining, and consists of nearly sterile white quartz sand, almost devoid of nutrients. The topsoil contains little or no visible humus. Even cassava and coconuts fail on soils of this type, which are therefore useless for agriculture and should not be cleared of their sparse original thicket cover. The sand is suitable for making concrete blocks.

71. Atuabo series

Atuabo series is a highly leached groundwater podsol with well developed organic pan. It is developed in flat, low-lying, fine sandy alluvial deposits which fill the sites of former coastal lagoons, and is remarkable for the fact that it supports only sedges and grasses. This is the usual series of the small edaphic savanna patches found behind the littoral.

Detailed description

Fig. 73 gives an average description based on eight pits sampled within the basin.



Topsoil (A1 horizon)

0–3 inches: dark grey (10YR 4/1) slightly humous, very fine sand, structureless and loose. Highly acid (average pH 4.9).

3–9 inches: grey (10YR 6/1) very fine sand, structureless and loose. Highly acid (average pH 5.0).

Subsoil (A2 horizon)

9–21 inches: light grey (10YR 7/1) very fine sand, structureless and loose. Highly acid (average pH 5.0).

21–32 inches: light grey to white (10YR 7/1 to 8/1) very fine sand, structureless and loose. Moderately acid (average pH 6.0).

(B1 horizon)

32–44 inches: light brownish grey (10YR 6/2) fine sand, indurated to form soft organic pan. Highly acid (average pH 5.0).

44–52 inches: dark brown (10YR 4/3) massive organic pan. Highly acid (average pH 5.0).

Fig. 73. Atuabo series.

Range in characteristics

Depth and thickness of the pan vary slightly. There is usually a zone a little above the organic pan layer which is much nearer neutral than the rest of the highly acid profile.

Agricultural value

These soils are waterlogged for much of the year, but are at the same time liable to dry out completely in the short dry seasons. These extremely unsatisfactory water relations probably contribute to the

TABLE 28

ANALYTICAL DATA FOR ATUABO AND ESIAMA SERIES

Series and Profile Number	*Vegetation*	*Lower depth of horizon in inches*	*pH*	*% Fine earth*	*Exchangeable Bases (m.e. per 100 gm.)* Ca	Mg	Mn	K	S (TEB)	T (CEC)	*Ca/Mg*	*Mg/K*	*C*	*N*	*C/N*	*O.M.*	*Moisture % Air-dry*	*Total P p.p.m.*
Atuabo																		
B 865 ...	Savanna	3	5·6	100	·58	·36	·01	·07	1·02	2·08 (*a*)	1·61	5·14	1·20	·073	16·44	2·06	·38	36
		10	5·8	100	·16	·06	·01	·01	·23	1·04	2·67	16·00	·36	·029	12·41	·62	·16	16
		15	5·8	100	·12	Nil	·01	·02	·14	·93	0	0	·21	·025	8·40	·36	·15	17
		25	6·0	100	·11	Nil	·01	·02	·13	·41	8	8	·10	·007	14·29	·17	·09	2
Atuabo																		
B 999 ...	do.	2	4·6	100	.50	·31	·005	·05	·97(*c*)	3·47 (*a*)	1·61	6·20	2·02	·085	23·76	3·47	·34	52
		8	5·0	100	·18	·01	·005	·05	·37	·87 (*a*)	·18	·2	·27	·012	22·50	·46	·02	43
		23	4·8	100	·15	·01	·005	·02	·21	·82 (*a*)	·15	·5	·08	·006	13·33	·14	·06	38
		31	4·4	100	·35	·24	·005	·04	·72	25·64 (*b*)	1·46	6·00	3·10	·113	27·43	5·33	1·95	73
		47	4·85	100	·31	·16	·005	·02	·56	41·28 (*b*)	1·94	8·00	3·58	·088	40·68	6·16	3·74	84
		61	5·90	100	·15	·01	·005	·02	·20	1·25 (*a*)	·15	·05	·13	·006	21·67	·22	·06	14
Esiama																		
B 867 ...	do.	2	5·0	100	2·02	1·55	·01	·15	3·73	7·34 (*a*)	1·30	10·33	3·15	·166	18·98	5·42	2·82	71
		10	6·1	100	1·31	·97	·01	·09	2·38	3·30	1·35	10·78	·97	·058	16·72	1·67	·70	17
		18	6·5	100	·92	·68	·01	·01	1·61	2·34	1·35	68·0	·29	·023	12·61	·50	·34	28
		32	6·4	100	·66	·79	·01	·02	1·47	2·23	·84	39·0	·18	·021	8·57	·31	·52	17

(*a*) As determined with ammonium acetate.
(*b*) As determined with barium acetate.
(*c*) Including Na.

fact that only grasses and sedges can survive on these soils (Ahn, 1959). The upper part of the profile, the fine white sand, is free draining, but water is held up by the pan and this series may be under several inches of water for part of the wet season.

Two profiles have been analysed (Table 28): these are described briefly below.

B 865 *was sampled from a nearly flat low-lying savanna patch north of Krisin and consists of white very fine sand to* 25 *inches, brown fine sand from* 25 *to* 38 *inches, with massive dark brown organic pan below this.*

B 999 *from Sample strip* 17, *was sampled in the flat, low-lying, seasonally waterlogged savanna patch behind Atuabo. It consists of loose fine sand to* 23 *inches, a dark greyish brown transitional zone to* 31 *inches, and massive dark brown organic pan between* 31 *and* 47 *inches.*

These analyses show that both potash and nitrogen are extremely low. As suggested by the white leached sand, almost no bases have been left in the upper horizons of these soils. Magnesium is almost absent from half of the horizons of each example, while manganese is also ·01 m.e. per 100 gm. or less throughout. Phosphorus, in particular, is markedly lower than in associated soils, such as Fredericksburg series, supporting coconuts. These excessively low figures together with the unsatisfactory and rather extreme water relationships account for the near-sterility of this series.

Coconuts and food crops planted on this series have failed. The vegetation of the savanna patches is discussed more fully below, page 243. To improve the drainage by breaking up the pan would certainly not be economic, and this series is best used, as at present, for poor rough grazing.

72. Esiama series

This soil, like Atuabo series, supports only grasses and sedges: it has been found only on the savanna patch behind Esiama. It consists of a grey to white leached silty loam to light clay, flooded for part of the year.

Detailed description

Fig. 74 is based on three pits dug on the Esiama savanna patch.

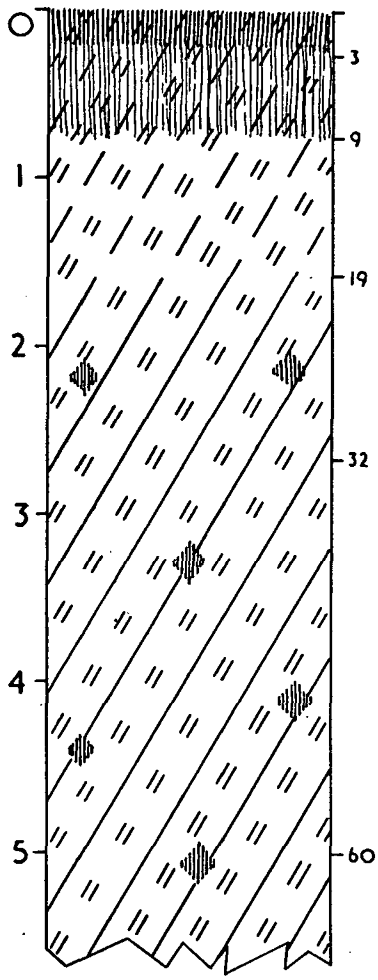
Agricultural value

The low-lying flat site of this series, situated in a flattish patch between higher sand dunes towards the sea and higher land inland, accounts for its seasonal waterlogging[10], but the soil nevertheless dries out during dry spells.

Only one example of this very minor series has been analysed (B 867, Table 28). This is a typical example very similar to the average for the series given above. As in the case of Atuabo series the pH rises from the topsoil to a less acid zone in the upper subsoil: in this example the topsoil pH is 5·0, rising to 6·5 at 10–18 inches. Total exchangeable bases, though low, are considerably higher than for Atuabo series, due to a higher clay and organic matter content, though manganese and potash are relatively very low, and nitrogen is also present in particularly small quantities. Carbon/nitrogen ratios are high, reflecting a relatively slow decomposition of the organic matter. As in the case of Atuabo series, total phosphorus figures are much lower than is usual for soils of the basin, and this may well be an important limiting factor in both series. The reaction trend in both soils is also unusual for the area.

Clumps of thicket, including palms and small savanna trees, are found on patches of this series very slightly above the general level where the drainage is a little better. These may represent the sites of former termitaria. Elsewhere the series supports only grasses and sedges, which are burnt annually at the end of the dry season. The vegetation of the Esiama savanna patch is discussed more fully below, page 243. All attempts to grow other crops have failed and, as in the case of Atuabo series, this soil is best left as poor rough grazing.

[10] More recent analyses suggest the presence of a clay pan below three feet and show an accumulation of sodium salts in the topsoil.



Topsoil

0–3 inches: grey (2.5YR 6/1) humous, silty light loam, crumbly and loose. Highly acid. (average pH 4.9).

3–9 inches: grey (10YR 6/1) humous, silty light loam, slightly crumbly and slightly loose. Very acid (average pH 5.4).

Subsoil

9–19 inches: grey (10YR 6/1) silty loam to light clay, structureless and firm, very acid (average pH 5.4).

19–32 inches: light grey to white (10YR 7/1 to 8/1) slightly stained yellow and brown silty light clay, structureless and very firm. Moderately acid (average pH 5.6).

32–60 inches: white mottled orange and brown silty light clay, structureless and very firm. Moderately acid (average pH 5.6).

Fig. 74. Esiama series.

SECTION II—VEGETATION

Most of the basin is still under undisturbed or little-disturbed original forest which can be divided, according to its floristic composition, into two main associations. The composition of these forest associations and that of associated swamp forest is discussed first, together with that of small areas of coastal savanna and thicket. These constitute the natural vegetation of the region, undisturbed by biotic influences. Nevertheless biotic influences, particularly the felling of forest areas for farms, have affected considerable areas (Fig. 4) and the floristic composition of the various stages of regrowth vegetation which succeed each other after a farm is abandoned is described subsequently (pages 244–247).

THE ORIGINAL VEGETATION OF THE BASIN

Forest

The original high forest of the basin has been described in general terms in Part I (pages 14 - 18). Taylor (1952) has divided the forests of Ghana into the rain forest of the south-west corner, and the moist semi-deciduous forest which occupies the remainder of the forest zone. Within the basin, almost all the area south of the latitude of Samreboi except for a narrow band behind the coast is, or was, under rain forest. To the north of this, observations made during the course of the survey suggest that the remainder of the basin north of Samreboi is occupied by the *Celtis-Triplochiton* association of the moist semi-deciduous forest, though within the basin this association is modified by the occasional occurrence of certain rain forest trees within parts of it.

The rain forest

The rain forest is confined to a relatively small area in the south-west corner of Ghana, to the west and north-west of Takoradi. It is found in that part of the Lower Tano Basin having a rainfall of over 65–70 inches per annum, where the upland soils are mostly oxysols (page 26). The northern limit of the rain forest within the basin, as shown by the distribution of the main indicator trees, is approximately the latitude of Samreboi (5° 35′ N.) and it thus includes the southern part of the Tano Nimri forest reserve, while there are a few rain forest trees in the very south of the Boin and Fure Headwaters reserves. To the south the rain forest extends almost to the coast, being separated from it by a narrow band of thicket (now usually replaced by coconut palms) sometimes only a few hundred yards wide and, in the Lake Amansuri area, by somewhat more extensive areas of swamp forest.

The rain forest is typified by the *Cynometra-Lophira-Tarrietia* association, which is characterised both by the presence of *Cynometra ananta*[11], *Lophira alata*, and *Tarrietia utilis*, and by the absence of two easily recognised trees which are very common in the rest of the forest zone, *Celtis mildbraedii* (esa) and *Triplochiton scleroxylon* (wawa). Within the rain forest the typical trees are not deciduous, deciduousness being confined to species which also occur outside the area (Taylor, 1952).

The rain forest differs from the semi-deciduous forest to the north in that it is lower and has a less well developed emergent layer, so that there are frequently only two strata. These are the upper tree layer at about 80 feet, and an understorey at 40–50 feet. Detailed enumerations carried out on the nineteen sample strips recorded within the basin confirm that there are fewer emergents within the rain forest than in the semi-deciduous forest. Within these sample strips over 29,000 trees were identified and mapped, and a summary of these observations in tabular form is given in Table 29. This table shows the most frequent emergents in the rain forest to be, in order of frequency, *Piptadeniastrum africanum* (*Piptadenia africana*), *Distemonanthus benthamianus*, *Anopyxis klaineana*, *Nauclea diderichii* (*Sarcocephalus diderichii*), *Ceiba pentandra*, *Terminalia ivorensis*, *T. superba*, *Chlorophora excelsa*, *Hannoa klaineana* and *Guarea cedrata*.

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[11] *See* footnote on page 15.

The two main layers of the forest are irregular and often merge into each other and so lose their identity. The understorey is particularly well developed, forming a dense layer which lets through very little sunshine. Because of this the undergrowth is poor, consisting of small shrubs and slender seedlings of tree species represented in the upper layers. In many places a scrambling shrub is found, *Scaphopetalum amoenum*, and here the forest floor is usually quite bare of other shrubs. Grasses are ususually absent from the rain forest, except along paths and in disturbed areas.

The indicator trees, *Lophira alata*, *Cynometra ananta* and *Tarrietia utilis* are all frequent. *Cynometra* and *Tarrietia* in particular are gregarious and may locally be very common indeed. There are very large numbers of *Tarrietia* just south of Samreboi in the southern part of the Tano Nimri forest reserve and on the road to Prestia, so that *Tarrietia* occurs in considerable numbers very close to the northern boundary of the rain forest[12] but is also found throughout the rain forest zone except on some of the well drained sandy soils of the south. The distribution of *Cynometra* is similar, and this tree is also somewhat gregarious, though widespread. *Lophira* is not usually as common as *Tarrietia* or *Cynometra*, but it becomes very frequent on the well drained sandy soils of the Fredericksburg association where certain patches of rain forest amid the coastal thicket consist predominantly of *Lophira alata* and a species of *Parinari*. Associated with these indicator trees are *Diospyros sanzaminika* (ebony), a small semi-gregarious tree, also found in smaller quantities north of the rain forest zone, and *Protomegabaria stapfiana*, which is particularly common on less well drained lower-slope areas.

Many other tree species of the rain forest, though not indicator trees, are commoner in the rain forest than elsewhere. These include *Ongokea gore* (*O. klaineana*), also somewhat gregarious, *Strombosia glaucescens* var. *lucida*, *Dacryodes klaineana* (*Pachylobus barteri*), *Berlinia* sp., several species of *Chrysophyllum*, *Garcinia gnetoides*, *G. mannii*, *Mammea africana*, a species of *Parinari*, *Pentadesma butyracea*, *Trichoscypha arborea*, several species of *Vitex* and of *Xylopia*, *Allanblackia floribunda*, *Scottelia chevalieri*, *Dialium dinklagei*, *Anopyxis klaineana*, *Pentaclethra macrophylla*, *Octhocosmus africanus*, *Carapa procera*, *Canarium schweinfurthii* and *Turraenthus africanus* (*T. vignei*). All these species occur frequently in both the upper and lower layers of the rain forest, together with other trees growing throughout the forest zone, such as *Piptadeniastrum africanum*, *Fagara macrophylla*, *Pycnanthus angolensis*, *Combretodendron macrocarpum* (*Petersia africana*), *Distemonanthus benthamianus*, *Khaya ivorensis*, *Nauclea diderichii*, *Ceiba pentandra*, *Chlorophora excelsa* and others listed in Table 29.

The shrubby undergrowth is very poorly developed and sometimes absent. The commonest species in this layer, where it is present, are *Conopharyngia chippii*, *Pleiocarpa mutica*, *Mareya micrantha* (*M. spicata*), *Cola chlamydantha*, species of *Pavetta* and *Randia*, and *Baphia nitida*.

Enumerations carried out on sample strips suggest that the species listed above are very uneven in their distribution and that many of them are more or less gregarious. A sample strip on the Samreboi-Prestea road showed much greater densities of *Tarrietia* and *Ongokea* than were found on a strip at Abenia, further south, where the soils are very similar, which was characterised by very frequent *Pentadesma butyracea*, *Strombosia glaucescens* var *lucida*, *Drypetes glomerata* and *Cola gigantea* in the under-storey. In the south of the rain forest zone, however, a distinct correlation between the distribution of rain forest species and the soil was found. On the granite and phyllite areas of the Ankasa and Boi associations respectively, the usual indicator trees were recorded, but on the well drained Tikobo association over Tertiary sands, in the same latitude and under the same rainfall, these indicator trees were almost absent. *Dacryodes klaineana* (*Pachylobus barteri*) and *Strombosia glaucescens* var. *lucida* on the other hand were very common on these Tertiary sands. Since these soils are as acid as neighbouring associations, it seems possible that trees like *Strombosia* and *Dacryodes* which become progressively more frequent to the south of the basin are simply acid tolerant, and are not sensitive to drainage, whereas *Cynometra* and *Tarrietia* are confined to areas which are both acid and fairly moist throughout the year. This hypothesis is supported by the fact that *Tarrietia* and *Cynometra* reappear on the less well drained Tertiary sand soils.

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[12] Maps shown by M. Aubreville at the West African Science Association Conference, Achimota, 1958, indicated a similar distribution in the Ivory Coast.

Semi-deciduous forest

In the north of the basin, north of the latitude of Samreboi, the natural vegetation is moist semi-deciduous forest slightly different in floristic composition from the rain forest discussed above. This semi-deciduous forest is found in areas with a rainfall below 65 - 70 inches per annum where the soils are, on the average, less acid than the oxysols of the rain forest zone to the south.

The name moist semi-deciduous forest refers to the fact that some of the trees in the upper and emergent layers shed their leaves, usually during the dry season. The structure of this forest has the normal three strata, i.e. emergents at over 120 feet, an upper strata forming a canopy and a lower storey, but these are replaced in certain poor areas within the basin by patches of a lower tangled growth containing such climbers as *Calamus deeratus*, *Hybophrynium braunianum* and *Acacia pennata*. These tangles occur on areas of poor soil, such as on the summits of hills with shallow highly ferruginous soils overlying ironpan (Nsuta series) or on some low areas subject to waterlogging.

The moist semi-deciduous forest is usually divided into three associations (Taylor, 1952). These are: the *Lophira-Triplochiton* association, the *Celtis-Triplochiton* association, the *Antiarias-Chloro phora* association.

Of these, the *Antiaris-Chlorophora* association is absent entirely from the basin, while the most extensive, the *Celtis-Triplochiton* association, is found only in the northern tip. To the south of this association is a relatively narrow zone, the *Lophira-Triplochiton* association, which is described as an ecotone or transitional zone between the rain forest and the *Celtis-Triplochiton* association. In this transitional zone both *Celtis mildbraedii* and *Triplochiton scleroxylon* are said to be found together with *Cynometra* and *Lophira* of the rain forest zone, so this is an area of mixing and overlapping rather than one in which any of the typical trees are found at their best development. Within the Lower Tano Basin, however, this ecotone or transitional zone (the *Lophira-Triplochiton* association) was found to be very poorly represented, if not absent altogether, enumerations carried out during the course of the survey suggesting that the *Celtis-Triplochiton* association is found as far south as Samreboi, with both *Celtis* and *Triplochiton* plentiful to this latitude, *Cynometra* absent except in the west, and *Lophira* occurring in small numbers only. Immediately south of Samreboi, the typical rain forest species, particularly *Tarrietia* and *Cynometra*, occur in large numbers, so that there is a relatively well defined change in this latitude confined to a narrow zone, and not extending over a broad transitional area.

The commonest large trees within the semi-deciduous forest of the northern half of the basin are *Celtis mildbraedii* and *Triplochiton scleroxylon*, both of which are very common throughout the area and occur in all the layers of the forest, *Ceiba pentandra* (silk cotton), one of the largest trees in the forest, *Chlorophora excelsa* (odum), *Guarea cedrata*, *Hannoa Klaineana*, *Khaya ivorensis Mimusops heckelii*, *Nesogordonia papaverifera*, *Combretodendron macrocarpum* (*Petersia africana*) *Piptadeniastrum africanum*, *Pycnanthus angolensis*, and *Terminalia superba*, all of which are found in both the upper storey and emergent layers. Other less common emergents include *Alstonia boonei*, *Amphimas pterocarpoides*, *Anopyxis klaineana*, *Antiaris africana*, *Blighia sapida*, *Bombax buonopozense*, *Canarium schweinfurthii*, *Celtis adolfi-frederici*, *Chrysophyllum africanum*, *Daniellia ogea*, *Distemonanthus benthamianus*, *Entandrophragma cylindricum* and *E. utile*, *Khaya anthotheca* and *K. grandifoliola*, *Klainedoxa gabonensis* var. *oblongifoia*, *Lovoa trichilioides* (*L. klaineana*) *Mammea africana*, *Nauclea diderrichii*, *Parinari excelsa* (*P. tenuifolia*), *Parkia bicolor*, *Pterygota macrocarpa*, *Sterculia oblonga* and *S. rhinopetala*, and *Terminalia ivorensis*.

The upper storey contains a number of species additional to those found in the emergent layer, such as *Albizia adianthifolia* and *A. zygia*, *Allanblackia floribunda*, *Berlinia auriculata*, *Bosquiea angolensis*, *Fagara macrophylla*, *Funtumia elastica*, *Dacryodes klaineana*, *Pentaclethra macrophylla*, *Ricinodendron heudelotii*, *Strombosia glaucescens* var *lucida*, *Treculia africana*, *Turraenthus africanus* and *Xylopia quintasii*.

The lower storey is the most varied of all since it contains examples of all the species found in the upper storey and in the emergent layer, often in the seedling stage, together with a number of shorter species which do not usually reach the heights of the upper layers. The commonest understorey species in original forest are *Albizia adianthifolia* and A. *zygia*, *Antrocaryon micraster*, *Baphia pubescens*, *Blighia sapida*, *Bosquiea angolensis*, *Bussea occidentalis*, *Carapa procera*, *Cleistopholis* *patens, Cola gigantea, C. nitida, Conopharyngia chippii, Corynanthe puchyceras, Enantia chlorantha, Fagara macrophylla, Ficus asperifolia, F. capensis, F. exasperata, Funtumia elastica, Hannoa klaineana, Hymenostegia afzelii, Macaranga heterophylla, M. hurifolia, Monodora myristica, Myrianthus arboreus* and *M. serratus, Dacryodes klaineana, Ricinodendron heudelotii, Rinoria kibbiensis, Olax subscorpioides, Sterculia rhinopetala, S. tragacantha, Strombosia glaucescens* var *lucida, Trichilia heudelotii, T. prieureana, Uvaria afzelii* and *Xylopia quintasii.* Small trees of *Terminalia, Combretodendron, Piptadeniastrum, Celtis* and *Triplochiton* are also very common in this layer. In certain areas, particularly where the upper layers are not so well developed and the forest is somewhat lower than usual, the understorey is unusually dense and well developed and then often contains very large numbers of *Dacryodes* and *Strombosia*, together with *Albizia zygia.* These areas sometimes resemble patches of biotic disturbance since the forest structure is altered in favour of the understorey.

In the shruby undergrowth of the forest are found a species of *Pavetta, Cleidion gabonicum, Baphia nitida, Ochna membranacea* (*O. barteri*) and *Sphenocentrum jollyanum.* In the damper areas herbs such as a species of *Commelina* occur. The usual climbers are *Millettia zechiana* and *Buettneria africana.* Unlike the rain forest, grasses are usually present in small quantities, particularly *Streptogyne gerantogaea, Olyra latifolia* and *Leptaspis cochleata*, the last two becoming more common along paths.

The above account gives a general description of the semi-deciduous forest of the *Celtis-Triplochiton* association as found within the basin. Within this area there are certain minor changes with latitude. *Dacryodes* and *Strombosia*, in the understorey, become more frequent as the rain forest is approached, while *Mansonia altissima* and *Afrormosia elata*, which occur in the very north of the basin, diminish or disappear entirely in the remainder of it. *Hildegardia barteri* (*Erythropsis barteri*), common in the north of the forest zone, also appears only in the extreme north of the basin.

The main modification, however, is the presence in certain areas only of fairly well marked concentrations of *Cynometra* together with lesser numbers of *Tarrietia.* These are revealed by Forestry Department enumerations in the Yoyo forest reserve north of Enchi, where a 5 per cent enumeration of 568 acres actually showed *Cynometra* to be the commonest tree, while lesser numbers were recorded in the Tano Anwia forest reserve together, in each case, with a relatively small number of *Tarrietia.* An examination of the individual traverses shows that the *Cynometra* of the Yoyo forest reserve, though the total number recorded was high, were confined to small patches with a very high density to the acre and that large areas of the same forest reserve were quite without *Cynometra.* The distribution of this very gregarious tree is therefore uneven and, within the semi-deciduous forest discussed here, occurs only in small, well defined areas near the southern boundary of the forest. These are shown approximately in Fig. 5.

It has been suggested that in areas of cultivation, the rain forest trees tend to disappear and that this may help to explain the absence of these species from areas of settlement near the Enchi-Asankrangwa road, but traverses through high forest in the same general area make it clear that these indicators are also absent in the original vegetation and occur merely as outliers of the rain forest in certain high areas of the Yoyo and Tano Anwia forest reserves which may also be a little wetter than the usual for their latitude. Even in these areas the patchy and uneven distribution of these trees must be emphasised.

Other modifications of the semi-deciduous forest due to edaphic factors (i.e. swamp forest) and to biotic disturbance (regrowth vegetation types) are discussed separately, below.

Swamp forest

In both the rain forest and semi-deciduous forest, poorly drained areas support a distinctive vegetation adapted to the local conditions. This is described as swamp forest, and it is recognised by its floristic composition, not by the apparent drainage of the ground, since it also occurs in areas which are not as waterlogged as the name swamp suggests and in areas which, though damp or even flooded for part of the year, are fairly well drained in the dry seasons.

Swamp forest contains fewer large trees than surrounding high forest and is also much poorer in species. Throughout the basin, the floristic composition of swamp forest is more or less the same, with relatively slight modifications to correspond with the division of the high forest into rain forest and semi-deciduous forest, and with varying drainage conditions.

By far the commonest tree is the raphia palm, *Raphia vinifera,* while the thorny scandent palm, *Calamus deeratus,* which in certain areas corkscrews upward to climb to the top of the forest, and the spiny cane, *Ancistrophyllum opacum,* are commonly associated with it. In most moderately damp areas which have not been disturbed by cultivation the typical trees found with these are *Carapa procera, Berlinia auriculata, Chrysophyllum laurentii* and *C. Macrophyllum, Uapaca guineensis, Cleistopholis patens* and *Pseudospondias microcarpa,* together with *Alstonia boonei* in the north of the basin and *Tarrietia utilis, Protomegabaria stapfiana, Funtumia africana* and *Mitragyna stipulosa* in the south of the basin. These may be associated with scrambling shrubs such as *Glyphaea brevis,* while herbs present in such areas include *Phrynium conferta* and *Sarcophrynium brachystachyum.*

In particularly waterlogged areas subject to flooding for a considerable part of the year, such as are common in the south of the basin, the usual trees are *Raphia vinifera, Chrysophyllum macrophyllum, Spondianthus preussii, Gilbertiodendron splendidum.* (*Macrolobium splendidum*), *Mitragyna stipulosa, Symphonia globulifera* and *Nauclea pobeguinii.* These are associated, within the rain forest area, but not outside it, with a large spiny aroid, *Cyrtosperma senegalense.* A sedge, *Rhyncospora corymbosa,* is common in more open parts.

Modifications of the swamp forest due to biotic disturbance are discussed below, under swamp regrowth vegetation.

Edaphic savanna patches

Edaphic savanna within the Lower Tano Basin is confined to a number of striking patches with a total area of about 4½ square miles occurring in the south of the Nzima area behind the littoral. The normal soil of these patches is Atuabo series, which is subject to seasonal waterlogging but dries out in the dry season. Other small savanna areas are known within the Ghana forest zone, occurring on very shallow soils overlying massive ironpan or bauxite, but patches of this type have not been found within the basin.

The short grass savanna of the Nzima patches consists mostly of a species of *Hyparrhenia,* not yet identified, which is associated with *Rhyncospora wallichiana,* with lesser amounts of *Scleria hirtella* and *Panicum kerstingii.* In areas where waterlogging persists for longer than average a somewhat different cover is found, characterised principally by the sedges *Fuirena umbellata* and *Rhyncospora aberrans,* C.B.Cl., while at the Esiama and Eikwe patches, *Rhytachne rottboellioides* was found to be frequent in areas of recent burning, but to disappear later in the season. This is the grass best liked by cattle. Many of the patches have small clumps of thicket within them, mainly *Syzygium guineense.* A more detailed account of the vegetation of these patches is contained in Ahn, 1959.

Thicket

The thicket of the Nzima littoral is not equivalent to the usual coastal thicket of coastal areas to the east from Takoradi to the Accra Plains, since it is not as low, compact, and thorny, and consists mainly of soft-wooded plants, many of them belonging to the Rubiaceae. The commonest species is *Syzygium guineense,* a shrub or tree with shiny leaves and purplish black edible fruits, which is usually associated with *Dialium guineense, Chrysobalanus ellipticus, Gaertnera paniculata, Uvaria globosa, Baphia nitida, Ochthocosmos chippii* and species of *Canthium* and *Ixora.* Where the thicket is less well developed, a species of *Selaginella* is also found. Under certain conditions it is thought that this thicket might develop into a type of low rain forest, particularly on the spit west of Half Assini where the thicket merges into forest areas in which *Lophira alata* and a species of *Parinari* predominate.

REGROWTH VEGETATION TYPES APPEARING AFTER BIOTIC DISTURBANCE[13]

Forb regrowth

Forb regrowth is a general term given to the herbaceous vegetation which springs up rapidly as soon as a farm in the forest zone is abandoned and is no longer weeded. This consists mainly of quick-growing soft-stemmed suffrutescent herbs or forbs which very soon form a fairly dense mass of foliage up to 4–6 feet high or more, though because of the lack, as yet, of woody shrubs this growth is relatively easily cleared or cutlassed. The composition of this regrowth varies very considerably according to the locality, the soil, and the composition of the previous and surrounding vegetation. It usually has mixed with it remains of cassava and other crops such as pineapples left over from the previous farms, as well as wild peppers and pawpaw; it may contain abandoned tree crops and, as in all regrowth stages, there are usually scattered tall trees which were spared during the initial clearing of the forest either in order to give shade, or because they were difficult to fell. This leafy soft-stemmed vegetation persists for one and a half to two years, by which time some of the species have grown into large woody-stemmed shrubs or climbers, and other shorter lived species have been driven out and replaced by shrubs not previously in evidence and by coppice shoots growing up from tree stumps and stocks. When woody-stemmed shrubs become dominant, the forb regrowth stage has passed and given place to thicket, described below.

The height and composition of forb regrowth vary considerably. Broadly speaking, there are two types: the first grows up in areas where original forest has been cleared, cultivated briefly and then allowed to revert to regrowth. The second type is found on older cultivated areas subjected to repeated and frequent clearing and replanting, usually to cassava.

The first type is more varied than the second. *Aframomum sceptrum*, *Ageratum conyzoides*, *Palisota hirsuta*, *Thaumatococcus daniellii* and *Marantochloa flexuosa* are all very common, the last two particularly in the north of the basin, while *Tristemma coronatum*, which is tolerant of acid soils, becomes very frequent in the south. Other typical species found are *Hilleria latifola*, *Brillantaisia lamium* *Fleurya aestuans*, *Solanum anomalum* and *S. torvum*, *Pupalia lappacea*, *Piper umbellatum*, *Conopharyngia chippii*, *Pollia condensata*, the climbers *Tylophora conspicua* and *Passiflora foetida*, *Urera mannii* and an unidentified species of *Momordica*. On road cuttings, clearing and timber tracks in the south of the basin, two acid-tolerant species, *Lycopodium cernuum* (stagshornmoss) and *Gleichenia linearis*, a branching fern, are locally frequent. Grasses such as *Paspalum conjugatum*, *P. scrobiculatum* and *Setaria chevalieri* are often mixed with the herbs, and in the later stages fast growing trees such as *Musanga cecropioides* and *Trema guineensis* begin to appear.

The second type of forb regrowth found in older cultivated areas often contains relatively few species, and sometimes consists simply of a dense mass of yellow-flowered *Aspilia africana* (Pers.) Adams (*Aspilia latifolia*) and *Melanthera scandens* (Schum. & Thonn.) Roberts (*Widelia africana*), 4–6 feet high. *Solanum torvum*, somewhat resembling the garden egg plant, is widespread and common, as are *Vernonia cinerea*, *Ageratum conyzoides* and a species of *Centrosema*, with *Microglossa afzelii* and *M. pyrifolia* (Lank) Kunze (*M. volubilis*) appearing mostly in the north of the basin. The very first weeds to spring up after abandoning the farm are often *Physalis angulata*, the climber *Cardiospermum halicacabum* and a species of *Ipomea*.

In both types of forb regrowth, coppice shoots are common and become more important as the regrowth gets older. The most common are from stumps and roots of *Ceiba pentandra*, *Allanblackia floribunda*, *Blighia sapida*, *Terminalia superba*, *Lannea welwitschii* (*L. acidissima*), *Alstonia boonei* and various species of *Ficus*.

On the poor sandy soils immediately behind the coast which are intensely cultivated a third forb regrowth type can be distinguished. This consists of a poor growth of herbs, including *Scoparia dulcis*, *Dissotis rotundifolia* and species of *Sida* and *Desmodium*, sometimes with grasses such as

[13] This section follow closely the author's paper on the subject (Ahn, 1958*b*)

Sporobolus pyramidalis, Perotia sp., Brachiaria deflexa, Eragrostis ciliaris and *E. tremula.* This is relatively short-lived since at about six months it is already being replaced by shrubs and coppice shoots of *Baphia nitida* and species of *Conopharyngia* and *Voacanga.*

Thicket [14]

Thicket succeeds forb regrowth when woody stemmed shrubs, climbers and coppice shoots replace the soft-stemmed herbs of the latter. This usually takes place about two years after a farm is abandoned, depending on local conditions. Thicket is usually an impenetrable mass of vegetation, including thorny species and climbers, which grows up to 20 feet high and is difficult to clear. Thicket does not vary in structure or floristic composition within the basin to correspond with the associations of the original forest vegetation, but two main types of thicket can be distinguished which succeed the two types of forb regrowth described above. The first of these occurs in newly cleared forest areas where the soil has not been greatly exhausted by previous cultivation and where there are still frequent forest trees left standing. The second occurs in areas of old cultivation with little or no tree shade and exhausted, long-cultivated soils. The second type persists for a longer period than the first because the development of the next regrowth stage, secondary forest, is slower.

The first type of thicket is less compact and impenetrable that the second as it has fewer shrubs and more coppice shoots and young trees, both seedlings of such tall forest trees as are found in the area, and small trees of the rapidly growing light-demanding species typical of young secondary forest growth. In addition, there are the usual tall shade trees spared during previous clearing, and remnants of herbs and grasses left over from the forb regrowth state. The commoner shrubs in this type of thicket are *Microdesmis puberula, Baphia nitida, Mallotus oppositifolius, Hoslundia opposita, Griffonia simplicifolia,* and *Phyllanthus muellerianus* (*P. floribundus*), a woody climber. Seedlings and small trees of the following are usually fairly frequent: *Terminalia superba, Discoglypremna caloneura, Ficus asperifolia, Musanga cecropioides, Ricinodendron heudelotii, Trema guineensis, Ceiba pentandra, Combretodendron macrocarpum, Alstonia boonei, Celtis mildbraedii* (in the north of the basin only), species of *Albizia, Trichilia heudelotii, Allanblackia floribunda, Pentadesma butyracea, Blighia sapida* and *Cola gigantea.* Some of the herbs listed under forb regrowth, such as *Palisota, Thaumatococcus, Marantochloa* and *Pollia* may survive to this stage, and the thicket is often bound together by climbers, of which the commonest are *Acacia pennata* and *Combretum smeathmannii* (*C.mucronatum*), which are thorny, and, in the north of the basin only, *Millettia zechiana.* Because of the frequency of young trees in this type of thicket and the fact that the soil is not exhausted by frequent previous cultivation and disturbance, the succeeding stage of secondary forest may be reached five to six years after the area has been allowed to revert to natural vegetation. This thicket type is often found in original forest areas, cleared only once and planted to cocoa trees. As this type of thicket gets older, two distinct layers develop: a lower shrub layer at 15–20 feet, and an upper layer of fast-growing trees which is still well below the level of the trees left from the original forest. Trees such as *Hymenostegia afzelii, Randia genipaeflora, Trichilia prieuriana, Cleidion gabonicum, Myrianthus serratus, Maesobotrya edulis,* a species of *Celtis,* and other previously mentioned tall forest species become more in evidence, while shrubs such as *Phyllanthus* and *Hoslundia* disappear, as do the herbs, though forest grasses such as *Olyra latifolia* and *Streptogyne gerontogaea* appear. This final thicket stage precedes the development of secondary forest.

The thicket developed in more open areas of long cultivation and relatively exhausted soils is much denser, more compact, thorny and impenetrable than that described above, and persists for a longer period. There are few, if any, tall trees left standing, so that the intensity of sunlight is greater. The thicket shrubs are dense up to about 20 feet above the ground, above which are fast-growing light-demanding small trees. Herbs and grasses are usually absent, except perhaps in the early stages, but cassava, often old and tall, is frequently mixed in with the thicket to form a tangled mass.

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[14] This is not to be confused with coastal thicket (page 243)

The commonest shrubs of this thicket type are *Rauwolfia vomitoria, Bridelia micrantha, Alchornea cordifolia, Bandeiraea simplicifolia, Spondias mombin, Hoslundia opposita, Baphia nitida, Microdesmis puberula, Harungana madagascariensis, Allophyllus africanus, Lonchocarpus sericeus, Macaranga hurifolia, M. heterophylla, Mallotus oppositifolius, Cnestis ferruginea* and a species of *Canthium*. There are also numerous scambling shrubs such as *Byrsocarpus coccineus, Mussaenda erythrophylla, M. afzelii, Hybophrynium braunianum* and *Phyllanthus muellerianus*, and thorny climbers of which the commonest are *Clerodendron capitatum, Acacia pennata, Combretum mucronatum* and *Mezoneurum benthamianum*. A sedge, *Scleria barteri*, is often found climbing to considerable heights. In addition to these shrubs, many of which will persist to form the undergrowth in the succeeding secondary forest, there are numerous coppice shoots and young seedlings, some of which will eventually dominate the formation, at which stage it becomes secondary forest. In thicket of this type, on long cultivated soils, this may not occur until eight to ten years after the farm has been abandoned. The most important of these young trees are *Musanga cecropioides* (in the south of the basin these occur in almost pure stands), *Albizia zygia, Albizia adianthifolia, Sterculia tragacantha, Ficus capensis, Milletia sp., Trema guineensis, Canthium glabriflorum, Vernonia conferta, Anthocleista vogelii* and (particularly in the north of the basin) *A. nobilis, Macaranga heterophylla, Bridelia micrantha, Harungana madagascariensis, Spondias mombin* and *Morinda lucida*.

Secondary forest

Secondary forest develops from the thicket stage described above when the fast-growing light-demanding trees have become dominant. At this stage the thicket shrubs become less dense, so that the undergrowth is shrubby but fairly open, though still draped with climbers. Secondary forest has therefore three distinct layers, the shrubby undergrowth, the main canopy of secondary forest trees at about 40 feet or more, which gets higher as the forest matures, and an upper layer of original forest trees at 100–120 feet left during the first clearing of the forest.

Just as forb regrowth and thicket vary according to soil fertility and the history of previous cultivation, so does the secondary forest which succeeds the thicket vary both in composition and the length of time it takes to develop. On the more favourable sites, in newly cleared forest areas, secondary forest may appear five to six years after the farm or clearing is abandoned and it then contains a proportion of young high forest species in addition to the normal secondary forest trees, while on poor long-cultivated sites with more exhausted soils and few or no remaining shade trees, not only does the secondary forest take longer to develop but it consists predominantly of quick-growing light-demanding varieties which form a dense layer 30–40 feet high. On such sites it may be a relatively long time before soft wooded but tall trees such as *Combretodendron macrocarpum* (*Petersia africana*), *Ricinodendron heudelotii, Lannea welwitschii, Sterculia tragacantha, Terminalia superba, Pycnanthus angolensis, Ceiba pentandra, Pentadesma butyracea, Dacryodes klaineana* (*Pachylobus barteri*) and *Staudtia stipitata*, together with *Triplochiton scleroxylon* and *Allanblackia floribunda* in the north and the south of the basin respectively, emerge to form an upper layer. On the poorer sites it may take up to fifteen years from the abandonment of the site to develop a good layered structure.

The lower storey of all types of secondary forest irrespective of site consists of small trees, many of them of the species found in thicket, though as the forest develops and there is less light many of these will be crowded out by slower growing but stronger species better adapted to shade conditions. The more important of these lower storey trees are *Musanga cecropioides, Harungana madagascariensis, Macaranga heterophylla, Elaeis guineensis, Bridelia micrantha, Allophyllus africanus, Trichilia heudelotii, Albizia zygia, A. Adianthifolia, Myrianthus serratus, M. arboreus, Anthocleista vogelii, Canthium glabriflorum, Ficus capensis, Spondias mombin, Funtumia elastica, Phyllanthus discoideus* and *Spathodea campanulata*. Of these, *Anthocleista, Macaranga, Bridelia, Musanga* and *Elaeis* are more frequent in the south of the basin than in the north, where the different species of *Albizia* and *Sterculia tragacantha* are common. A creeper, a species of *Culcasia*, is often seen, and forest grasses such as *Streptogyne gerontogaea* and *Leptaspis cochleata* appear. Of the shrubs, *Baphia nitida* and *Microdesmis puberula* persist from the thicket stage.

As secondary forest gets older it resembles more and more the original high forest of the area, though it is not known how long it takes to become high forest or whether the floristic composition of old secondary forest will be the same as that of the original forest it has replaced. It is certain that in some areas of long cultivation the regrowth forest is poorer in species than original forest. On the other hand it is difficult to tell if some forest areas in the basin are, in fact, original forest or a very old secondary growth. Obviously the more high forest trees left standing during the clearing the more rapid will be the regeneration and the greater the chances of it eventually approximating to the original virgin forest previously partly cleared.

Swamp regrowth vegetation

Just as in normal forest areas, a clearing once abandoned supports a growth of forb regrowth, thicket and secondary forest successively, so do clearings in swamp forest areas regenerate in a similar way to give a succession of corresponding regrowth vegetation types known as swamp forb regrowth, swamp thicket, and secondary swamp forest.

Swamp forb regrowth in moderately damp areas often consists of a variety of herbs including *Ageratum conyzoides* and a number of the *Rubiaceae* and *Marantaceae*, particularly *Borreria ramisparsa* and *Sarcophrynium brachystachyum*, together with grasses such as *Paspalum conjugatum* and species of *Fimbristylis* and *Cyperus*. In the wetter swamps, there is a profuse growth of a variety of sedges, of which the commonest is *Rhyncospora corymbosa*, ferns, the aroid *Cyrtosperma senegalense*, and numerous seedlings of *Raphia vinifera*, *Mitragyna stipulosa* and a species of *Stipularia*, together with a runner grass, *Acroceras amplectens*.

Swamp thicket is similar in floristic composition to swamp forb regrowth, but is higher, denser and more impenetrable. In addition to the species listed above, *Anthocleista vogelii* and *Alchornea cordifolia* may be present, while the scandent palm *Calamus deeratus* and the spiny cane, *Ancistrophyllum opacum* will also develop. This growth gets higher, with the trees and palms developing at the expense of the grasses, sedges, and herbs until, about seven years after the clearing has been abandoned, secondary swamp forest succeeds the thicket.

Secondary swamp forest is dominated by the raphia palm, *Raphia vinifera* and also contains *Calamus deeratus*, *Ancistrophyllum opacum* and such trees as *Spondianthus ugandensis*, *Mitragyna stipulosa*, *Anthocleista vogelii* and shrubs of *Stipularia africana* and *S. elliptica*. In open parts the sedge *Scleria racemosa* and the herb *Phrynium confertum* are found.

Table 29. Summary of vegetation enumerations in nineteen sample strips within the basin, totalling 3,040 acres, in which over 29,000 individual trees were identified and mapped. Of the 3,040 acres included in the sample strips, 37 per cent was under original forest, 16 per cent was under secondary forest, 26 per cent was under thicket regrowth, 3 per cent was under forb regrowth, 2 per cent was under edaphic short grass savanna, and the remaining 16 per cent was under tree crops or current cultivation.

Species	*Enumeration of* 1,120 *Acres Semi-Deciduous Forest*				*Enumeration of* 1,920 *Acres Rain Forest*				*Remarks*
	Under Storey (1)	*Upper Storey* (2)	*Emer-gent* (3)	*Total*	*Under Storey* (1)	*Upper Storey* (2)	*Emer-gent* (3)	*Total*	
Afzelia africana	—	—	—	—	6	5	—	11	—
Albizia adianthifolia ..	56	56	—	112	63	37	—	100	=
Albizia ferruginea ..	—	1	—	1	—	2	—	2	—
Albizia zygia	83	63	—	146	23	32	—	55	=
Allanblackia floribunda ..	45	28	—	73	100	81	—	181	=, but more frequent in RF.
Alstonia boonei (formerly A. congensis)	23	16	17	56	15	27	—	42	=
Amphimas pterocarpoides	14	16	6	36	7	14	2	23	=
Aningueria robusta ..	3	2	—	5	27	18	—	45	mostly in RF, but occurs in SDF, especially in Yoyo Forest Reserve.
Anopyxis klaineana ..	3	3	7	13	1	21	16	38	rather frequent in RF.
Anthocleista nobilis ..	1*	—	—	1	—	—	—	—	Regrowth species. Vogelii is widespread but becomes very frequent in RF, to replace nobilis confined to the north of the basin.
Anthocleista vogelii ..	176	5	—	181	347	122	—	469	(remark shared with Anthocleista nobilis)
Anthonotha lamprophylla (formerly Macrolobium lamprophyllum) ..	—	—	—	—	7	5	—	12	RF.
Antiaris africana	33	9	32	74	5	5	4	14	SDF, only a few in RF.

(1) 10–30 feet high (2) 30–120 feet high (3) above 120 feet * Smaller examples frequent.

= occurs throughout the basin.

— unimportant (occurring in small numbers only).

RF. more important in the rain forest.

SDF. more important in the semi-deciduous forest to the north of the rain forest.

TABLE 29—*continued*

Species	*Enumeration of* 1,120 *Acres Semi-Deciduous Forest* Under Storey (1)	Upper Storey (2)	Emer-gent (3)	Total	*Enumeration of* 1,920 *Acres Rain Forest* Under Storey (1)	Upper Storey (2)	Emer-gent (3)	Total	*Remarks*
Antidesma venosum ..	3	6	—	9	30	10	—	40	=
Antrocaryon micraster ..	40	7	—	47	15	21	—	36	=
Baphia nitida	28	—	—	28	43	—	—	43	—, mostly occurs as thicket shrub.
Baphia pubescens	14	—	—	14	15	—	—	15	—
Berlinia auriculata ..	22	35	—	57	9	21	7	37	=
Berlinia sp	—	—	—	—	—	57	—	57	RF.
Blighia sapida	58	33	6	97	45	23	2	70	=
Bombax buonopozense ..	11	1	2	14	29	9	1	39	=
Bosquiea angolensis ..	52	34	—	86	3	4	—	7	SDF.
Bridelia micrantha ..	4	—	—	4	106	13	—	119	=regrowth species, but more frequent in RF.
Bussea occidentalis ..	120	7	—	127	6	—	—	6	mostly in SDF.
Canarium schweinfurthii ..	7	3	3	13	11	17	5	33	=, but more in RF.
Canthium glabriflorum ..	29	—	—	29	1	—	—	1	= in secondary vegetation.
Carapa procera	183	—	—	183	411	—	—	411	=, but in SDF is confined to valley bottoms whilst in RF it is found irrespective of site.
Ceiba pentandra	18	29	77	124	28	66	15	109	=
Celtis adolfi-frederici ..	10	31	2	43	—	—	—	—	SDF.
Celtis mildbraedii	195	288	83	566	—	—	—	—	SDF: indicator tree.
Chlorophora excelsa and C. regia	30	32	16	78	41	57	12	110	= but more frequent in the SDF.
Chrysophyllum africanum	8	9	9	26	11	12	1	24	=

(1) 10–30 feet high (2) 30–120 feet high (3) above 120 feet.

=occurs throughout the basin.

—unimportant (occurring in small numbers only).

RF. more important in the rain forest.

SDF. more important in the semi-deciduous forest to the north of the rain forest.

TABLE 29—continued

Species	*Enumeration of 1,120 Acres Semi-Deciduous Forest* Under Storey (1)	Upper Storey (2)	Emer-gent (3)	Total	*Enumeration of 1,920 Acres Rain Forest* Under Storey (1)	Upper Storey (2)	Emer-gent (3)	Total	Remarks
Chrysophyllum laurentii ..	—	—	—	—	144	27	—	171	RF, along the Tano alluvial.
Chrysophyllum sp. ..	9	—	—	9	162	2	—	164	RF: an understorey tree and in swamps.
Cistanthera—*see* Nesogordonia.									
Cleidion gabonicum ..	1	—	—	1	—	—	—	—	SDF, where more common than figures indicate.
Cleistopholis patens ..	72	—	—	72	90	48	—	138	=along streams and in swamps.
Cola chlamydantha ..	54	—	—	54	177	—	—	177	=, but becomes more frequent in RF.
Cola gigantea	159	15	—	174	132	11	—	143	=, but more frequent in north, and small in size in RF.
Cola nitida	288	23	—	311	176	21	—	197	=
Combretodendron macrocarpum (formerly Petersia africana and C. africanum)	140	10	30	180	39	105	19	163	=
Conopharyngia chippii ..	88	—	—	88	29	—	—	29	—
Cordia millenii	1	3	—	4	—	4	—	4	= but scarce throughout.
Corynanthe pachyceras ..	123	7	—	130	140	14	—	154	=
Cussonia barteri (formerly C. djalonensis)	7	—	—	7	3	—	—	3	—

(1) 10–30 feet high (2) 30–120 feet high (3) above 120 feet

=occurs throughout the basin.

—unimportant (occurring in small numbers only).

RF. more important in the rain forest.

SDF. more important in the semi-deciduous forest to the north of the rain forest.

TABLE 29—continued

Species	*Enumeration of 1,120 Acres Semi-Deciduous Forest* Under Storey (1)	Upper Storey (2)	Emer-gent (3)	Total	*Enumeration of 1,920 Acres Rain Forest* Under Storey (1)	Upper Storey (2)	Emer-gent (3)	Total	*Remarks*
Cynometra ananta ..	—	16	—	16	102	276	—	378	RF, but frequent north of Enchi in SDF.
Dacryodes klaineana (formerly Pachylobus barteri)	116	33	—	149	570	718	—	1,288	=, particularly abundant in RF.
Daniellia ogea	5	2	10	17	28	48	6	82	=, but more frequent in RF.
Desplatsia subericarpa ..	4	—	—	4	7	—	—	7	—, occurs in swampy areas.
Dialium dinklagei ..	3	10	—	13	1	71	6	78	RF.
Diospyros sanzaminika ..	4	4	—	8	263	190	—	453	RF.
Diospyros kamerunensis ..	—	—	—	—	24	—	—	24	RF.
Discoglypremna caloneura	3	5	—	8	6	2	—	8	—
Distemonanthus benthamianus	25	21	15	61	20	33	19	72	=
Dracaena sp.	4	—	—	4	—	—	—	—	—
Drypetes sp.	—	—	—	—	269	18	—	314	RF.
Ekebergia senegalensis ..	—	2	—	2	—	—	—	—	—
Elaeis guineensis	97	11	—	108	268	122	—	390	=, but particularly in secondary forest in the RF. areas.
Enantia chlorantha ..	36	1	—	37	183	—	—	183	= but more frequent in RF.
Entandrophragma cylindricum	—	3	3	6	—	3	1	4	=

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SDF. more important in the semi-deciduous forest to the north of the rain forest.

TABLE 29—*continued*

Species	*Enumeration of* 1,120 *Acres Semi-Deciduous Forest* *Under Storey* (1)	*Upper Storey* (2)	*Emer-gent* (3)	*Total*	*Enumeration of* 1,920 *Acres Rain Forest* *Under Storey* (1)	*Upper Storey* (2)	*Emer-gent* (3)	*Total*	*Remarks*
Entandrophragma angolense (formerly E. macrophyllum)	17	29	—	46	2	16	9	27	=
Entandrophragma utile ..	3	3	3	9	3	2	2	7	=
Erythrina senegalensis ..	4	—	—	4	12	—	—	12	—
Erythropsis barteri—*see* Hildegardia.									
Fagara macrophylla ..	65	32	—	97	56	36	—	92	=
Ficus asperifolia	68	13	—	81	37	11	—	48	= regrowth species.
Ficus capensis	100	—	—	100	68	14	—	82	= regrowth species.
Ficus exasperata	43	3	—	46	69	5	—	74	= regrowth species.
Ficus sp.	2	4	—	6	6	12	—	18	— regrowth species.
Funtumia africana ..	—	—	—	—	30	52	—	82	frequent in RF—mostly in swamps
Funtumia elastica	99	38	—	137	186	76	—	262	=
Garcinia gnetoides ..	—	—	—	—	229	18	—	247	RF.
Garcinia kola	—	—	—	—	1	1	—	2	= but scarce throughout.
Garcinia mannii	3	—	—	3	104	—	—	104	RF.
Gilbertiodendron splendidum (formerly Macrolobium s.)	—	—	—	—	11	40	—	51	RF, in swamp forest.
Guarea cedrata	41	13	9	63	36	68	11	115	=
Guarea thompsonii ..	3	—	—	3	20	15	—	35	= but more in the RF.

(1) 10–30 feet high (2) 30–120 feet high (3) above 120 feet

=occurs throughout the basin.

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RF. more important in the rain forest.

SDF. more important in the semi-deciduous forest to the north of the rain forest.

TABLE 29—continued

Species	*Enumeration of 1,120 Acres Semi-Deciduous Forest* Under Storey (1)	Upper Storey (2)	Emergent (3)	Total	*Enumeration of 1,920 Acres Rain Forest* Under Storey (1)	Upper Storey (2)	Emergent (3)	Total	Remarks
Hannoa klaineana ..	70	14	15	99	39	57	12	108	=
Harungana madagascariensis	12	—	—	12	164	—	—	164	= regrowth species.
Hevea brasiliensis	3	—	—	3	1	8	—	9	Introduced.
Hildegardia barteri (formerly Erythropsis barteri).	1	—	—	1	—	—	—	—	Common in Antiaris-Chlorophora association, becomes less frequent in Celtis-Triplochiton association and is rare or absent in the RF.
Holoptelea grandis ..	—	3	—	3	—	—	—	—	—; only a few in SDF.
Homalium letestui ..	14	16	—	30	7	29	5	41	=
Hura crepitans	—	—	—	—	—	2	—	2	Introduced.
Khaya anthotheca ..	2	—	2	4	—	—	—	—	—
Khaya grandifoliola ..	9	16	8	33	3	19	4	26	=but K. ivorensis is more frequent than grandifoliola in all the associations.
Khaya ivorensis	17	10	41	68	3	14	42	59	
Khaya senegalensis ..	—	—	—	—	—	2	—	2	—
Klainedoxa gabonensis var. oblongifolia	3	8	1	12	8	42	8	58	mostly in RF.
Lannea welwitschii (formerly L. acidissima) ..	18	26	—	44	15	12	—	27	mostly in SDF.
Lecaniodiscus cupanioides	2	—	—	2	12	—	—	12	—

(1) 10–30 feet high (2) 30–120 feet high (3) above 120 feet

=occurs throughout the basin.

—unimportant (occurring in small numbers only).

RF. more important in the rain forest.

SDF. more important in the semi-deciduous forest to the north of the rain forest.

TABLE 29—*continued*

Species	*Enumeration of 1,120 Acres Semi-Deciduous Forest* Under Storey (1)	Upper Storey (2)	Emer-gent (3)	Total	*Enumeration of 1,920 Acres Rain Forest* Under Storey (1)	Upper Storey (2)	Emer-gent (3)	Total	*Remarks*
Lophira alata	—	1	—	1	24	45	4	73	RF.
Lovoa trichilioides (formerly L. Klaineana) ..	9	3	1	13	15	15	2	32	=
Macaranga barteri ..	—	—	—	—	135	—	—	135	widespread, but commonest on Tano alluvium.
Macaranga heterophylla ..	136	—	—	136	636	302	—	938	widespread, but appears more common in RF (regrowth species).
Macaranga hurifolia ..	119	—	—	119	18	—	—	18	=
Macrolobium lamprophyllum—*see* Anthonota.									
Macrolobium splendidum —*see* Gilbertiodendron.									
Maesobotrya barteri var. sparsiflora (formerly M. edulis)	13	—	—	13	44	—	—	44	=understorey tree.
Mammea africana ..	3	9	5	17	133	127	9	269	RF, few in SDF.
Mareya micrantha (formerly M. spicata) ..	22	—	—	22	19	—	—	19	—
Microdesmis puberula ..	20	—	—	20	—	—	—	—	a small tree common in SDF, also a frequent thicket species.
Mimusops heckelii ..	9	6	30	45	—	18	6	24	=, but more common in SDF.

(1) 10–30 feet high (2) 30–120 feet high (3) above 120 feet

=occurs throughout the basin.

—unimportant (occurring in small numbers only).

RF. more important in the rain forest.

SDF. more important in the semi-deciduous forest to the north of the rain forest.

TABLE 29—continued

Species	*Enumeration of* 1,120 *Acres Semi-Deciduous Forest* Under Storey (1)	Upper Storey (2)	Emer-gent (3)	Total	*Enumeration of* 1,920 *Acres Rain Forest* Under Storey (1)	Upper Storey (2)	Emer-gent (3)	Total	*Remarks*
Mitragyna stipulosa ..	1	—	—	1	147	128	—	275	RF, in swampy areas.
Monodora myristica ..	63	8	—	71	85	33	—	118	=, understorey species.
Monodora tenuifolia ..	7	—	—	7	4	—	—	4	—
Morinda lucida	3	—	—	3	54	—	—	54	=, especially in open places.
Musanga cecropioides (formerly M. smithii) ..	526	71	—	597	693	302	—	995	=, a common regrowth species.
Myrianthus arboreus ..	110	—	—	110	26	—	—	26	Both are widespread but M. serratus is mostly in the original and old secondary forest whilst M. arboreus is in regrowth.
Myrianthus serratus ..	224	—	—	224	146	—	—	146	
Nauclea diderrichii (formerly Sarcocephalus d.)	2	10	11	23	2	9	16	27	=, increases in RF.
Nauclea pobeguinii ..	—	—	—	—	3	20	—	23	RF, in swamps.
Nesogordonia papaverifera (formerly Cistanthera p.)	22	38	5	65	—	—	—	—	SDF, absent from RF.
Newbouldia laevis ..	6	—	—	6	—	—	—	—	—
Octhocosmus africanus ..	—	—	—	—	8	2	—	10	mostly rain forest.
Olax subscorpioidea ..	7	—	—	7	18	—	—	18	—
Omphalocarpum ahia ..	11	6	—	17	8	8	—	16	=
Ongokea gore (formerly O. klaineana)	—	5	—	5	10	172	—	182	RF, rather gregarious.

(1) 10–30 feet high (2) 30–120 feet high (3) above 120 feet

= occurs throughout the basin.

— unimportant (occurring in small numbers only).

RF. more important in the rain forest.

SDF. more important in the semi-deciduous forest to the north of the rain forest.

TABLE 29—continued

Species	*Enumeration of 1,120 Acres Semi-Deciduous Forest*				*Enumeration of 1,920 Acres Rain Forest*				*Remarks*
	Under Storey (1)	*Upper Storey* (2)	*Emergent* (3)	*Total*	*Under Storey* (1)	*Upper Storey* (2)	*Emergent* (3)	*Total*	
Pachylobus barteri—*see* Dacryodes.									
Pachypodanthium staudtii	—	6	—	6	2	1	—	3	—
Pandanus candellabrum ..	—	—	—	—	8	—	—	8	coastal swamp only.
Panda oleosa	10	15	—	25	12	7	2	21	=
Parkia bicolor	37	35	—	72	30	100	—	130	=, more frequent in RF.
Parinari sp.	—	—	—	—	12	56	—	68	RF.
Parinari excelsa (formerly P. tenuifolia)	3	4	10	17	8	22	9	39	RF.
Pentaclethra macrophylla	32	54	—	86	116	90	—	206	=, more in the RF.
Pentadesma butyracea ..	63	1	—	64	255	139	—	394	RF.
Petersia africana—*see* Combretodendron.									
Phyllanthus discoideus ..	30	7	—	37	49	—	—	49	=, regrowth species.
Piptadeniastrum africanum (formerly Piptadenia africana)	146	103	90	339	75	158	79	312	=
Pleiocarpa mutica ..	—	—	—	—	1	—	—	1	—
Protomegabaria stapfiana	—	—	—	—	665	132	—	797	RF. (few in the SDF.)
Pseudospondias microcarpa	2	—	—	2	1	—	—	1	—, found principally along streams
Pterygota macrocarpa ..	8	15	6	29	—	3	—	3	SDF.

(1) 10–30 feet high (2) 30–120 feet high (3) above 120 feet

=occurs throughout the basin.

—unimportant (occurring in small numbers only).

RF. more important in the rain forest.

SDF. more important in the semi-deciduous forest to the north of the rain forest.

TABLE 29—*continued*

Species	*Enumeration of* 1,120 *Acres Semi-Deciduous Forest* Under Storey (1)	Upper Storey (2)	Emergent (3)	Total	*Enumeration of* 1,920 *Acres Rain Forest* Under Storey (1)	Upper Storey (2)	Emergent (3)	Total	*Remarks*
Pycnanthus angolensis (formerly P. kombo) ..	96	82	4	182	105	153	22	280	=
Randia genipaeflora ..	20	—	—	20	10	—	—	10	—
Randia malliefera	16	—	—	16	12	8	—	20	—
Raphia vinifera	137	2	—	139	467	37	—	504	=, but more in the swamps in RF.
Rauwolfia vomitoria ..	36	—	—	36	37	—	—	37	=
Ricinodendron heudelotii (formerly R. africanum)	76	67	—	143	29	29	—	58	= but less in RF.
Rinorea sp.	—	—	—	—	25	—	—	25	—
Sarcocephalus—*see* Nauclea									
Scaphopetalum amoenum	—	—	—	—	110	—	—	110	RF.
Scottelia chevalieri ..	11	9	—	20	317	12	—	329	=, but in RF., mostly.
Spathodea campanulata ..	2	—	—	2	—	—	—	—	—
Spondias mombin ..	—	—	—	—	15	—	—	15	=regrowth tree.
Spondianthus preussii (formerly S. ugandensis) ..	—	—	—	—	42	32	—	74	RF, in swampy areas.
Staudtia stipitata	—	—	—	—	—	5	—	5	RF, but uncommon.
Sterculia oblonga	4	1	1	6	1	9	3	13	= but uncommon.
Sterculia rhinopetala ..	32	23	2	57	—	1	—	1	SDF, rare in RF.
Sterculia tragacantha ..	38	13	—	51	59	33	—	92	=, mostly in regrowth.

(1) 10–30 feet high (2) 30–120 feet high (3) above 120 feet
=occurs throughout the basin.
—unimportant (occurring in small numbers only).
RF. more important in the rain forest.
SDF. more important in the semi-deciduous forest to the north of the rain forest.

TABLE 29—continued

Species	*Enumeration of* 1,120 *Acres Semi-Deciduous Forest* *Under Storey* (1)	*Upper Storey* (2)	*Emer-gent* (3)	*Total*	*Enumeration of* 1,920 *Acres Rain Forest* *Under Storey* (1)	*Upper Storey* (2)	*Emer-gent* (3)	*Total*	*Remarks*
Strombosia glaucescens var. lucida (formerly S. pustulata)	336	159	—	495	926	466	—	1,392	frequent throughout but more in RF.
Syzygium guineense ..	—	—	—	—	34	—	—	34	coastal thicket only.
Taclea grandifolia ..	5	—	—	5	2	—	—	2	—
Tarrietia utilis	—	5	—	5	190	347	40	577	RF. (indicator tree).
Terminalia ivorensis ..	3	20	7	30	4	24	15	43	=
Terminalia superba ..	90	150	45	285	19	66	14	99	SDF, with some few only along the Tano in the RF.
Tetrapleura tetraptera ..	33	—	—	33	7	—	—	7	—
Treculia africana	38	12	—	50	11	44	—	55	= along streams.
Trema guineensis	16	—	—	16	1	—	—	1	only in young regrowth—less frequent in RF.
Trichilia heudelotii ..	204	—	—	204	122	—	—	122	= but more in SDF.
Trichilia prieureana ..	392	—	—	392	74	—	—	74	=
Trichoscypha arborea ..	30	11	—	41	134	210	—	344	RF.
Triplochiton scleroxylon ..	117	190	159	466	—	11	19	30	SDF. with a few in the Fure Reserve.
Turraeanthus africanus (formerly T. vignei) ..	36	29	—	65	84	113	—	197	RF, but frequent in SDF as the RF is approached.

(1) 10–30 feet high (2) 30–120 feet high (3) above 120 feet

=occurs throughout the basin.

—unimportant (occurring in small numbers only).

RF. more important in the rain forest.

SDF. more important in the semi-deciduous forest to the north of the rain forest.

Species	Enumeration of 1,120 Acres Semi-Deciduous Forest Under Storey (1)	Upper Storey (2)	Emergent (3)	Total	Enumeration of 1,920 Acres Rain Forest Under Storey (1)	Upper Storey (2)	Emergent (3)	Total	Remarks
Uapaca guineensis ..	51	5	—	56	226	194	—	420	RF. U. guineensis occurs irrespective of site, but U. togoensis mostly along the Tano.
Uapaca togoensis ..	—	—	—	—	—	26	—	26	
Uvaria afzelii	—	—	—	—	10	—	—	10	=understorey tree.
Vitex sp.	7	—	—	7	48	—	—	48	more in RF.
Voacanga sp.	4	—	—	4	101	—	—	101	Coastal thicket areas as well as in original forest in the RF.
Xylopia aethiopica ..	7	1	—	8	38	20	—	58	RF.
Xylopia elliotii	—	—	—	—	8	—	—	8	RF, in swamps.
Xylopia quintasii	53	17	—	70	55	71	—	126	=
Xylopia staudtii	—	8	—	8	39	81	—	120	RF.

(1) 10–30 feet high (2) 30–120 feet high (3) above 120 feet
=occurs throughout the basin.
—unimportant (occurring in small numbers only).
RF. more important in the rain forest.
SDF. more important in the semi-deciduous forest to the north of the rain forest.

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GLOSSARY OF SOME OF THE COMMONER SOIL AND VEGETATION TERMS USED IN THIS REPORT

Alluvial Soil—Soil developed in alluvium. (*See* Part I, page 20).

Alluvium—Transported material, usually silt and clay but occasionally sand, deposited by streams and rivers.

Association—Group of related soil series, usually over the same parent material or group of parent materials (e.g. sedentary material and associated alluvium), often forming a regular topographic sequence (catena).

Base Exchange Capacity—Soil capacity, expressed in milli-equivalents per 100 gm. of the fine earth fraction, of retaining bases in the exchange complex. This depends on the amount and nature of the humus and the clay in the soil (*see* Part I, page 24).

Bases—Substances which, when they react with an acid, form a salt. The lower the base content, the more acid the soil. Exchangeable bases in the soil include calcium, magnesium, manganese, and potash.

Brash—Rock fragments, often angular.

Broken Forest—Original high forest of the area, undisturbed except for occasional timber felling etc., and not yet cleared for agriculture.

Clay—The finest particles of the soil, below 0·002 mm. diameter. Clay consists of hydrated silicates of aluminium with other impurities, and is partly colloidal. The finer the clay, the more plastic (q.v.) it is. The clay and the humus (q.v.) form the complex capable of retaining bases in the soil and, in general, the greater its clay content the greater its capacity to hold moisture and plant nutrients.

Climatophytic Earth—Soil order whose characteristics are determined mostly by climate and vegetation. Term coined by C. F. Charter: *see* Part III, pages 127-9.

Colluvial Soil—Soil developed in colluvium. (*See* Part I, pages 20-21).

Colluvium—Soil material (usually silt and clay, sometimes sand), derived from higher soils, which is washed down-slope to accumulate on the lower slopes.

Concretions—Local concentrations of certain chemical compounds (such as iron hydroxide, manganese peroxide or calcium carbonate) that form hard nodules in the soil. In this report the concretions referred to are, unless otherwise stated, ironstone concretions. These are more or less spherical, and of pea size, but are sometimes larger and irregular in shape. True concretions are formed by the concentric deposition of impure iron, but partly rounded small fragments of iron pan or ferruginised rock, similar in appearance, are often associated with true concretions in the normal gravel zone of many forest soils and are usually included under the term.

Crumbly—Soil structure, in which soil particles loosely combine to form crumb-like aggregates. Usual structure of humous topsoils.

Cumulopeds, Cumulosols—Suborder and great soil group family respectively, subdivisions of topohydric earths, characterised by accumulation of peat in poorly drained sites. (*See* Part III, pages 127-9).

Eluviation—Washing out and removal from the soil, or from some horizons in the soil, of fine particles and material in solution.

Exchangeable Bases—Bases (q.v.) held in the exchange complex of the soil which are available to plants.

Ferruginised—Hardened through being impregnated with iron.

Fine Earth—Soil material passing a 2mm. sieve. Analyses given in this report are for this fraction only.

Forb—Soft-stemmed, leafy herb.

Forb Regrowth—Herbaceous growth appearing on newly abandoned clearings and persisting for up to about two and a half years when, if not cut down, it develops into thicket (q.v.). *See* Part III, page 245.

Gleisol—Poorly drained soil in which lack of oxygen results in reducing conditions, or partial reducing conditions, often resulting in the development of mottles. *See also* Part III, pages 127-9.

Grit—Small angular fragment of quartz below 2 mm. in size, common in soils developed over granite.

Groundwater Podsol—Podsol (q.v.) in poorly drained areas where formation of indurated horizon is connected with groundwater fluctuations.

Horizon—Horizontal layer in the soil differing from those above or below due to different colour, texture, structure or content of stones, gravel, humus, etc. Also used to refer to the three zones of topsoil, subsoil and weathered substratum, so that a soil with all three has a three-horizon profile.

Humous—Containing humus.

Humus—Dark brown colloidal material in the soil derived from the decomposition of organic matter. Important for its capacity to hold moisture and mineral nutrients in forms available to plant roots and for its effect on soil structure.

Illuviation—Washing in. Zone of illuviation: zone within a soil profile of addition and accumulation of soil material.

Immature Soil—Soil in which normal profile development has been retarded, e.g. by steep site or resistant parent material.

Indurated—Hardened. The normal indurated zone of many Ghanaian forest soils is coarsely mottled and hardened to various degrees.

Intergrade—Transitional soil between two well defined series or types, e.g. oxysol-ochrosol intergrade in which pH of topsoil is lower than in an ochrosol but not as low as in an oxysol, i.e., between 5·0 and 5·5.

Ironpan—Very hard rock-like ironstone layer formed in the soil and often found either as sheets on or near the surface, or as boulders resulting from the break-up of such a sheet.

Latosol—A highly weathered tropical soil (formerly known as a tropical red earth), red, brown or yellow and usually kaolinitic, in which most of the weatherable material has been broken down and only insoluble residues such as quartz, kaolinitic clay and iron and aluminium hydroxides remain. Divided, in Ghana, into oxysols and ochrosols (q.v.).

Leaching—The removal by percolating water of mineral salts from the soil. When exchangeable bases are removed, the soil becomes more acid.

Levee—Alluvial deposit on the banks of streams and rivers, usually lighter in texture than that further away from the stream.

Lithosol—Stony or immature soil in which normal soil forming processes are prevented by steepness of slope or resistant nature of parent material. These soils consist of a topsoil directly overlying the weathered substratum or unweathered rock: there is little or no subsoil.

Loam—Soil texture intermediate between clay and sand (for practical tests used, *see* page 129). Subdivided into light loam, loam, heavy loam.

Milli-equivalent (*m. e.*)—Abbreviation of milligram equivalent, the unit in which exchangeable base content or exchangeable base capacity is measured (i.e. the weight in milligrams of an element needed to displace 1 milligram of hydrogen in exchange reactions).

Morphology—The structure and form of the soil profile, particularly the number and thickness of its horizons, their colour, texture, structure and content of stones, gravel, and humus.

Ochrosol—A latosol (q.v.) characterised by a topsoil reaction of pH 5·5–7·5 and increasingly acidic reaction of the profile with depth. *See also* oxysol.

Organic Matter—Material of organic origin in the soil, including humus (q.v.). In analytical tables this is conventionally taken as 1·72 x the carbon content.

Organic Pan—Highly indurated layer in which particles are cemented by organic matter.

Oxysol—Latosol (q.v.) in which topsoil pH is 5·0 or below, though pH rises in the subsoil. *See also* ochrosol.

Parent Material—Material from which, or in which, a soil is formed: can be a rock (parent rock) or any other soil forming material such as an alluvial or colluvial deposit, beach sand, etc.

Peneplain—Nearly flat or very gently undulating plain formed at the end of an erosion cycle when all the hills and mountains have been worn down.

Peneplain Remnant—Small area of a formerly extensive but now dissected peneplain, such as is found on the flat summits of certain hills in the Ghanaian forest zone.

pH—See soil reaction.

Plastic—Plastic clays are heavy clays which, when moist, can be shaped without cracking or breaking.

Podsol—Soil with pale grey leached horizon below topsoil. This leached horizon overlies a darker horizon formed through accumulation of matter leached out of upper part of profile.

Profile—Vertical cross section of the soil showing horizons.

Regosols—Great soil group family in which profile development is retarded by the inert nature of the parent material. e.g. a quartz sand. *See* Part III, page 128.

Sand—Particles between 2·0 and 0·02 mm. in size, usually consisting of quartz grains.

Secondary Forest—Recent forest which has grown up on a previously cleared site. May include a few trees from the original forest spared during clearing. *See* Part III, pages 246 - 247.

Sedentary Soil—Soil developed in non-transported parent materials, usually in the products of weathering of the parent rock below. *See* colluvial, alluvial.

Silt—Fine soil particles between sand and clay in size, i.e. between 0·02 and 0·002 mm.

Skeletal Soil—Shallow immature (q.v.) soil containing frequent pieces of hard parent rock.

Soil Reaction—The degree of acidity or alkalinity of the soil. The acidity of the soil reflects the percentage of the total base exchange capacity (q.v.) actually occupied by metallic bases. *See* Part I pages 24–26. Soil acidity is measured on the scale pH 7 (neutral) to pH 0 and, in the text, is described as follows:

pH 7	Neutral
pH 6·6 — 6.9	Slightly acid to neutral
pH 6·1 — 6.5	Slightly acid
pH 5·6 — 6.0	Moderately acid
pH 5·1 — 5.5	Very acid
pH 4·6 — 5.0	Highly acid
pH 4·1 — 4.5	Very highly acid
pH 4·0 and below	Extremely acid

Soil Series—Soils having similar profiles developed under similar conditions from or in similar parent materials: subdivided into subseries and phases (*See* Part II, page 53).

Structure—The natural units formed when soil particles combine loosely to form aggregates, defined by size and shape, e.g. crumbly, nutty, granular, blocky.

Structureless—Soil with no regular visible structure, amorphous.

Subsoil—Zone of illuviation forming, in normal soils, the horizon between the topsoil above and the weathered substratum below. In sedentary forest soils this includes the gravel zone, if present.

Substratum—The zone below the subsoil in which weathered rock products and weathered rock are found, or in which the parent material has been relatively little modified.

Swamp Thicket, Swamp Forest—Thicket (q.v.) or forest consisting mostly of species adapted to poorly drained soils. *See* Part III, pages 243, 247.

Terrace—A topographic feature preserving remnants of alluvium deposited by the stream or river during an earlier era before it had cut down to its present position, and therefore at a higher level than contemporary alluvium. *See* Part III, page 157.

Thicket—Dense secondary growth of shrubs, coppice-shoots, young trees and climbers, usually on sites cleared two to eight years previously and then abandoned. *See* Part III, page 245.

Variant—Very minor soil which varies sufficiently from an established series to be classified as a separate series, but which is so unimportant or uncommon that it has not yet been described in detail.

Weathering—The disintegration and chemical decomposition of rocks due to natural processes.

1a. Felling a forest giant amid little disturbed forest. There are frequent climbers and small trees (left) between the larger trees of the upper storey and emergent layers (centre). This photograph indicates the difficulty and cost of clearing a farm from high forest

1b. View over the Tano valley, south-west of Sefwi-Wiawso, showing forest broken by occasional farm clearings

2a (above). A carrier walking along a forest footpath north of Enchi: it is the rainy season and the footpath here is under about a foot of water. The vegetation includes regrowth and swamp species

2b (right). A similar footpath near Abenia, in the centre of the basin, also under a few inches of water

3a (above). Mature forb regrowth with young secondary forest behind (Aiyinasi Agricultural Station)

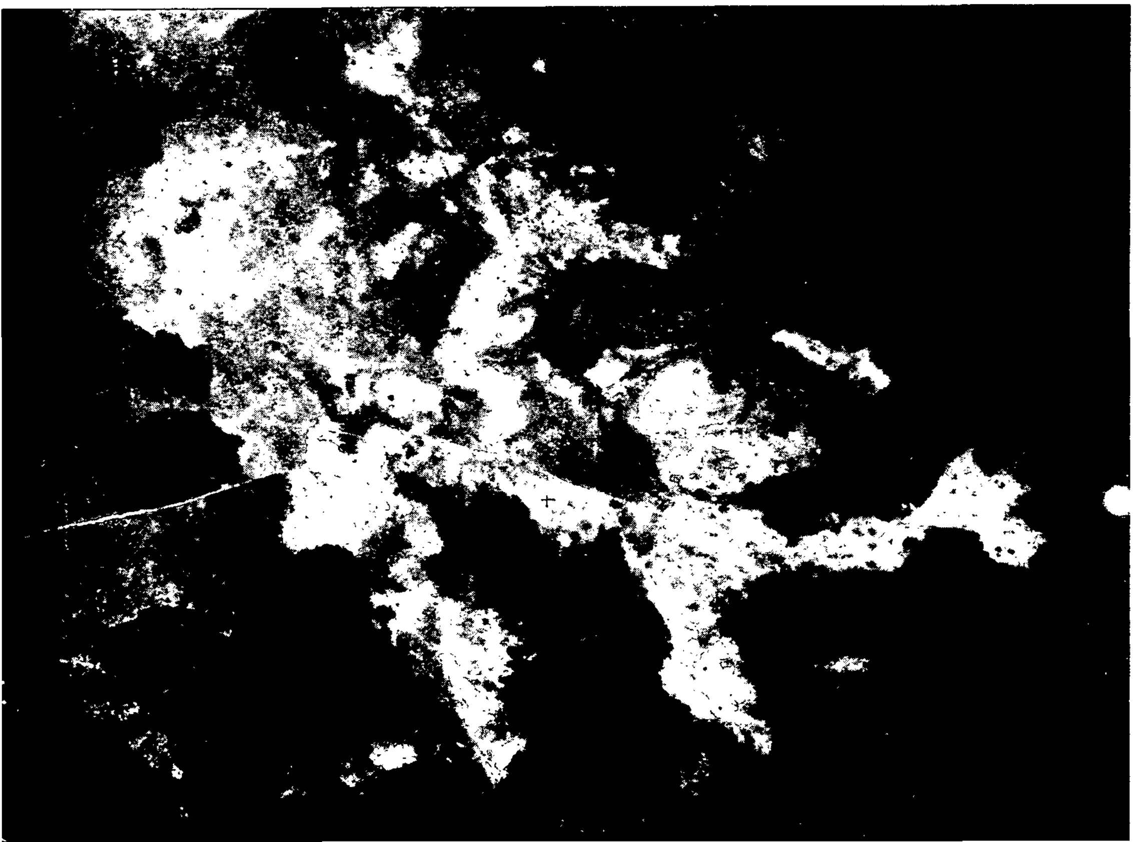
3b (right). Young forb regrowth showing *Solanum* and *Setaria* spp., with oil palm and secondary forest in the background

3c (below). A dense mass of slightly older forb regrowth, showing *Thaumatococcus*, *Aframomum*, *Bridelia* and numerous coppice shoots

4a (top). View of Eikwe savannah patch, looking east, showing low rain forest in background outside patch and borassus palms within it

4b Sparse grass (*Hyparrhenia* sp.) showing greyish white fine sand soil (Atuabo series) between the tufts. Krisin savanna patch

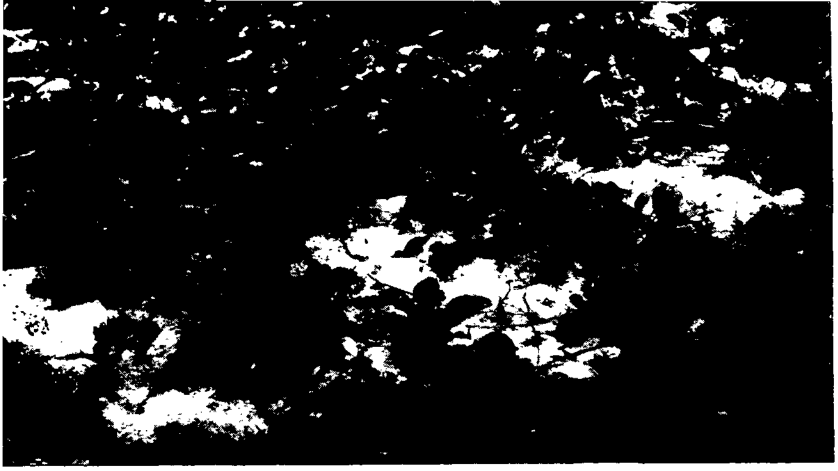
4c (bottom). Aerial photograph of part of the Eikwe savanna, showing pale soils and the irregular shape of the patch, with forest outside it (north is to the right)



5a (top). Swamp forest bordering the river Amansuri, west of Axim. The water is dark brown because of included organic matter.

5b. Swamp forest (mainly Raphia palms) with swamp regrowth forbs in the foreground

5c (bottom). Swamp forb regrowth, showing frequent *Cyrtosperma senegalense*



6a (top). Beach vegetation, showing *Canavalia obtusifola* and *Remirea maritima* colonising beach sand (Krisin series)

6b. A typical cocoa farm with good canopy, a few remaining shade trees (centre) and well developed leaf litter layer

6c. Coconut palms on dune sand immediately behind the beach. Salt spray can be seen in the middle distance. The ground vegetation includes *Sansevieria* sp. The soil is Fredericksburg series, a brown medium sand

7a (top). A young maize farm cleared on a too steep site where there is danger of soil erosion: a skeleton of the original forest remains

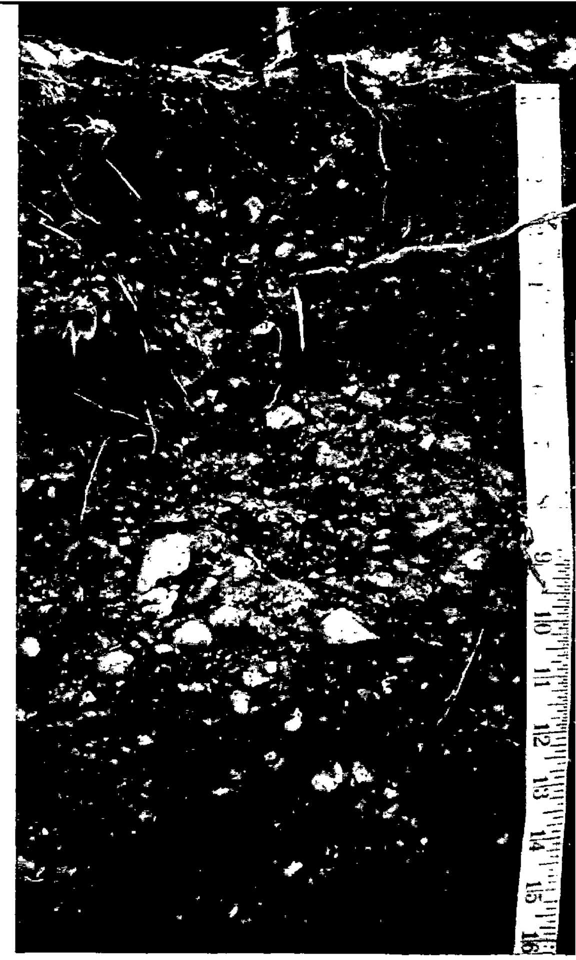
7b. Typical mixed plantain and cocoyam farm, with a young cocoa seedling in the left foreground

7c (below). Rice farm in flat, poorly drained, valley bottom Grass in background is *Pennisetum purpureum*. Within the basin, rice farms are commonest in the Asankrangwa area

8a (top left). Pit showing typical sedentary soil (Nzima series), with gravelly subsoil grading gradually into the weathered substratum. The pit is about five feet deep

8b (top right). Immature skeletal soil showing a thin topsoil grading directly into the weathered substratum containing frequent brash of schistose rock

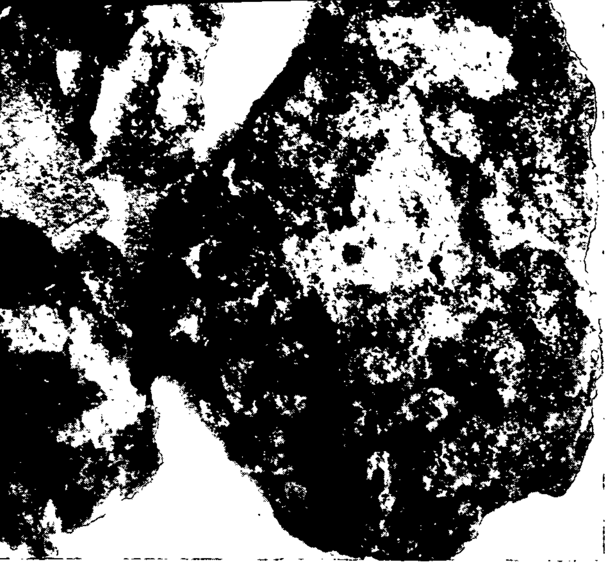
8c (bottom). View of Asankrangwa town with surrounding forest, mostly secondary, and with frequent farms. The two low flat-topped hills in the left and right background are remnants of the Akumadan surface



9a (top left). Close-up of a typical gravelly subsoil showing small quartz stones, quartz gravel, ironstone concretions and occasional roots

9b (top right). A similar photograph showing the first 16 inches of a gravelly sedentary soil. Only the top 2–3 inches are free of stones and gravel

9c (bottom). A pit dug in Atonsu series showing the highly gravelly subsoil with a sharp transition, at about 28 inches, into an indurated, mottled horizon. The ruler at top right is twelve inches long. There are no roots visible in the indurated layer.

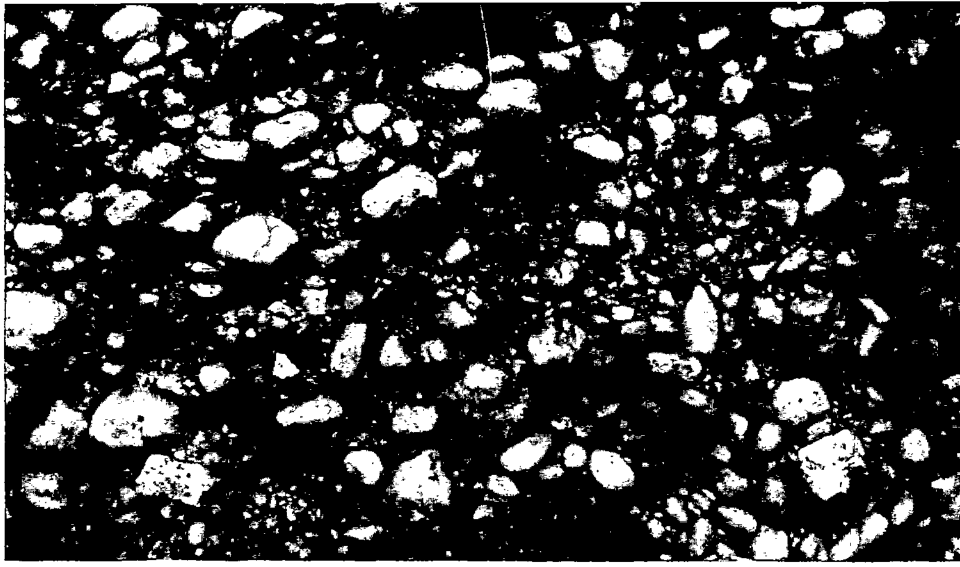


10a (top left). Coarsely mottled material showing soft, pale grey, kaolinitic patches and slightly hard reddish brown ones. This is the first stage in the process of induration

10b (top right). Fragments of fairly hard pan showing holes and vesicles

10c (centre). Moderately indurated material, between 10*a* and 10*b* in hardness, showing mottles and frequent irregular small holes and channels. This material is typical of the indurated horizons of such soils as Atonsu and Omappe series

10d (below). A boulder of ironpan. This completely indurated, rock-like material represents the final stage of induration. The boulder shown once formed part of a continuous sheet (note the flat upper surface); material of this type occurs in Nsuta series, a shallow soil consisting of gravel over ironpan, but ironpan sheets are more common in the forest zone north of the basin than within it



11a (top right). An alluvial soil (photographed at Samreboi) showing yellow-brown clay containing a well marked pebble bed

11b (top left). Close-up of a pebble bed showing sub-rounded quartz pebbles and gravel

11c (bottom). Atuabo series, a groundwater podsol: 30 inches of greyish white very fine sand overlie dark brown massive organic pan. The tape is five feet long. There is water in the bottom of the pit, impeded by the pan