AGL: SF/GHA 14
Technical Report 1

PILOT IRRIGATION DEVELOPMENT SCHEME, ASUTSUARE

GHANA

SOIL SURVEY

UNITED NATIONS DEVELOPMENT PROGRAMME

FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS ROME, 1971

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Report prepared for
the Government of Ghana
by
the Food and Agriculture Organization of the United Nations
acting as executing agency for
the United Nations Development Programme

based on the work of

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Senior Soil Surveyor

UNITED NATIONS DEVELOPMENT PROGRAMME

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ABSTRACT

The surveyed areas (surveyed at scale 1: 1 000) are situated in the northern part of the Accra Plains. The climate is characterized by a very uneven rainfall distribution variable in time and amount and generally giving rise to a long and a short dry season. The potential evapotranspiration is also high.

The major soils represented in the surveyed areas are the very gravelly soil (Nyigbenya) and claypan soil (Agawtaw) derived from highly weathered drift material, and soils developed on fluvial and local alluvium (Chichiwere, Hake, Amo, Tefle and Lupu), and generally characterized by a very variable texture and drainage. The selected areas for the auxiliary farms and the two pilot areas cover the most important soils not already represented by the University of Ghana Kpong Agriculture Irrigation Station and the Department of Irrigation Reclamation and Drainage Ashiaman Experiment Station. The acreages of the different soil mapping units are given in Table 3.

The mapping unit symbol indicates the kind of soil profile (Soil Series), the texture of the surface layer and any problem of wetness, slope and shallow depth.

Auxiliary farm No. 1 is representative of the soils developed on recent floodplain alluvium of the Volta River; Chichiwere, Hake and Amo are present in area 1, and Hake, Amo and Tefle in area 2. Auxiliary farm No. 2 is representative of soils developed on highly weathered drift materials; Agawtaw and Nyigbenya are represented in these.

Pilot Area A contains mostly soils developed on recent floodplain alluvium (Chichiwere, Hake, Amo, and Tefle), and to a smaller extent soils developed on old river terrace (Aveime and Zipa). Soils developed on highly weathered drift materials (Agawtaw) and on transported material derived from the black shrinking clays formed from basic rocks (Lupu), are also sparsely represented.

Pilot Area B contains soils developed directly or indirectly from basic rocks (Akuse, Prampram or Akuse shallow, and Ashiaman), soils developed on highly weathered drift materials (Agawtaw), soils developed on old river terrace (Zipa) and soils developed on recent floodplain alluvium derived from the adjoining black clays upland (Lupu).

The irrigation suitability land classification has been made according to the U.S. Bureau of Reclamation (1953) system based on the requirements for common arable upland crops; but these subclasses can be readily reinterpreted for other crops like pasture or wetland rice as can be seen in Table 5. The acreages under the different suitability classes and subclasses are given in Table 4.

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Chapter 1

INTRODUCTION

1.1 OBJECTIVES

The report covers work of the Senior Soil Surveyor from 15 April 1968 until 20 October 1969. Generally, the objectives were to direct, supervise and execute all work related to soil survey, including the examination of soil samples, the preparation of soil maps, and to advise on the selection of appropriate crops and the extension of the research station on representative soils. It was also required that the expert should advise on possible expansion of irrigation development on the Accra Plains and review generally existing soil information.

The focus of the report is the detailed survey carried out on the two areas demarcated for the two pilot schemes and the selection of two auxiliary trial farms, as well as a very detailed surveys of the areas selected for the development.

1.2 LOCATION AND EXTENT

The four surveyed areas lie in the northern part of the Accra Plains between parallels 5°59' N and 6°90' N and meridians 0°2' E and 0°18' E. The total of about 4 165 acres is made up as follows: auxiliary farm No. 1 474 acres; auxiliary farm No. 2 456 acres; pilot area A 1 656 acres and pilot area B 1 480 acres. (See Map No. 1)

1.3 GEOLOGY AND PARENT MATERIAL

The geology of the area surveyed is covered in a report by Junner and Bates (1945) and, in parts, by more recent systematic geological mapping (Geol. Surv. 1968). The Accra Plains are mainly covered by ancient igneous rocks of Archaeanage called Dahomeyan gneisses and schists. These form three broad bands running approximately north-south across the region. The western and eastern are acidic gneisses and are separated by a central band of basic gneiss. The two auxiliary farms lie within the central band of basic gneiss just east of the western band of acidic gneiss. The western part of pilot project block A lies in the central band of basic gneiss while the eastern part lies in the eastern band of acidic gneiss. The boundary between these two bands passes through Klebwenya and Kasunya. This indicates that the western part of pilot project block B is underlain by basic gneiss while the eastern part is underlain by acidic gneiss.

The basic gneiss consists almost entirely of garnetiferous hornblende gneiss. The acidic gneiss consists mainly of fine-grained muscovite-biotite schists and gneisses and contains few quartz veins.

In auxiliary farm No. 2, partially or fully decomposed bedrock is usually present within 6 feet (ft) but no rock outcrops are encountered. The rock is hornblende gneiss, often garnetiferous. Quartz veins and muscovite schists are also occasionally encountered.

On the higher ground (at auxiliary farm No. 1), hornblende gneiss, often garnetiferous, is observed in partially weathered bedrock within 6 ft from the surface, but not as rock outcrops. The lower areas are covered by a thick layer of recent alluvium brought in by the Volta and Okwe rivers.

In pilot area B, on the upper northern and southern slopes, decomposed hornblende gneisses and muscovite schists are found occasionally within 6 ft of the surface. No rock outcrops are encountered. The northwest slopes appear to be covered by old terrace deposits. The broad valley floor forming the main part of block B is covered by a thick layer of valley fill brought in by the flood waters from the adjoining uplands of Black Clays.

In pilot area A, rock outcrop or partially or even fully decomposed rock is not encountered. The covering appears to be a thick layer of alluvium brought in by the Volta River on the north and east and by flood waters from the high land of Black Clays to the west.

Even in the areas where partially or fully decomposed bedrock is encountered in a soil profile, the upper layer, usually 2 to 3 ft in thickness, is derived from material locally transported during peneplanation (strictly erosion surface formation). This drift material creates the smooth observable topography. The underlying material has a very irregular surface. The drift material in auxiliary farm no. 2 has a very high content of well developed, concretionary, laterite gravel as the base gravel layer. This indicates that the drift is highly weathered.

Calcium carbonate found in the region could become an important source for fertilizer. Between Amedica and Bator, along the Volta River, shell from the clam, used as food and tipped along the river banks as waste, accumulates at the rate of approximately 5 000 tons per year. In addition, old buried shell deposits washed onto the sandy bottoms of old river channels and buried under silt during periods of flooding are also known to exist at eight different locations. These have a total estimated volume of 230 000 cubic yards (yd^3) and can be recovered by open cast mining methods.

1.4 RELIEF AND SURFACE DRAINAGE

Three of the surveyed areas, auxiliary farm No. 1 and pilot areas A and B have a low elevation lying between 66 and 15 ft above mean sea level. The fourth area, auxiliary farm No. 2 has an elevation from 165 to 215 ft.

All the areas, however, have a very low elevation difference. The land is almost flat to very gently sloping, slopes being commonly less than 2 percent and in some areas less than 1/4 percent. Only in a few places are gradients of up to 4 percent encountered.

Surface runoff is slow or very slow in the surveyed areas. Soils in the Dahomeyan gneisses and some soils in the alluvium are very slowly or slowly impermeable and hence a very great proportion of the water leaves the area as surface runoff. Of the amount entering the ground a significant proportion flows laterally as seepage (in areas with a more permeable upper soil over the impervious layer), following every heavy rainfall, the whole ground surface may be covered with a slowly moving sheet of water. As it concentrates in the valleys extensive flooding occurs. Such floods are generally of short duration, usually one to three days. On the almost flat land, flood waters tend to remain on the surface for long periods extending into the dry season. When the project drainage channels are installed this problem will be eliminated.

1.5 CLIMATE

The climate data relevant to the Accra Plains are available from Akuse, Accra, Kpong and Osudoku. Only Akuse, Kpong and Osudoku are within the area circumscribing the four project areas and data from Kpong and especially Osudoku are limited in scope and duration or continuity.

1.5.1 Rainfall

The total mean annual rainfall increases from north to south, and in the four project areas situated in the northern part of the Accra Plains, the annual total is estimated to be about 40 to 50 inches. This however, varies considerably from year to year, At Kpong where the mean is 49.3 inches, the totals have ranged from 33.9 inches to 80.2 inches (Kpong, 1964-65; and unpublished meteorological records) and at Akuse where the mean is 44.0 inches, the totals have ranged from 24.7 inches to 77.2 inches (Walker, 1957; and unpublished meteorological records).

The rainy seasons on the average are from March to July and from September to November, with the monthly totals reaching their maximum in May and June and again in October. December, January and February and commonly August are very dry months. Very considerable variations exist between successive rainy seasons in time of onset, duration and amounts received. In some seasons, individual rainfalls are numerous and well distributed and in others scattered and infrequent. The great variability in monthly rainfall totals and also in yearly totals is due to these variations in the rainy seasons. It is not unusual for an entire month in a season customarily regarded as wet to be without significant amounts of rain. This is a feature of grave significance to the agricultural development of the country and has been a subject of detailed studies by the Ghana Meteorological Department.

A minimum monthly rainfall of 2.50 inches is considered as necessary for plant growth without irrigation, and for about 3 in 4 years, December, January and February, and August are dry. July and September are dry for about 2 out of 3 and 1 out of 3 years respectively. April, May and June are the wet months with a dry probability of about 1 out of 20 years. The other normally wet months, March, October and November have a higher probability of about 1 in 5 years. The frequency of values above 10 inches in May, June, October (and even July), August and September are important only on account of the danger of flooding. Supplementary irrigation and adequate drainage will be therefore necessary for the smooth agricultural development of the Accra Plains. In addition, the short harvest season cannot always be depended upon to allow adequate drying in the field, and artificial methods, even open drying sheds, will be necessary.

The diurnal pattern of rain and the accompanying wind velocities are also of agricultural significance. An analysis of the rainfall for the period 1947-51 for Accra clearly shows that, during the earlier part of the first rainy season (i.e. March to May) and during the later part of the second rainy season (i.e. November), squall type of rains associated with winds having velocities of over 25 m.p.h. and a dominant easterly component are more frequent. These rains often fall in the late afternoons and evenings and may give rise along their path to limited damage. During the later part of the first rainy season and the earlier part of the second, a monsoonal type of rain associated with a southwesterly wind having wind velocities of less than 25 m.p.h. is more frequent. These rains often fall in late night or pre-dawn time and any local damage is due to flooding. In the dry months of December, January, February and August, significant dominance of one kind of rain over the other cannot be determined due to low frequency.

1.5.2 Temperature

As is to be expected in a tropical area not too far from the coast, the mean temperatures are high with little variation from month to month. Thus at Akuse, the range in mean temperature is only 7°F; the mean temperature is highest (84°F) in February and March just before the onset of the rains and decreases gradually to the lowest value (78°F) in July and August which is a cloudy period under the influence of the south westerly cool winds. The monthly mean maximum temperature also follows the same pattern; the highest (95°F) and lowest (85°F) are reached in February-March and July-August respectively. The monthly mean minimum temperature, however, has a slightly different pattern. It is highest (74°F) in March and low from July to January, reaching the lowest value (70°F) in August and again in December. The diurnal variation changes from the highest value of 22°F in December, January and March to the lowest value of 15°F in July (unpublished meteorological records). The temperature pattern at Kpong is similar (Kpong, 1964-65).

1.5.3 Evaporation and Evapotranspiration

Annual evaporation from an extensive permanent open water surface, which should be approximately equal to potential evapotranspiration over a long period of time such as a year, may be taken as 5½ ft for the Accra Plains. This is intermediate between the values of 4½ ft for the forest areas and 6½ ft for the northern savannah (Walker, 1957a).

The actual evapotranspiration from most cultivated crops surface will not be as high as the calculated potential evapotranspiration or open water evaporation. Nevertheless to obtain the maximum yields with a crop like wetland rice, provision for irrigation to supplement the available water from the rains up to this amount will be necessary. At Kpong, the estimated requirement of water at field inlets for the supplementary irrigation on Akuse soils of the first (March-July) and the second (September-January) season rice crops, allowing an irrigation efficiency of 60 percent due to seepage losses is 38 and 48 inches respectively. This is in agreement with the actual use of 40 inches for a second season crop (Kpong, 1967-68). In addition to the data on rainfall and open pan evaporation, measurements or estimates of runoff and deep percolation losses are needed to make reasonable estimates of monthly irrigation requirements of the different soils for different crops.

Chapter 2

SOILS

2.1 GENERAL CHARACTERISTICS AND FACTORS CONSIDERED IN THE DETAILED AND VERY DETAILED SOIL SURVEYS

The four areas surveyed are representative of the more important soils found in the Accra Plains. Akuse soils, an important group in the region, are already well represented in the existing fields of the Agricultural Irrigation Research Station, Kpong (Brammer, 1955). The major soils covered in the four surveyed areas are Lupu, Tefle, Amo, Hake, Chichiwere, Agawtaw and Nyigbenya. These represent two important groups - those on highly weathered drift materials and those on alluvium from the Volta River and from streams of the Black Clays upland. Small areas of Avieme, Zipa, Akuse, and related soils are also included. Table 1 gives the acreages of the Soil Series in the Accra Plains as estimated by Kaiser Engineers and Constructors Inc. (1964) and the actual acreages in each of the four surveyed areas in the present project.

Table 1

ACREAGES OF THE SOIL SERIES IN THE ACCRA PLAINS AND WITHIN THE SURVEYED AREAS

Soil Series	Accra Plains	Pilot Area A	Pilot Area B	Auxiliary Farm No. 1	Selected Area 1 Auxiliary Farm No.1	Selected Area 2 Auxiliary Farm No.1	Auxiliary Farm No. 2	Selected Area Auxiliary Farm No.2
Akuse	141 200	–	125	11	–	–	–	–
Prampram	22 900	–	26	11	–	–	–	–
Ashiaman	300	–	47	–	–	–	–	–
Bundase	100	–	–	12	–	–	–	–
Lupu	7 200	16	764	–	–	–	–	–
Minya	1 400	–	–	–	–	–	} 343	} 58.6
Agawtaw	177 900	4	237	4	–	–		
Nyigbenya	22 600	–	–	–	–	–	113	15.5
Aveime	5 200	7	–	–	–	–	–	–
Zipa	5 900	74	43	–	–	–	–	–
Chichiwere	2 300	11	–	64	8.9	1.4	–	–
Hake	29 300	289	–	161	24.8	13.3	–	–
Amo	13 000	1 081	4	208	6.2	10.0	–	–
Tefle	14 000	174	234	3	–	10.6	–	–
Total	443 300	1 656	1 480	474	39.9	35.3	456	74.1

Considering only soils occupying an extent greater than 100 acres, those with a potential for development that have not been included in the pilot areas or the auxiliary farms are (in acres):

Alajo	800	Oyarifa	20 300
Beraku	5 400	Papao	9 900
Bumbi	22 600	Simpa	52 000
Chum	700	Tachem	8 100
Dome	1 700	Tepanya	200
Hacho	16 100	Toje	66 000
Kenya	7 600		
Koloidaw	12 100	Total	237 800
Krabo	14 300		

The remainder are found on slopes too steep (greater than 5 percent), too stony, shallow, or coarse textured, or occurring in areas liable to flooding, salinity, or as unstable sands.

These soils (in acres) are:

Fete	3 100	Osudoku	100
Salom	700	Danfa	400
Korle	18 400	Mamfe	11 500
Koni	700	Muni	3 000
Kenya	7 600	Keta	9 400
Agbozome	6 700	Ada	31 400
Doyum	13 800	Mepe	2 000
Oyibi	33 000		
		Total	141 800

Thus, the major soils of the Accra Plains not represented here are mostly dominant in the extreme south or west of the region or are those whose irrigation feasibility has been rated low (Kaiser Engineers and Constructors Inc., 1964). An important exception is the Simpa Series. Auxiliary Farm No. 2 was located using the soil map of the Accra Plains (Brammer, 1967) to include them but subsequent correlation with the Simpa soils in the southern part of the Accra Plains revealed that the Agawtaw - Simpa complex on the map is really Agawtaw-Nyigbenya complex. The Nyigbenya soil is similar to Simpa in drainage and in being formed on highly weathered drift material. The only difference is that the gravels in Nyigbenya are laterite concretions with a few quartz cobbles while in the Simpa the gravels are ferruginized and unferruginized quartz gravel and cobbles. The other soils, Bumbi and Tachem though not covered by the surveyed area are transitional between Akuse and Lupu, Zipa and Tefle respectively. Thus their potential can be later evaluated from experience on these four soils.

In the systematic soil surveys undertaken, the main objectives have been the recognition and evaluation of the relevant physical characteristics of soil topography and drainage for irrigation suitability. All areas have been already covered by a reconnaissance survey at 1:125 000 (Brammer, 1967). In addition, three of the areas, namely auxiliary farm No. 1 and pilot areas A and B were covered by detailed soil surveys at a scale of 1:16 000 and published at 1:32 000 in the Report of the Survey of the Lower Volta River Floodplains (FAO, 1963). The present soil survey has been able to benefit from these and other published reports (Brammer, 1955, Kaiser Engineers and Constructors Inc. 1964; Nippon Koei. Co. Ltd., 1965).

Table 2

INTENSITY OF SAMPLING AND PROBLEMS ENCOUNTERED

Area	Pilot Area A	Pilot Area B	Auxiliary Farm No.1	Auxiliary Farm No.2	Selected Area 1 in Auxiliary Farm No.1	Selected Area 2 in Auxiliary Farm No.1	Selected Area in Auxiliary Farm No.2
Acreage	1 656	1 480	474	456	39.9	35.3	74.1
Map Scale	1:5 000	1:5 000	1:5 000	1:1 000	1:1 000	1:1 000	1:1 000
Traverse line interval (in ft)	200	200	250	400 & 200	62½	62½	50
Sampling interval on traverse lines (in ft)	200 or 100	100 or 200	50 or 100	50 or 100	50	50	50
Special diffi-culties encount-ered	Variable texture and drainage	None	Very variable texture and drainage	Very complex soil pattern due to very variable depth to gravel	Very variable texture and drainage	Very variable texture and drainage	Very complex soil pattern due to very variable depth to gravel

The surveys for the maps on the scale 1:5 000 were conducted at a detailed level using traverse lines out at 200 ft to 400 ft apart, and, depending on the complexity of the area, augur samplings were made at intervals of 50 ft to 200 ft along the traverse. For the maps on the scale 1:1 000, the surveys were conducted at a very detailed level by auguring every 50 ft along traverse lines 50 or 62½ ft apart (Table 2). The soil pattern is very complex in three of the four surveyed areas, namely the two auxiliary farms and pilot area A. The air photographs available were at a scale of 1:16 000 and hence were not suitable for soil survey at the scales 1:5 000 and 1:1 000.

Pilot area A and the major part of auxiliary farm No. 1 form parts of an alluvial floodplain in which the former courses of the river or its overflow channels can still be seen in the form of long, linear or curved depressions usually under permanent but shallow water, erroneously called lagoons in the maps of the region. The surface drainage pattern though involving relief of only a few feet is very irregular.

Texture varies rapidly both areally and with depth in a random manner, especially in the alluvial parts of auxiliary farm No. 1. There at the confluence of Okwe and Volta Rivers the land has undergone much deposition, possible reworking and even human disturbance, during the last few hundred years. The relief of the two areas, though macroscopically that of a floodplain, is very uneven on detailed examination, showing differences of elevation of a few feet in a random manner. This variability, like that of texture, is also more pronounced in auxiliary farm No. 1. Due to variations in texture and relief, the soil drainage also varies rapidly giving a complex distribution pattern.

In the survey and classification of soils of the alluvial areas of auxiliary farm No. 1 and pilot area A, the chief criteria have been dominant texture of the profile, presence or absence of stratified layers of markedly coarser or finer materials, texture of the surface layer, permeability (as inferred from texture, structure and porosity), and finally soil drainage class(as inferred purely from the matrix and mottle colours in conjunction with texture). In determining soil drainage class, yellower hues and low chromas giving gray colours are considered to be signs of impeded drainage. The dominance of these colours as matrix colour or their pattern and frequency as mottles, have been used to differentiate between imperfectly, poorly and very poorly drained soil classes. The presence of strong red mottles in a yellow or gray matrix is considered as an indication of a rapidly receding water table while the absence of such contrasting mottles in a yellow or gray matrix is considered as an indication of a slowly receding water table and prolonged periods of saturation.

A good correlation between soil drainage class and texture was expected from earlier reports to give well drained to moderately well drained sandy soils (Chichiwere Series) on the levees, moderately well drained to imperfectly drained light sandy clay loams (Hake Series) on the upper slopes, imperfectly drained to poorly drained heavy clay loams (Amo Series) on the lower slopes, and very poorly drained clays (Tefle Series) in the depressions. Nevertheless, detailed observations indicated that in the surveyed alluvial areas especially of auxiliary farm No.1, a wide range of soil drainage classes are associated with the textures corresponding to Chichiwere, Hake and even Amo.

In the very detailed soil survey at 1:1 000, the various dominant ranges in drainage within textures corresponding to Chichiwere, Hake, Amo and a stratified variant of Hake, have been mapped.

Auxiliary farm No. 2 has a gently sloping, smooth topography in marked contrast to the complex soil distribution pattern found there. The pattern of the two soils, a deep gravel-free clayey hardpan soil (Agawtaw Series) and a shallow, friable soil over a very gravelly subsoil (Nyigbenya Variant), is governed by the random manner in which the depth of the gravel layer below the ground surface varies areally, even though the ground surface is absolutely uniform.

The criteria used in surveying this area have been the presence or absence of a clayey hardpan and/or a very gravelly layer consisting of laterite concretions and/or quartz cobbles, the depth at which these layers are encountered and the texture and thickness of the dark surface horizon. For the map on the scale of 1:5 000, the intensity of sampling and the map scale did not allow for all the practically significant features to be shown. But in the very detailed map on the scale of 1:1 000, the depth phases of both Nyigbenya Variant and Agawtaw Series and two related soils have been mapped.

Pilot area B has been the only area with a simple distribution of soils having a high degree of correlation with the observable topography. The flat valley bottoms have been formed largely by locally transported valley fills and have a uniform texture and drainage. The soils on the relatively higher ground are developed on soil parent material derived from basic rocks (Akuse and related soils), soil parent material of highly weathered drift material (Agawtaw Series), and old river terraces (Zipa Series). Thus though a wider range of soils are encountered, they are readily mappable.

2.2 SOIL CLASSIFICATION

The soils encountered in the project areas can be broadly divided into four groups as follows:

i) those developed by weathering in place of basic rocks like garnetiferous hornblende gneiss similar to the underlying rock, or developed from drift material associated with peneplanation or erosion surface formation and presumably derived from similar rocks (black, shrinking clays, very sticky when wet and very cloddy when dry);

ii) soils developed on highly weathered drift material associated with peneplanation or erosion surface formation and presumably derived from a laterite crust and associated acid gneisses similar to the underlying bedrock. These occur usually as an association or sometimes as a complex of deep gravel-free claypan soils and thick, very gravelly soils;

iii) soils developed on old, river terrace alluvium. These are imperfectly drained to well drained clays and sandy clay loams;

iv) soils developed on recent alluvium of the Volta River system and varying in drainage from excessively drained to very poorly drained and in texture from sands to very heavy clays.

The Soil Series nomenclature used by the Soil Research Institute of the Council for Scientific and Industrial Research of Ghana has been used for the soils mapped in this survey. Where necessary, descriptive phrases have been added to the series name to indicate either a narrower range of property or a feature not fully recognized in the original series description.

The basis of soil classification has been the observable properties of the soil in a soil profile, though, as far as possible morphological properties have been interpreted in terms of genetic concepts. The standards and terms used in describing the soils are those defined in the FAO Guidelines for Soil Description and in the Soil Survey Manual of the United States Department of Agriculture (Handbook No. 18, 1951).

Brief description of the Soil Series are given in the section on soil mapping units. Each Soil Series description is followed by a definition of the corresponding soil mapping units. Prominent inclusions of other Soil Series and Variants are mentioned.

2.3 SOIL MAPPING LEGEND

The symbols used to represent the mapping units are based on a combination of a letter and two-digit number (e.g. M20). The letter shows the dominant surface texture, the first digit of the number indicates the broad group based on parent material to which the soil belongs and the second digit indicates the specific Soil Series (e.g. in 42, the first digit 4 indicates the group of soils developed on recent alluvium and the second digit 2 indicates the series Hake).

Where limitations in depth of soil due to either bedrock, gravel layer or claypan occur, the degree of limitation is indicated by a number placed in front of the letter. Soils on slopes of 2 to 5 percent are shown by the letter B placed after the soil number. Degrees of wetness are indicated by symbols W1, W2 and W3 also placed after the soil number. As this did not occur on sloping land, there was no necessity to use both symbols for any given soil.

The mapping legend and system of mapping unit symbols have been based, as far as possible, on the system used in Soil Survey and Classification, Volume II of the Report on Survey of the Lower Volta River Floodplain (FAO, 1963). This has been done to make easier the correlation between the present areas studied and all areas covered by soil maps in the report just mentioned. Since depth to a limiting horizon, texture of the plow layer, slope and degree of wetness are the chief factors within a Soil Series influencing the suitability for irrigated agriculture, this system is quite satisfactory.

2.3.1 Texture Symbols

C – coarse texture; sand and loamy sand;
L – light texture; sandy loam and fine sandy loam;
M – medium texture: very fine sandy loam, loa, silt loam;
H – heavy texture: clay loam, sandy clay loam, silty clay loam;
V – very heavy texture: sandy clay, silty clay, clay.

Dominant texture of the A horizon which is commonly about 6 to 8 inches thick is considered here.

2.3.2 Soil Series

Soils from garnetiferous hornblende gneiss and other basic rocks:

10 Akuse Series (includes 1V10, Prampram which is basically a shallow phase of Akuse Series).

11 Ashiaman Series.
12 Bundase Series.
15 Lupu Series.

Soils from acidic gneiss:

20 Agawtaw Series (includes 2V20, Pejeglo which is basically a shallow phase of Agawtaw Series).

25 Nyigbenya Series, imperfectly drained variant.

Soils from old river terrace alluvium:

30 Avieme Series.
32 Zipa Series.

Soils from recent alluvium:

40 Chichiwere Series.
42 Hake Series.
43 Amo Series.
45 Tefle Series.

2.3.3 Soil Depth

If the soil had a gravelly layer or a claypan horizon or decomposing or fresh bedrock limiting root development or moisture holding capacity, its depth is shown as a number placed in front of the texture symbol:

no number	–	depth greater than 16 inches for gravelly layer or claypan and greater than 30 inches for bedrock;
1	–	depth between 8 inches and 16 inches for gravelly layer or claypan and between 12 inches and 30 inches for bedrock;
2	–	depth less than 8 inches for gravelly layer or claypan and less than 12 inches for bedrock.

2.3.4 Slope

no symbol	–	slopes between 0 and 2 percent;
B	–	slopes between 2 and 5 percent.

2.3.5 Wetness

Estimated relative wetness (i.e. high ground water table or a perched water table or prolonged saturation or a slowly receding flood in the rainy season) expected after construction of flood protection dikes and drainage channels.

W1	–	slight problem;
W2	–	moderate problem;
W3	–	severe problem.

2.4 SOIL MAPPING UNITS USED IN THE SURVEY AT SCALE 1:5 000

2.4.1 Soils Derived Directly or Indirectly From Basic Gneisses

10. Akuse Series (Deep, black, imperfectly drained, very sticky, heavy, shrinking clays, calcareous at moderate depth.)

The surface soil is a thick, very dark gray or black, heavy, very plastic, very sticky and neutral to slightly acid clay. Horizon differentiation is very weak and the subsoil is a dark gray or very dark grayish brown,moderately alkaline clay. Moderate amounts of small, black hard, manganese - rich nodules and small, hard, black or red, shiny laterite nodules are scattered throughout the subsoil. Coarse, white, hard, calcareous nodules are concentrated in lenticular patches in the lower subsoil. Weathered bedrock material with a sandy loam texture occurs commonly below a depth of 48 inches. The soil cracks vertically from the surface to a depth of 36 inches or more in the dry season. It is very hard, cloudy and compact when dry, and very sticky, plastic and heavy, when wet. In the uncultivated natural conditions Akuse soils quickly absorb water from the first rains at the end of the long dry season until the cracks close up. Once almost saturated they are impervious and lose as runoff much of the water that falls in the subsequent rains of the wet season. These can be regarded as having medium external drainage (surface runoff) and very slow internal drainage when wet.

Mapping Unit V 10 W1 — Akuse Series, on almost flat (o-2%) upper slopes and summits of the upland, and with a slight wetness and soil management problem. Land class 2sd.

Mapping Unit 1V 10B — Akuse Series, moderately shallow (12in-30in) to bedrock (also called Prampram subseries but strictly Akuse Series), shallow phase, and occurring on upper gentle slopes (2-3%). Land class 2st.

11. Ashiaman Series — Deep, very dark grayish brown, imperfectly to moderately well drained, very sticky, heavy, shrinking silty clay or clay changing to a dark brown, dense, calcareous clay with depth.

These soils are similar to the Akuse Series in all the properties except for the subsoil colour.

Mapping Unit V11 W1 — Ashiaman Series on almost flat (0-2%) upper slopes and summits of the upland and with a slight wetness and soil management problem. Land class 2sd.

12. Bundase Series (Reddish brown moderately well drained clays).

The surface horizon is a thick dark brown, friable light clay. The subsoil is a dark reddish brown clay. Highly weathered rock is encountered within 2 or 3 ft from the surface. The soil is very plastic and sticky when wet and very hard and cloudy when dry. These soils have good external drainage (surface runoff) and medium internal drainage.

Mapping Unit IV 10 B – 1H 12 B

Bundase Series and Akuse, shallow phase on gentle slopes (2–5%). Land class 2st.

15. Lupu Series

(Deep, black very poorly drained, very sticky, heavy shrinking clays commonly calcareous with depth.)

The surface soil is a thick, very dark gray or black, heavy very plastic, very sticky and neutral to slightly acid silty clay or clay. The horizon differentiation is weak and the subsoil a very dark grayish brown, slight mottled brownish yellow moderately alkaline to neutral, dense clay like to surface soil in consistence. Moderate amounts of small, black hard, manganese – rich nodules and commonly few, small, white, hard, calcareous nodules are scattered throughout the lower subsoil. The soil cracks vertically from the surface to a depth of 36 inches or more in the dry season. Slickensides giving to angular clods are common in the subsoil. The subsoil does not appear to dry out completely even though vertical cracks and slickensides give rise to a cloddy structure toward the end of the long dry season. The surface is very hard, cloddy and compact when dry, and very sticky, plastic and heavy when wet. In the uncultivated natural state the Lupu soils quickly absorb water from the first rains and the surface runoff from the adjoining upland at the end of the long dry season until the cracks close up. Once almost saturated with moisture they become impervious. Much of the water that falls and the large volume of surface runoff to which they are subjected during the subsequent rains of the wet season remain in the surface for prolonged periods only moving out very slowly as surface flow. These soils have very slow external (surface runoff) and internal drainage.

Mapping Unit V15 W3

Lupu Series, on flat or almost flat terrain (less than 1/4 percent slope), and having a moderate to severe drainage problem. Land class 4sd.

2.4.2 Soils Developed on Highly Weathered Materials

20. Agawtaw Series

(Olive brown, imperfectly drained clay loam soils with an essentially impermeable, compact, clayey hardpan.)

The surface soil is a very dark grayish brown or very dark gray, friable, neutral to slightly acid, sandy clay loam, commonly about 6 to 8 inches thick. This is separated by an olive brown, hard, firm, prismatic or angular blocky, sandy clay loam horizon from the underlying compact, clayey hardpan. The hardpan has an abrupt upper boundary and is encountered at a depth commonly varying from 8 inches to 16 inches from the surface. The hardpan itself is about 9 to 15 inches thick, and is an olive gray to gray, gritty clay loam or clay. It is massive, very firm and, when dry, cracks vertically into extremely hard, very large, six-sided blocks. This horizon, even as fragmented clods, absorbs water very slowly. The lower boundary of the hardpan is gradual and the hardpan is also relatively less hard with depth. White calcium-rich nodules and black, manganese-rich, fine, round concretions are common in the lower part of the hardpan in the immediately underlying horizon.

Commonly, a distinct gravelly layer or stone line composed of reddish brown, round, concretionary laterite gravel and/or angular quartz stones in a clayey matrix separates the horizons presumably formed on drift material from the underlying horizon which is a friable, subangular or angular blocky clay formed from rock weathered in place. Highly weathered saprolite followed by decomposing acid gneiss occurs at a depth of 4 to 6 ft or even deeper.

The Agawtaw soils occur on flat to almost flat (0-2%) terrain having a concave aspect often serving as broad valleys. They are generally waterlogged for a few days following each heavy rainfall due to the large amount of runoff received from the uplands, the slow flow of this water and the nearly impermeable clayey hardpan in the subsoil.

In some places, usually in the lower areas, the gravelly layer or stone line comes nearer the surface and is incorporated in the clayey hardpan. When the gravel layer is thick and the gravel content high, the Agawtaw soil intergrades in character to the Nyigbenya Series, imperfectly drained variant, with which it occurs intimately mixed in the broad transition zone on the upper slopes between the summits and the broad valleys. This intergrade known as Minya Series, is however, not separately mapped at 1:5 000 since it occurs in very small patches and randomly in relation to any observable feature like slope value, slope aspect or position on the slope. The Nyigbenya Series, imperfectly drained variant (described under soil Mapping Unit L25) also occurs within the Agawtaw Series especially on the upper slopes as numerous, very small, isolated patches and randomly in relation to any observable feature. The change from a typical Agawtaw soil to a typical Nyigbenya, imperfectly drained variant, sometimes takes place within 3 ft.

Also included in the mapping unit is a thick, dark surface horizon variant of Agawtaw. The very dark gray surfaced horizon is about 16 inches thick and the hardpan which is commonly about 24 inches below the surface is not massive and breaks into weak, coarse, angular blocks. This soil may be regarded as an intergrade to Akuse Series (described under soil Mapping Unit V10).

Mapping Unit M20 W1-2M20 W1	Agawtaw Series on almost flat (0-2%) slopes with a concave aspect, and with a slight wetness problem. <u>Land class 3sd</u>.
Mapping Unit V20 W1	Agawtaw Series like M20 W1 but with a sandy clay or clay surface horizon. <u>Land class 3sd</u>.

<u>25. Nyigbenya Series, Imperfectly Drained Variant</u>

(Reddish brown, mottled, imperfectly drained soils with a thick, very gravelly subsoil, the gravel being mostly hard, round well developed, laterite concretions and occasional angular quartz.)

The surface gravel-free horizon is a thin, very dark grayish brown friable, very fine sandy loam or light sandy clay loam. The very gravelly sandy clay may have a dark grayish brown, friable upper part it it comes within 10 inches of the surface. The very gravelly subsoil is a slowly permeable, reddish brown layer mottled yellowish brown or light brownish gray. It is very compact and hard in places but large detached clods are friable. The gravel is mostly hard, round, well developed, medium and fine laterite concretions and occasional coarse, angular quartz embedded in a clayey matrix. The gravel content commonly is greater than 70 percent by volume of this very gravelly layer. The total thickness of the very gravelly layer commonly exceeds 36 inches. This layer gradually changes with depth into a friable gravel-free, clayey layer mottled red, yellow and gray, and overlying highly weathered acid gneiss or garnetiferous hornblende gneiss.

These soils are very similar to Nyigbenya Series, but are imperfectly drained on account of the slow runoff on the gentle slopes and the poor internal drainage of the very gravelly layer. They are also similar to Simpa Series which is an imperfectly drained, very gravelly soil differing through being coarse angular quartz. The very gravelly laterite layer, in places is exposed at the surface and commonly there, has become cemented. This gives rise to a hard laterite sheet. The Nyigbenya Series, imperfectly drained variant occurs almost exclusively on the summits of the ridge. On the middle slopes it is intimately mixed with the Agawtaw Series. In places where the shallow, thick, very gravelly layer increases in depth or decreases in thickness, there is commonly a development of a compact clayey horizon giving rise to intergrades of the Agawtaw Series. But equally commonly the subsoil above the deep gravelly layer is a yellowish brown, friable, sandy clay loam and these soils are considered as a thick, gravel-free phase of the Nyigbenya variant. Since the depth and thickness of the gravelly layer or stone line change very rapidly and randomly in relation to the observable topographic features, it is only possible to map some areas as a complex of Nyigbenya, imperfectly drained variant and Agawtaw.

Mapping Unit L25 - 2L25 — Nyigbenya Series, imperfectly drained variant. The gravel-free surface layer over the thick very gravelly layer is commonly between 8 inches and 16 inches thick. The soil occurs on the middle and upper slopes and summits of almost flat land (0-2%) slopes with a convex aspect. Land class 3s-4s.

Mapping Unit M20 W1 - 1L25 — Nyigbenya, imperfectly drained variant Agawtaw complex. The clayey hardpan of the Agawtaw soil in this unit commonly has a high content of laterite gravel and the gravel-free surface layer of the Nyigbenya Variant has a very variable thickness, ranging from about 8 inches to more than 16 inches. This unit, like L25-2L25, occurs on the middle and upper slopes of almost flat land (0-2%) slopes with a convex aspect. Land class 3s-3sd.

2.4.3 Soils Developed on Old River Terrace Alluvium

30. Aveime Series

(Very deep, moderately permeable, well drained, red, porous, friable, fine sandy loams.)

The surface soil is a thick, very dark grayish brown to dark reddish brown, porous, friable fine sandy loam. It changes with depth into a dark red to red, slightly hard, porous, light sandy clay loam subsoil. The soils are neutral to slightly acid. There is a good distribution of roots to a depth of about 5 ft. Lenses of oyster shells are commonly encountered in the subsoil.

These soils occur on the gently sloping old terrace remnants distinctly above the present floodplain.

Mapping Unit L30	Aveime Series, on gentle slopes (0-2%). Land class 1.

32. Zipa Series (Deep, moderately well drained soil with a compact, strongly mottled red, yellow and gray clayey subsoil.)

The surface soil is a dark grayish brown, porous loam, hard when dry and friable when moist. The subsoil which has a strong, coarse prismatic structure breaking down into coarse angular blocks, is a brownish gray horizon with many, coarse, prominent, red or dark red mottles. It is dense with very few pores and has a sandy clay or clay texture. Roots are very largely confined to the dark surface layer.

The Zipa soils have a dense, slowly permeable subsoil and hence the internal soil drainage is poor to medium.

Mapping Unit M32B	Zipa Series, on almost flat (1-2%) and gentle slopes (2-4%). Land class 2t.
Mapping Unit V 32 W1	Zipa Series on almost flat (1-2%) slopes and having a clayey surface soil. These soils have a slight wetness problem. Land class 2d.

2.4.4 Soils Developed on Recent Floodplain Alluvium

40. Chichiwere Series (Deep, pale brown or yellow, loose, sandy soils.)

The surface soil is a dark brown, loose sand or sandy loam held together by many fibrous roots. This gradually changes into a pale brown or yellow loose sand with a very fine sandy loam. Commonly a heavier textured layer may be encountered abruptly below a depth of 24 inches. The soils are moderately to rapidly permeable and neutral to strongly acid. Drainage varies with topographic position from well drained in their type location along the levees of the Volta River, to poorly drained in low lying positions.

Mapping Unit L40	Chichiwere Series, on almost flat (0-2%) summits of old levees. Land class 2s.
Mapping Unit L40 W1	Chichiwere Series, on the almost flat (0-1%) floodplain behind the levees. They usually have a slight wetness problem, due to a seasonally high water table and slow runoff. Land class 2sd.

42. Hake Series	(Deep, brownish yellow, friable, imperfectly drained, moderately permeable sandy clay loams.)

The surface soil is a thin, loose, very dark grayish brown, neutral to moderately acid, light sandy clay loam or silt loam. This is followed by a gradual transition to a friable, very acid, sandy clay loam, or silty clay loam subsoil, mottled dark gray or gray in a brownish yellow matrix colour.

The Hake soils are typically imperfectly drained, though poorly drained and moderately well drained phases are also common.

Sandy layers are commonly encountered within a depth of 6 ft but below 3 ft. In some places a slowly impermeable compact subsoil is present at a depth of about 2 ft giving rise to a perched water table. Neither of these variations appear to be uniformly extensive or predictable. Thus they are not readily mappable.

Hake soils with a thick, loamy surface soils and upper subsoil are present in some areas and these are mapped as Hake, a light textured variant.

Mapping Unit M42	Hake Series, moderately well drained phase on almost flat (0-2%) slopes. Land class 1.
Mapping Unit M42 W1	Hake Series, imperfectly drained phase, on almost flat (0-2%) land and having a slight wetness problem due to slow runoff and seasonally high water table. Land class 2d.
Mapping Unit L42	Hake Series, light textured variant, on almost flat (0-2%) slopes. Land class 1.
Mapping Unit L42 W1	Hake Series, light textured variant, on almost flat (0-2%) slopes and having a slight wetness problem due to seasonally high water table and flooding. Land class 2d.
Mapping Unit L42 B	Hake Series, light textured variant, on gentle (2-4%) slopes. Land class 2t.
Mapping Unit L40 - M42	Complex of Hake Series, moderately well drained phase and Chichiwere Series on almost flat (0-2%) slopes. Land class 1-2S.

43. Amo Series	(Deep, brownish yellow, firm, poorly drained clays and silty clays.)

The surface soil is a very dark grayish brown, friable, light silty clay or silty clay loam. In the subsoil, there commonly occurs at a depth of about 2 ft a dense, extremely hard, silty clay or clay horizon with an abrupt upper boundary. The soil horizon immediately above this dense clayey horizon is a white or gray, porous, silty clay loam developed in the zone of a laterally moving perched water table. The dense clayey horizon is light grayish brown with prominent red or strong brown mottles and has a strong, very coarse, prismatic structure. This is underlain by a light brownish gray, very firm, angular blocky, silty clay. The soils are slightly to strongly acid.

Amo soils are typically poorly drained, though an imperfectly drained phase is also encountered. Surface runoff is slow and permeability is also slow. A seasonally high fluctuating groundwater table is common.

Stratification with light textured layers is not common in Amo soils. Amo soils with a silty clay or clay surface layer over a heavy clay subsoil are common. They are mapped as Amo, a heavy textured variant.

Mapping Unit M43 W1 — Amo Series, imperfectly drained phase, on almost flat (0–1%) slopes. These soils have a slight wetness problem. Land class 2d.

Mapping Unit M43 W2 — Amo Series, poorly drained phase, on almost flat (0–1%) slopes. These soils have a moderate wetness problem. Land class 3d.

Mapping Unit H43 W2 — Amo Series, heavy textured variant, on almost flat (0–1%) slopes. These soils have a moderate wetness problem like M43 W2. Land class 3d.

45. Tefle Series

(Deep, gray, mottled, very poorly drained, heavy clays).

The surface soil is a very dark gray, heavy clay, friable when dry during the end of the long dry season. The subsoil which appears to be always moist is a very dark gray, very firm clay, mottled yellowish red along the vertical root channels. It has a strong, very coarse, prismatic structure extending to a depth of about 16 inches. The underlying layer is a gray clay mottled strong brown and having a strong or moderate angular or subangular blocky structure with prominent slickensides. The soils are slightly to strongly acid. Roots are very dense in the surface horizon and common in the upper soil, while in the lower subsoil they are few and tend to be concentrated along the slickensides.

The Tefle soils have a very slow permeability, a seasonally high water table, very slow outflow by surface runoff, and flooding by a large volume of surface runoff flowing from adjoining uplands.

Mapping Unit V45 – W3 — Tefle Series, on flat valley bottoms, depressions, and the lower end of very gentle slopes (less than 1/4%) and having a severe wetness problem. Land class 4d.

Table 3

DESCRIPTION OF SOIL MAPPING UNITS (IN ACRES)

Soil Series & Mapping Units Symbol	Pilot Area A	Pilot Area B	Auxiliary Farm No. 1	Selected Area 1 Auxiliary Farm No.1	Selected Area 2 Auxiliary Farm No.2	Auxiliary Farm No. 2	Selected Area Auxiliary Farm No.2
Akuse Series							
V10W1	-	125	11	-	-	-	-
Prampram (Akuse shallow) 1V10B	-	26	-	-	-	-	-
Prampram & Bundase Series							
1V10B - 1H12B	-	-	23	-	-	-	-
Ashiaman Series							
V11W1	-	47					
Lupu Series							
V15W3	16	764	-	-	-	-	-
Agawtaw Series							
M20W1-2M20W1	3	237	-	-	-	296	-
M20W1	-	-	-	-	-	-	16.6
1M20W1	-	-	-	-	-	-	36.7
2M20W1	-	-	-	-	-	-	0.4
V20W1	-	-	4	-	-	-	-
M21W1	-	-	-	-	-	-	0.7
M24W1	-	-	-	-	-	-	4.2
Agawtaw & Nyigbenya Series							
1M20W1-1L25	-	-	-	-	-	94	-
Nyigbenya Series							
1L25-2L25	-	-	-	-	-	66	-
L25	-	-	-	-	-	-	0.4
1L25	-	-	-	-	-	-	8.1
2L25	-	-	-	-	-	-	7.0
Aveime Series							
L30	7	-	-	-	-	-	-
Zipa Series							
M32B	74	21	-	-	-	-	-
V32W1	-	22	-	-	-	-	-
Chichiwere Series							
L40	11	-	38	4.1	1.4	-	-
L40W1	-	-	6	3.4		-	-
L40W2	-	-	-	0.9		-	-

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Table 3 (Cont'd)

Soil Series & Mapping Units Symbol	Pilot Area A	Pilot Area B	Auxiliary Farm No. 1	Selected Area 1 Auxiliary Farm No.1	Selected Area 2 Auxiliary Farm No.2	Auxiliary Farm No. 2	Selected Area Auxiliary Farm No.2
Chichiwere & Hake Series							
L40–M42	–	–	39			–	–
Hake Series							
M41	–	–	–	1.1	1.4	–	–
M41W1	–	–	–	2.5	0.6	–	–
M41W2				2.4			
L42	6	–	–	0.2	–	–	–
L42W1	4	–	–	0.3	–	–	–
L42B	22	–	10	–	–	–	–
M42	8	–	30	8.5	1.5	–	–
M42W1	249	–	102	8.3	9.8	–	–
M42W2	–	–	–	1.3	–	–	–
Amo Series							
M43	–	–	–	3.6	–	–	–
M43W1	19	4	47	2.8	7.6	–	–
M43W2	234	–	63	–	2.1	–	–
H43	–	–	–	–	–	–	–
H43W1	–	–	–	–	–	–	–
H43W2	828	–	98	0.2	0.3	–	–
Tefle Series							
V45W3	174	234	3	–	3.8	–	–
Water	75	–	10	–	6.8	–	–
River	–	–	(19)	–	–	–	–
Farmhouse	–	–	–	–	–	–	0.3
Total	1 731	1 480	484	39.9	35.3	456	74.4

2.5 DESCRIPTION OF PHASE RECOGNIZED IN THE VERY DETAILED SOIL SURVEYS OF SELECTED AREAS IN THE AUXILIARY FARMS

The soils on the alluvial floodplain to the south of the Okwe River have many gully-like valleys leading into them. In addition, the alluvial parent material originating from the Volta River is modified by the addition of material from the adjoining uplands of Black Clays. Hence the southern side was not considered suitable for the selection of the auxiliary farm. On the northern side of the Okwe River, the better drained extensive area of Chichiwere and Hake soils often contain layers with a contrasting light texture. Within the remaining areas, it was not possible to select a contiguous area of about 50 acres with favourable topography and representing the full range of soils for the initial development. Hence two separate blocks each about 25 acres were selected to cover Chichiwere, Hake, Amo and Tefle soils.

2.5.1 Selected Areas in Auxiliary Farm No. 1

In the detailed soils survey at a scale of 1:1 000 of the two selected areas in auxiliary farm No. 1, textural and drainage ranges have been used to define additional units. Hake soils, in which a light textured layer thicker than 4 inches occurs within a depth of 42 inches, have been separated as a Hake, stratified layer variant. The impeded drainage in Hake and Amo soils is largely caused by flooding and a perched water table due to a heavier textured layer in the subsoil giving rise to lateral seepage. The whole area is flat to almost flat (0-2%) slopes and hence no slopes phases are mapped. The following Soil Mapping Units have been used.

Mapping Unit L40	Chichiwere sandy loam, moderately well drained phase. Moderately to rapidly permeable, deep, pale brown or yellow, loose sandy loam; finer textured layer is often present below a depth of 24; almost flat (0-2%) slopes of old levees. Land subclass 2s.
Mapping Unit L40 W1	Chichiwere sandy loam, imperfectly drained phase. Similar to L40 except for the imperfect drainage due to a seasonally high water table and slow runoff; on the almost flat (0-1%) slopes of the floodplain. Land subclass 2d.
Mapping Unit L40 W2	Chichiwere sandy loam, poorly drained phase. Similar to L40 except for the poor drainage due to a seasonally high water table and slow runoff; on the almost flat (0-1%) slopes of the floodplain. Land subclass 2d.
Mapping Unit M41	Hake (stratified layer variant) sandy clay loam, moderately well drained phase. Deep, brownish yellow, friable,moderately to rapidly permeable soil similar to M42 except that the sandy clay loam surface layer to a depth of commonly 18 ins is underlain by a coarse textured layer of thickness greater than 4 in; on almost flat (0-2%) slopes of the floodplain. Land class 1.
Mapping Unit M41 W1	Hake (stratified layer variant) sandy clay loam, imperfectly drained phase. Similar to M41 in all respects except for the impeded drainage due to seasonally high water table and slow runoff; on almost flat (0-2%) slopes of the floodplain. Land subclass 2d.

Mapping Unit M41 W2	Hake (stratified layer variant) sandy clay loam, poorly drained phase. Similar to M41 except for the poor drainage due to seasonally high water table and slow runoff; on almost flat (0-2%) slopes. Land subclass 2d.
Mapping Unit M42	Hake sandy clay loam, moderately well drained phase. Deep brownish yellow, friable, moderately to rapidly permeable sandy clay loam becoming mottled and slightly fine textured with often either a coarse textured layer encountered between 3 and 6 ft or a slowly permeable, compact, clayey subsoil at about 2 ft; on almost flat (0-2%) slopes of the floodplain. Land class 1.
Mapping Unit M42 W1	Hake sandy clay loam, imperfectly drained phase. The typical drainage phase, similar to M42 in all respects except for the imperfect drainage due to seasonally high water table and slow runoff; on almost flat (0-2%) slopes of the floodplain. Land subclass 2d.
Mapping Unit M42 W2	Hake sandy loam, poorly drained phase. Similar to M42 except for the poor drainage due to seasonally high water table and slow runoff; on almost flat (0-2%) slopes of the floodplain. Land subclass 2d.
Mapping Unit L42	Hake (moderately coarse textured variant) loam, moderately well drained phase. Similar to M42 except that the surface soil and subsoil are moderately coarse textured; on almost flat (0-2%) slopes of the floodplain. Land class 1.
Mapping Unit L42 W1	Hake (moderately coarse textured variant) loam, imperfectly drained phase. Similar to L42 except for the imperfect drainage due to seasonally high water table and slow runoff; on almost flat (0-2%) slopes of the floodplain. Land subclass 2d.
Mapping Unit M43	Amo silty clay loam, moderately well drained phase. Brownish yellow, mottled, friable, silty clay loam commonly abruptly underlain by an extremely hard, dense, slowly permeable silty clay; on almost flat (0-1%) slopes of the floodplain. Land class 1d.
Mapping Unit M43 W1	Amo silty clay loam imperfectly drained phase. Similar to M43 but imperfectly drained due to seasonally high water table and slow runoff; on almost flat (0-1%) slopes of the floodplain. Land subclass 2d.

Mapping Unit M43 W2	Amo silty clay loam, poorly drained phase. Similar to M43 W1 except for the greatly impeded drainage due to slow runoff and greater flood-plain on almost flat (0-1%) slopes of the flood-plain. Land subclass 3d.
Mapping Unit H43	Amo (fine-textured variant) silty clay moderately well drained phase. Similar to M43 except for a finer textured subsoil and surface soil; on almost flat (0-1%) slopes of the floodplain. Land class 1.
Mapping Unit H43 W2	Amo (fine-textured variant) silty clay poorly drained phase. Similar to H43 except for poor drainage on almost flat (0-1%) slopes of the floodplain. Land subclass 3d.
Mapping Unit V45 W3	Tefle clay. Very poorly drained, deep, heavy clays with a very dark gray, friable clay surface soil cover, a dark gray mottled yellowish red, very firm, very slowly permeable, clay subsoil; on flat (0-0+25%) bottom land. Land class 4d.
Mapping Unit - Water	Area covered by shallow water; the soil appears to be similar to Tefle clay (V45 W3).

2.5.2 Selected Area in Auxiliary Farm No. 2

The soils of auxiliary farm no. 2 occur in a very intricate complex pattern. In the soil map in the scale 1:5 000, the Soil Mapping Units M20 W1 - 2M20 W1 (Agawtaw Series) and L25 - 2L25 (Nyigbenya imperfectly drained variant) themselves only indicated the dominant soil and included scattered small patches of the other soils. In the remaining parts where no large enough area of dominantly one soil is mappable, the Soil Mapping Unit is M20 W1 - 1L25, a complex of Agawtaw and Nyigbenya variant. The area selected contains the full distribution of these soils and is near the proposed source of water, the Accra pipeline.

From a practical point of view, the depth to a limiting horizon (claypan in the case of Agawtaw and gravel layer in the case of Nyigbenya variant) is important. Hence three phases indicating depths of less than 8 inches, 8 inches to 16 inches and more than 16 inches are mapped. These phases are fundamental for Nyigbenya but may not be as important for Agawtaw if economically feasible methods of disrupting the claypan are developed.

In addition to mapping the three depth phases, two variations occurring to limited extents and included with the Agawtaw on the 1:5 000 map are shown separately. One is the soil containing a high content of laterite gravel in the claypan and sometimes called Minya Series. The other is a variant of Agawtaw having a thick, very gray surface horizon and with the claypan usually more than 24 inches below the surface.

The following Soil Mapping Units have been used:

Mapping Unit M20 W1	Agawtaw Series on almost flat (1-2%) slopes and with a slight wetness problem; the friable surface layer over the clayey hardpan is more than 16 inches thick.
Mapping Unit 1M20 W1	Agawtaw Series on almost flat (1-2%) slopes and with a slight wetness problem; the friable surface layer over the clayey hardpan is 8 to 16 inches thick.
Mapping Unit 2M20 W1	Agawtaw Series on almost flat (1-2%) slopes and with a slight wetness problem; the friable surface layer over the clayey hardpan is less than 8 inches thick.
Mapping Unit M21 W1	Agawtaw Series, with a thick dark surface horizon variant, intergrading to Akuse Series, on almost flat (1-2%) slopes and with a slight wetness problem. The clayey hardpan is commonly about 24 inches below the surface.
Mapping Unit 1M24 W1	Agawtaw Series, gravelly clay hardpan variant also called Minya Series, on almost flat (1-2%) slopes and with a slight wetness problem; the friable surface layer over the gravelly clay hardpan is commonly 8 to 16 inches thick.
Mapping Unit L25	Nyigbenya Series, imperfectly drained variant on almost flat (1-2%) slopes; the gravel-free friable surface layer over the very gravelly layer is more than 16 inches thick.
Mapping Unit 2L25	Nyigbenya Series, imperfectly drained variant on almost flat (1-2%) slopes; the gravel-free friable surface layer over the very gravelly layer is less than 8 inches thick.

Chapter 3

IRRIGATION SUITABILITY

3.1 DEFINITIONS OF IRRIGATION SUITABILITY LAND CLASSES

3.1.1 Class 1 Diversified Crops, Arable

Lands that are highly suitable for irrigation farming. They are capable of producing sustained and relatively high yields of climatically suited upland crops at reasonable cost when properly provided with essential cultural management, including irrigation, drainage, fertilization, weed and pest control. The surface is smooth with a gentle gradient between 2 and 0.25 percent. The soil to a depth of 60 inches has a moderate to moderately heavy texture with a porous, friable, stable structure favourable for root development, permeability to air and water, and a good moisture retention capacity and no adverse drainage restrictions affecting plant growth. These soils have a moderate to high cation exchange capacity and a high base saturation. They have a low soil extract conductivity (less than 2 millimhos) and are free of toxic elements and will continue to be so under proper irrigation and drainage maintenance. Both soil and topographic conditions are such that with project land development and facilities, there will be no drainage or flooding problems, and erosion resulting from irrigation will be negligible. These lands have a relatively high net farm income potential.

Areas under class 1 are Soil Mapping Unit L30: Aveime Series, on almost flat (0-2%) slopes. Mapping Unit M42: Hake Series, moderately well drained phase on almost flat (0-2%) slopes. Mapping Unit L42, a light textured variant of Hake on almost flat (0-2%) slopes.

3.1.2 Class 2 Diversified Crops, Arable

Lands that are moderately suitable for irrigation farming, being measurably lower than class 1 in productive capacity, adapted to a narrower range of climatically suited upland crops, more costly to farm or generally involving greater risk. They are not so desirable nor of such high value as lands of class 1 because of certain correctable or noncorrectable limitations of soils, topography or drainage. Any one of the limitations may be sufficient to reduce the lands from class 1 to class 2 but frequently a combination of two or more of them are present.

The subclasses are defined by the symbols "s", "t" and "d" for soil topography and drainage to indicate the dominant type or types of limitations. The new areas under class 2 may have a low available moisture capacity as indicated by coarse texture (land subclass 2s: Mapping Unit L40 - Chichiwere Series on old levees); or they may be, in addition, slowly permeable due to topographic position (land subclass 2sd: Mapping Unit L40 W1). They may be only slowly permeable and be heavy and very sticky, when wet, and cloddy and hard, when dry (land subclass 2sd: Mapping Units V10 W1 and V11 W1); or they may be, in addition, on gentle slopes promoting greater runoff and erosion but minimizing to some extent the wetness problem (land subclass 2st: Mapping Units 1V10B and 1V10B-1H12B). Simple topographic limitation includes steeper slopes necessitating special care and greater costs to irrigate and prevent erosion (land subclass 2t: Mapping Units M32B and L42B). Drainage limitation or flood hazard may be present (land subclass 2d: Mapping Units V32 W1, L42 W1 and M43 W1). Some may be moderately saline (conductivity between 2 and 4 millimhos) which involves moderate costs for leaching and maintaining a low level of salinity. In spite of the greater costs, risks, limited range of crops or lower productivity capacity, these lands of class 2 can have adequate net farm income under proper management.

3.1.3 Class 3 Diversified Crops, Arable

Lands that are suitable for irrigation development but are approaching marginality in upland crops adaptability range or economic potential. They are of distinctly restricted suitability because of more extreme deficiencies in the soil, topographic or drainage characteristics than class 2 lands. These deficiencies restrict the range of crop adaptability or impose severe management problems or soil improvement measures.

These lands may have a smooth topography but have inferior soils (land subclass 3s: parts of Mapping Unit L25-2L25 - Nyigbenya variant, an infertile soil with a very gravelly subsoil); in addition, they may have impeded drainage (land subclass 3sd: Mapping Units M20 W1 - 2M20 W1 and V20 W1 - Agawtaw Series, infertile, droughty and with a claypan impeding internal drainage). The limitations may be simply poor internal drainage and flooding hazards (land subclass 3d: Mapping Units M43 W2 and H43 W2). The basis of the system of land classification for irrigation suitability and the set of generalized specifications for irrigation suitability classification of land are given in Appendix 2.

3.1.4 Class 4 Diversified Crops, Arable

Lands that have one or more noncorrectable deficiencies making them unsuited for most common crops. Some are well suited to wetland rice, and others only to meadow or pasture. They are capable of supporting a farm family with a moderate net farm income if operated in units of adequate size or in association with better lands.

The deficiency may be a soil characteristic such as due to very high content of inert gravel in the subsoil and the near-surface layer (land subclass 4s: parts of Mapping Unit L25 - 2L25). It may be inadequate internal drainage and an unfavourable topographic position causing seasonal flooding and slow runoff (land subclass 4d: Mapping Unit V45 W3); or it may, in addition, have a soil problem (land subclass 4sd: Mapping Unit V15 W3, very sticky, heavy clay, when wet, and cloddy and hard, when dry).

3.1.5 Class 5, Nonarable

Lands which are nonarable under existing conditions but with potential value sufficient to warrant tentative seggregation for special study prior to completion of classification; or, lands whose arability is dependent upon additional project construction or land improvements. This class does not appear in the maps or report.

3.1.6 Class 6, Nonarable

Lands which are considered nonarable because of failure to meet the minimum requirements for the other classes of land, or which are arable but not susceptible to delivery of irrigation water or to provision of project drainage.

For subclasses which are not susceptible to irrigation because of position, such as isolated (i), high (h), or low (l); or which need additional project drainage construction (d), the arable class or subclass is given in parentheses. Subclasses 6d (4sd), 6h (1) and 6h (2t) have been recognized in the surveyed areas.

The system of subclasses as numbered and defined in the previous paragraphs has been designed primarily to indicate levels of suitability and kinds of limitations for the climatically adapted, common, arable, upland crops like maize, sorghum, sugar cane, cotton, tomato, tobacco, kenaf, pineapple, sunflower, cowpea, groundnut, sesame, onions and shallot. Levels of suitability and limitations for other kinds of crops like tree crops, pasture or wetland rice need not be the same as those indicated by the number and letters of these subclass symbols since the crop requirements can vary. Nevertheless, the wide spectrum of subdivisions based on specific ranges of limitations of soil, topography and drainage conditions defined for the arable upland crops can be readily reinterpreted for the other kinds of crops. Only pasture and wetland rice are considered in addition to arable upland crops in Table 6, since tree crops will not be developed extensively in the Accra Plains.

The suitability levels for the three kinds of crops are indicated, for sake of clarity, by the terms high, moderate, low and nil; these correspond in crop adaptability and economic potential to the irrigation suitability land classes 1, 2 3 and 4 as defined in this section. Thus the suitability levels for common upland crops expressed by the land class numbers 1, 2, 3 and 4 in the first column (land class and subclass) are repeated by the terms: high, moderate, low and nil respectively in the fourth column (Suitability levels for arable upland crops) for easy comparison with the suitability for wetland rice and pasture.

3.2 RECOMMENDATIONS REGARDING LAND USE OF THE LAND CLASSES

3.2.1 Class 1

The soils of land class 1 in this project are characterized by ease of tillage, good internal drainage and a soil structure favourable for good root development. These features make them (Soil Mapping Units L30, L42 and M42), in an area dominated by imperfectly or poorly drained heavy clays, very desirable for a wide range of tuber crops, deep rooted crops and crops sensitive to impeded drainage. Some of the crops that can be grown are banana, plantain, pineapple, tobacco, yam, cassava, kenaf, pepper, cowpea, capsicum, tomato, garden egg, eggplant, okro and other vegetables. They are not suited for wetland rice.

It will be necessary to build up the organic matter content which tends to be low and to supplement low nutrient holding capacity by: growing leguminous cover crops in the rotation, using a trash mulch wherever possible and adding kraal manure, crop residues and household-refuse. Application of fertilizers, especially nitrogen and phosphorous will be necessary.

Table 4

DISTRIBUTION OF IRRIGATION SUITABILITY LAND CLASSES AND SUBCLASSES
(IN ACRES)

Land Class or Subclass	Pilot Area A	Pilot Area B	Auxiliary Farm No.1	Selected Area 1 Auxiliary Farm No.1	Selected Area 2 Auxiliary Farm No.1	Auxiliary Farm No.2	Selected Area Auxiliary Farm No.2
1	-	-	(49)	13.7	2.9	-	-
2s	11	-	(58)	4.1	1.4	-	-
2t	96	-	10	-	-	-	-
2d	272	26	149	13.9	18.0	-	-
2st	-	26	23	-	-	-	-
2sd(i)	-	-	6	4.3	-	-	-
2sd(id)	-	172	11	-	-	-	-
3s	-	-	-	-	-	(80)	8.5
3d	1 062	-	161	3.9	2.4	-	-
3sd	4	237	4	-	-	(343)	58.6
4s	-	-	-	-	-	(33)	7.0
4d	174	234	3	-	3.8	-	-
4sd	16	764	-	-	-	-	-
6h(1)	21	-	-	-	-	-	-
6h(2t)	-	21	-	-	-	-	-
6d(4d)	75	-	19	-	6.8	-	-
Total	1 731	1 480	474	39.9	35.3	456	74.1

NOTE: The areas in parentheses are obtained wholly or in part by partitioning equally the areas covered by a complex covering two subclasses.

Table 5

SUITABILITY LEVELS OF THE DIFFERENT IRRIGATION SUITABILITY LAND CLASSES (OR SUBCLASSES) AND SOIL MAPPING UNITS FOR DIFFERENT KINDS OF CROPS

Land Class or Subclass	Soil Mapping Unit	Soil Series	Suitability Levels for		
			Arable Upland Crops	Wetland Rice	Pasture
1	L30	Aveime	High	Low	High
	M42	Hake	High	Low	High
	L42	Hake	High	Low	High
2s	L40	Chichiwere	Moderate	Nil	Moderate
2t	M32B	Zipa	Moderate	Nil	High
	L42B	Hake	Moderate	Nil	High
2d	V32W1	Zipa	Moderate	Moderate	High
	M42W1	Hake	Moderate	Moderate	High
	M43W1	Amo	Moderate	Moderate	High
2st	IV10B	Akuse	Moderate	Low	High
	IV12B	Bundase	Moderate	Low	High
2sd(i)	L40W1	Chichiwere	Moderate	Low	High
2sd(ii)	V10W1	Akuse	Moderate	Moderate	High
	V11W1	Ashiaman	Moderate	Moderate	High
3s	L25-1L25	Nyigbenya	Low	Nil	Low
3d	M43W2	Amo	Low	Moderate	Moderate
	H43W2	Amo	Low	Moderate	Moderate
3sd	M20W1-2M20W1	Agawtaw	Low	Moderate	Moderate
4s	2L25	Nyigbenya	Nil	Nil	Low
4d	V45W3	Tefle	Nil	High	Moderate
4sd	V15W3	Lupu	Nil	High	Moderate

Furrow irrigation can be practised. Sprinkler irrigation would be more satisfactory because of high infiltration rates, but this is not possible in the present scheme. Some of the areas (Mapping Unit L30) do not have any flooding or drainage problem, but the others (Mapping Units L42 and M42) are liable to slight flooding under present natural conditions. The construction of dikes and drainage channels will, however, eliminate this and restore to the soil its inherent potential for good drainage. Terraces and grassed waterways are required for erosion control.

3.2.2 Class 2

The lands under class 2 have slight to moderate limitations of soil, topography or drainage as enumerated in section 3.6. These limitations have reduced their net farm income potential from relatively high to moderate. The crop adaptability range, however, varies with the specific limitations of the subclasses.

3.2.2.1 Subclass 2s

These have a well drained, rapidly permeable, light textured soil (Mapping Unit L40). They are well suited for a wide range of tuber crops, deep rooted crops and crops sensitive to impeded drainage. Crops sensitive to even short periods of drought are best avoided. Wetland rice also is unsuitable. Banana, plantain, pineapple, groundnut, tobacco, onion, shallot, yam, cassava, sugar cane, tomato, capsicum, garden egg, eggplants and okro can be grown.

More frequent irrigation because of low moisture holding capacity is required. Furrow irrigation can be practised. Sprinkler irrigation would be more satisfactory because of the high infiltration rates but this is not realizable in the present scheme. There is no flooding or drainage problem. The organic matter content which is low must be built up to increase the low nutrient holding capacity. It is suggested that leguminous cover crops are grown in rotation, and that trash mulch is used wherever possible, as well as kraal manure, crop residues and household refuse. Application of fertilizers, a complete mixture preferably, will be necessary. Under good management, these soils become highly productive.

3.2.2.2 Subclass 2sd

Two kinds of problems are grouped here together; a rapidly permeable, light textured soil with an impeded drainage due to topography, and a slowly permeable, heavy sticky clay with an inherent impeded drainage.

The former (Mapping Unit L40 W1) will be suited for a wide range of tuber and deep rooted crops following the installation of dikes and drainage channels. Crops sensitive to impeded drainage must be avoided since there is a risk of seepage of flood or irrigation water into the area from the adjoining soils. Soya bean, maize, sugar cane, kenaf, cotton, cowpea, cassava and other vegetables can be grown. Wetland rice is unsuitable though it may be cultivated if the surrounding soils are also under it. These lands will need to be irrigated more frequently than the surrounding areas with the furrow irrigation method though sprinkler irrigation would be more satisfactory. It will be necessary to build up the organic matter content and to use a complete fertilizer as in lands of subclass 2s.

The other group in subclass 2sd (Mapping Units V10 W1 and V11 W1), due to their inherent impeded drainage and intractable nature, are best suited for crops that can withstand short periods of moisture saturation. Sugar cane, sorghum, maize, cotton, sesame, kenaf, soya bean, cowpea and other legumes and vegetables can be grown under furrow irrigation. Wetland rice can be grown with appropriate land preparation for flood irrigation.

These soils are very hard and cloddy when dry and very heavy and sticky when wet. Timing of ploughing, bunding and other operations, should coincide with the transient optimum soil moisture range when the soil is neither too dry nor too wet. Heavy machinery will be needed for tillage. When the soil is allowed to become very dry, cracks, which are characteristic of these clay soils, are very extensive, wide and deep. First rains or added irrigation waters are lost by rapid flow down them into the lower subsoil and substratum till the soil swells up and closes. Subsequently much water is lost as surface runoff. Efficient water use should ensure that infiltration is improved and that only the surface and upper subsoil are initially saturated. An addition of moisture into the dry lower subsoil and substratum should be by percolation through the upper soil layers thereby promoting the leaching of any soluble salts that may have accumulated in the surface layers during a previous irrigation season or in dry weather. The maintenance of a surface trash mulch or soil mulch could minimize deep cracking and increase absorption of water by the surface soil horizons.

Inherent slow permeability necessitates adequate drainage improving measures. Interceptor drains are required as a protection against surface runoff and seepage from surrounding land. Deep drainage channels are needed to promote the downward movement of water from the surface and to carry away excess water, both seepage as well as surface runoff. The channels must be large enough to cope with severe flash runoff following heavy rainfalls.

Fertility is good but for continuous cropping and for high yielding varieties use of artificial fertilizers, especially nitrogen and phosphorus will be necessary. While the incorporation of large amounts of organic matter to maintain the nutrient status does not seem desirable on these impermeable clays, deep rooting legumes in the crop rotation solely as cover crops, such as pigeon pea, or with secondary value in the diet such as cowpea, would help to improve structure and permeability. Use of heavy machinery when the soils are very wet, or the use of pressure implements such as mould board ploughs should be avoided. Structure and drainage can be further improved by provision being made for deep drains between raised beds. If the soil is used for rice under flood irrigation, such improvements in soil structure and drainage will be neither possible nor necessary. If rice under flood irrigation is part of the rotation, the improvement in structure deemed favourable for the upland crops will suffer periodic setback, but may be justified by the total net farm income.

Though the soils in land subclass 2sd (Mapping Units V10 W1 and V11 W1) pose special management and drainage problems, they are nevertheless highly productive under skilful management.

3.2.2.3 Subclass 2st

These lands have a moderately deep to shallow, slowly permeable, sticky clay and are gently sloping. (Mapping Units 1V10B, 1V10B-1H12B.) Like the second group in subclass 2sd, they are best suited for crops that can withstand short periods of moisture saturation. Sugar cane, maize, cotton, tobacco, sesame, kenaf, soya bean, cowpea, and other legumes and vegetables can be grown under furrow irrigation. Wetland rice under flood irrigation is not recommended since extensive cutting and filling to prepare terraced fields would be necessary.

The same remarks made for the second group in subclass 2sd, on timing of tillage operations, improvement of water percolation and leaching, and provision of interceptor drains apply here. The drainage channels to carry away seepage and surface flow from the area need not be as elaborate owing to favourable topography. Use of fertilizers, the need for deep rooting cover crops to improve structure, and the need for avoiding pressure implements or wet soil conditions are also applicable.

3.2.2.4 Subclass 2t

These have moderate or light textured, moderately well drained to imperfectly drained soils and are gently sloping (Mapping Units M32B and L42B). A wide range of tuber crops and deep rooted crops are suited, following the installation of dikes and drainage channels to minimize flooding and facilitate drainage. Banana, plantain, pineapple, onion, shallot, tobacco, soya bean, maize, sesame, groundnut, cotton, sugar cane, yam, cassava, kenaf, cowpea, other legumes and vegetables under furrow irrigation will grow well. Wetland rice under flood irrigation is not recommended especially in Mapping Unit L42B.

More frequent irrigation than that for adjoining parts is required. Leguminous cover crops should be grown at more frequent intervals to improve soil structure, organic matter content and nutrient holding capacity and to help retard erosion. In the dry season, the soils tend to become droughty, incoherent and powdery when cultivated. Kraal manure, household refuse and crop residues should be applied wherever possible, and trash mulching adopted. The use of cover crops like pigeon pea will also be useful in controlling spear grass which is very common. Artificial fertilizers also must be used regularly.

Areas under Mapping Unit M32B have a more impervious subsoil and hence can retain water better. Nevertheless Mapping Unit L42B can also be used under furrow irrigation even though sprinkler irrigation would have been more satisfactory.

3.2.2.5 Subclass 2d

These lands have an imperfectly drained to poorly drained soil on almost flat slopes (Mapping Unit V32 W1, L42 W1, M42 W1 and M43 W1). A slight wetness is a general problem due to flooding and slow runoff, which will be largely eliminated with the installation of flood control dikes, and drainage channels. A variety of deep rooted crops and tuber crops will be suited particularly by areas under Mapping Units L42 W1, M42 W1 and M43 W1 using furrow irrigation. Banana, plantain, pineapple, onion, shallot, tobacco, soya bean, maize, sesame, groundnut, cotton, sugar cane, yam, cassava, kenaf, cowpea, and other legumes and vegetables will all do well. Areas under Mapping Unit V32 W1 will grow successfully wetland rice under flood irrigation. Mapping Units M42 W1 and M43 W1 can support wetland rice under flood irrigation especially if the surrounding areas are also used.

Leguminous cover crops should be grown at more frequent intervals in the rotation to improve fertility and to control spear grass. Artificial fertilizers also are essential. Trash mulching must be adopted, and wherever possible, kraal manure, household refuse and crop residue.

3.2.3 Class 3

The lands under class 3 have moderate to severe limitations of soil, topography or drainage as discussed in section 3.6. Limitations enable only a low or marginal net farm income potential under common upland crops. Crop adaptability range is very much restricted with ordinary land development methods and drainage facilities.

3.2.3.1 Subclass 3s

These have moderately deep to shallow, friable soils with a thick, very gravelly subsoil suffering from an impeded internal drainage (L25 and 1L25 in Mapping Unit L25-2L25). Only shallow rooted crops like groundnuts or pasture are suited here. Wetland rice is not recommended since the extensive soil cutting needed for making level terraces would expose the very gravelly material. However, as they are close to the proposed source of water for irrigation for auxiliary farm No.2, in the relatively deeper soils (2L25), other crops like kenaf, cassava, yam, maize, cotton, soya bean, cowpeas and other legumes and vegetables can be tried under furrow irrigation.

The soils are infertile and for continued cropping, artificial fertilizers must be added. Leguminous cover crops should be included in the rotation to improve soil fertility.

3.2.3.2 Subclass 3sd

These areas have an impeded drainage due to a slowly permeable claypan in the subsoil (Mapping Units M20 W1 - LM20 W1 and V20 W1). Infertility is general as is a shallow rooting zone. Permeability is very slow and gives rise to severe flash runoff and flooding during storms. The floods recede almost entirely by surface runoff, as percolation into the subsoil is very slow. Waterlogging during the rainy season is usual. The surface moves as lateral seepage over the claypan. In the dry season, it rapidly dries up and plants will suffer from drought. Under irrigation productivity can become adequate if percolation through the subsoil can be effected to prevent the build up of salinity or alkali in the surface from the saline, alkaline claypan and substratum. Deep ploughing and turning to break and mix the claypan is one solution. In addition, deep drains to facilitate leaching and removal of percolation water from the area are necessary. The soils will be suited to crops like maize, groundnut, kenaf, cotton, soya bean and cowpea if due care is taken to provide subsoil drainage and to prevent a build up of salinity and alkalinity. Deep rooted, leguminous cover crops should be included in the rotation to improve the organic matter content and soil structure after deep ploughing. Under flood irrigation wetland rice can be grown, and this could be used in the rotation to obtain maximum leaching of soluble salts.

3.2.3.3 Subclass 3d

A moderate wetness problem due to flooding and slow surface runoff on a soil with a clayey subsoil (Mapping Units M43 W2 and H43 W2) is characteristic. These areas are readily suited for wetland rice under flood irrigation since the clayey subsoil causes a temporary perched water table. Pasture and cover crops can be used in rotation to improve tilth. A more extensive system of interceptor drains and deep drainage channels would be needed to prepare the land for upland crops (particularly for the lands under Mapping Unit H43 W2). With such drainage upland crops like maize, cotton, groundnut, sesame, soya bean, cowpea, sugar cane, yam, cassava, kenaf and other legumes and vegetables can be grown. Deep-rooting leguminous cover crops should be included to improve subsoil structure and permeability. Due care to ensure adequate leaching and drainage is necessary to prevent the build up of saline alkaline conditions at the surface. Artificial fertilizers must be applied for continued cropping.

3.2.4 Class 4

These lands have severe limitations which preclude their use for common upland crops as defined in section 3.6 and are suited only for a special or a very limited range of crops.

3.2.4.1 Subclass 4s

These have a very shallow, friable soil over a thick, very gravelly, slowly permeable subsoil (2L25 of Soil Mapping Unit L25 - 2L25), and are suited only for pasture even though they are very close to the proposed source of water in auxiliary farm No. 2.

3.2.4.2 Subclass 4d

These are a very poorly drained, heavy clay susceptible to flooding from adjoining high ground and capable of only very slow surface runoff (Mapping Unit V45 W3). Interceptor drains to protect the land from flooding and deep drains leading to the main streams or river are necessary to promote leaching and drainage. Wetland rice under flooding irrigation is the only suitable crop. Pasture can be included in the rotation if necessary, but rice production with its corresponding high income is possible without any risk of accumulating toxic soluble sustances. Artificial fertilizers will be needed for continued cropping especially with the high yielding rice varieties.

3.2.4.3 Subclass 4sd

These are fertile but very slowly permeable when saturated (Mapping Unit V15 W3). They are susceptible to flooding from the surrounding high ground and capable of only very slow runoff. Like the second group of land in subclass 2sd, they are very heavy and sticky, when wet, and very hard and cloddy, when dry. Timing of tillage operations within the critical soil moisture range, and maintenance of a soil mulch or trash mulch to minimize cracking and improve percolation and leaching are important. Interceptor drains to protect the area from surface runoff from the surrounding high ground are necessary. Deep drainage channels to carry away seepage are needed to promote leaching and to prevent the build up of alkali or salinity. These soils are best suited to wetland rice under flood irrigation as additional measures required to improve the drainage further are too expensive to justify the growing of upland crops. Fertility is good but for continuous cropping and high yielding rice varieties artificial fertilizers, especially phosphorus and nitrogen, will be necessary. There appears no danger of an accumulation of reducing substances toxic to rice even when it is grown continuously, provided the interceptor drains and drainage channels are installed. Deep rooting leguminous crops solely as cover crops, such as pigeon pea, or as a food crop, such as cowpea, can be grown in rotation during the dry season to improve fertility and percolation. Cotton, vegetables and kenaf are other suitable dry season crops.

3.2.5 Class 6

Those under land class 6 are arable but either cannot be irrigated or drained under the project plan.

3.2.5.1 Subclass 6h

These areas are not susceptible to delivery of irrigation water because they are higher than the proposed irrigation channels passing by them. The arable class suitability if irrigable is given in parentheses (1, Mapping Unit L30 and 2t, Mapping Unit M32B).

3.2.5.2 Subclass 6d

Major project drainage construction is required before these can be utilised. This is unlikely in the project plan. The arable class suitability if provided with project drainage is given in parentheses (4d, Mapping Unit V45 W3), and would indicate the need for ordinary farm drainage channels in addition to the major project drainage construction. Rice could be well suited if project drainage were installed.

3.3 SUITABILITY OF AUXILIARY FARM No. 1

The suitability of auxiliary farm No. 1 is determined by the representativeness of the soils of the floodplains.

Soils in auxiliary farm No. 1 vary in drainage randomly within short distances. Topography is very irregular, and often suggesting remnants of old river channels. Texture also varies rapidly both areally speaking and vertically. Soil layers of contrasting textures are often encountered in soil profiles within a depth of 6 ft.

Apart from the Agawtaw, Akuse and related soils on the upper gentle slopes in the southwest part, the surveyed area is an almost flat (0-2% slopes) floodplain covered by soils derived from alluvium. Hake soils are one of the commonest, occupying about 32 percent of the surveyed area. A moderately well drained phase (M42) and an imperfectly drained phase (M42 W1) of the medium textured soil type, and a moderately well drained, gentle slope phase (ML42) of the light, textured soil type, have been mapped.

Chichiwere soils occur on the river levee as a well drained phase (L40). Further away from the river, an imperfectly to poorly drained phase (L40 W1) is mapped. In the northwestern part, a complex of Chichiwere and Hake soils well drained to moderately well drained phase (L40 - M42) occupy the relatively higher ground extending from the levee. The total acreage of Chichiwere soils is estimated to be about 13 percent.

Amo soils are the most abundant occupying about 44 percent of the area. An imperfectly drained phase and poorly drained phase (M43 W1 and M43 W2) of the medium textured soil type and poorly drained phase (H43 W2) of the heavy textured variant have been mapped in the eastern and southern parts of the surveyed area.

Very poorly drained Tefle soils occur in the southern corner and very probably in the area under water yet to be drained.

The Hake commonly contain layers of contrasting light texture within 6 ft and the Chichiwere contain almost invariably a medium to heavy textured layer within 3 ft. The Amo do not have such a contrasting soil layer within 6 ft. In both Chichiwere and Hake and to a less extent in the Amo, the upper subsoil layers appear to be saturated with moisture for long periods due to the effect of a perched water table.

The soils of auxiliary farm No. 1 have, on the whole, a faster intake rate than the corresponding soils in pilot project block A. This is probably due to the common occurrence of a light textured substratum layer. In addition, though the area gets flooded as readily as pilot project block A after a heavy rainfall, it appears to drain off the surface water more rapidly. When flood control dikes and drainage channels are installed, the soils in this area can be expected to be consistently productive.

Areas of very poorly drained Tefle soils (Mapping Unit V45 W3) and poorly drained Amo soils (Mapping Units M43 W2 and H43 W2) are suited for wetland rice during the major rainy season and for a limited range of upland crops like maize, cotton and vegetables during the minor rainy season. Continuous rice production is also possible without any risk of accumulating soluble toxic substances as long as adequate drainage is maintained. Such drainage is necessary since a tendency to form salt crusts in the almost flat alluvial land at the base of the gentle slopes of residual soils has been observed during the long dry season under present natural conditions. Artificial fertilizers must be used.

The well drained to imperfectly drained Chichiwere, Hake and Amo soils (Mapping Units L40, L40 W1, L40-M42, M42, M42 W1, L42B and M43 W1) can be used for a wide range of upland crops. Adequate control measures to minimize erosion on gentle slopes (Mapping Unit L42B) will be necessary. On the Chichiwere and Hake soils without any wetness problems (Mapping Units L40, L40-M42, M42 and L42B), the whole range of climatically adapted upland crops can be grown. High income crops like pineapple and tobacco can be included with other crops like yam, cassava, groundnut, soya bean, cowpea, maize and cotton in a suitable rotation. Measures to improve soil organic matter content must be adopted in addition to the use of artificial fertilizers. On the soils with a slight drainage problem (Mapping Units L40 W1, M42 W1 and M43 W1), unless a very effective system of drainage channels are maintained, crops sensitive to short periods of impeded drainage are best avoided.

3.4 SUITABILITY OF AUXILIARY FARM No. 2

The suitability of auxiliary farm No. 2 is determined by the representativeness of the soils of the gently sloping uplands of the Accra Plains but excludes the Black Clays that are already covered by the Agricultural Irrigation Research Station, Kpong.

Agawtaw, Mamfe and Nyigbenya are some dominant types. In auxiliary farm No. 2, Agawtaw and closely related soils and an imperfectly drained variant of Nyigbenya soils are present. Mamfe soils are very similar to Nyigbenya in having a high content of laterite gravel but differ in being associated with the forest areas while Nyigbenya occur in the savannah. Simpa soils are also very gravelly but the gravel is exclusively iron stained or clean quartz.

The Black Clays (Akuse Series and related soils) and the soils of the floodplains are the most suitable areas for development of irrigated agriculture. The Agawtaw and Nyigbenya and related soils are very poor but cover a large part of the Accra Plains. The purpose of auxiliary farm No. 2 will be to study if and how these can be used for successful irrigated agriculture. The Ashiaman Irrigation Scheme, started in 1967, has Agawtaw and Simpa soils along the left bank channel and will be able to provide supplementary data.

The Agawtaw and Nyigbenya imperfectly drained variant soils are formed on highly weathered parent material. The first have a near surface, dense, impermeable claypan restricting air and water movement and root penetration. Nyigbenya variant has a near surface, thick, very slowly permeable layer containing a very high content of inert, concretionary laterite gravel, restricting air and water movement and root penetration.

The surface layer above the restricting layer (claypan or gravel layer as the case may be) is a friable horizon favourable to moisture movement, retention and root development. The level of suitability of the Agawtaw or Nyigbenya variant therefore is determined by the thickness of this friable surface layer over the restricting subsoil layer. Three depth phases have been mapped on the very detailed survey at 1:1 000 scale in accordance with the depth ranges defined in the soil mapping legend. These depth phases are particularly important for the Nyigbenya variant. The shallow depth phases of Agawtaw may not be as important since deep ploughing could be expected to break the claypan and improve tilth.

At the 1:5 000 scale however, these depth phases were not mappable. In fact even the delineation between Agawtaw and Nyigbenya variant was not always possible and hence a mapping unit to cover the complex combination of the two soils is included.

The Agawtaw (Mapping Unit M20 W1 - 2M20 W1) have a lowland class suitability for common upland crops (Land subclass 3sd). They are suitable for crops with a shallow root system or a strong-root system which can withstand slight waterlogging. This, due to lateral seepage, can be minimized by the construction of deep diversion drains to remove seepage and excess rain water and by avoiding excessive additions of irrigation water. Percolation can be improved by deep ploughing and turning over to break up and mix the claypan and by maintaining deep drains. These measures will also be necessary to facilitate leaching and removal of percolation water in order to prevent the build up of salinity or alkali on the surface from the saline alkaline claypan and substratum. Crops like maize, groundnut, kenaf, cotton, soya bean, cowpea, tomato and other vegetables can be grown. Deep rooted, leguminous cover crops should be included in the rotation to improve the organic matter content and soil structure especially if deep ploughing to break or mix the claypan is undertaken. Wetland rice under flood irrigation can be grown, and this could be used in the rotation to obtain maximum leaching of soluble salts possible in a season.

The Nyigbenya soils (Mapping Unit L25 - 2L25) can vary in suitability from land subclass 3s to 4s. When the depth to the gravel layer exceeds 8 inches (land subclass 3s) the soils are suited for shallow rooted crops like groundnut or pasture. Wetland rice is not recommended since the extensive soil cutting needed for making level terraces will expose the very gravelly, inert subsoil layer to the surface. In the very limited areas of the Nyigbenya deep phase where the gravel layer is more than 16 inches below the surface, other crops such as kenaf, cassava, yam, maize, cotton, soya bean and cowpea can be included in the trials. This deep phase of Nyigbenya has a thick rooting zone of good physical structure and hence with irrigation, fertilizers and good management can become quite productive. The shallow phase where the depth to gravel is less than 8 inches (land subclass 4s) is suited only for long term pasture.

3.5 SUITABILITY OF PILOT AREA A

The land use class distribution is not simple since the soil distribution pattern of pilot area A is somewhat irregular. The soils have been formed on alluvium deposited and reworked by the Volta River as it changed its course many times through and in the vicinity of the area. As a consequence, topography is relatively uneven and irregular even though the total relief is smaller than that of pilot area B. Textural and drainage patterns do not show any simple relationship with present topography or distance from the present river channel. The alluvial material is modified in the sough by material brought in as valley fill along a valley leading from the area of Black Clays.

The soils are subject to much flooding by runoff from the adjoining highlands and to slow outflow by surface runoff. When the project flood control dikes and drainage channels are installed, they will become suited for a wide range of crops. The classes indicating drainage limitations have been based on existing soil drainage conditions, permeability and topographic position (since these three factors determine the degree of economically feasible reclamation) and are given as the best estimate of drainage conditions after land development and installation of project facilities.

Soils of land class 4 (subclasses 4sd and 4d) are best adapted for wetland rice. They are the Lupu and Tefle and occupy about 11 percent of the area surveyed. During the second rainy season, cotton, maize or vegetables can be grown. Continuous rice cultivation can be persued without any risk of accumulation of soluble toxic substances, provided adequate drainage facilities are installed and maintained.

Soils of land class 3 (subclass 3d) occupying 61 percent of the surveyed area are also inherently poorly drained. They are the Amo soils; the normal type and the heavy textured variant. They generally occupy lower topographic positions relative to the Hake soils (which are class 2 land) and have a heavier texture and lower permeability. These, especially the heavy textured variant of Amo are readily adapted for wetland rice, but with adequate drainage channels, the soils can be used for a limited range of upland crops like maize, cotton, sugar cane and vegetables. Deep rooted leguminous crops, cowpea or pigeonpea, should be included in the rotation to improve subsoil structure as well as soil tilth. Artificial fertilizers, especially phosphorus and nitrogen, should be used. Since this land class occupies the major part of the block, the pattern of use selected will determine the use patterns of the other land classes and hence of block A as a whole.

Soils of land class 2 include all soils with minor soil, topographic or drainage deficiencies. The drainage deficient soils occupying 15 percent of the surveyed area are the imperfectly drained phase of Amo and Hake soils. With the installation of the flood protection dike and drainage channels, a fairly wide range of upland crops such as tobacco, maize, cotton, sugar cane, onions, pineapple, groundnut, kenaf, yam, cassava and cowpea can be cultivated. Wetland rice can be grown on the Amo soils with adequate land preparation for flood irrigation. Artificial fertilizers especially phosphorus and nitrogen should be used.

The class 2 soils with a topographic limitation and occupying 6 percent of the surveyed area are the Hake and Zipa, found on gentle slopes. These are also suited for a wide range of upland crops. Adequate erosion control measures and the inclusion of cover crops and other sources of organic matter are necessary to minimize erosion and improve soil tilth. Artificial fertilizers especially phosphorus and nitrogen should be used.

The class 2 soils with a soil limitation, occupying less than 1 percent of the surveyed area, are the Chichiwere soils. They are suited for a wide range of upland crops. Furrow irrigation has been used on such soils, but more frequent applications are required than for the surrounding soils. They are not suited for wetland rice. Cover crops should be included in the rotation. In addition, other measures, addition of crop residues and kraal manure, should be adopted to build up soil organic matter, nutrient and water holding capacities. Artificial fertilizers also should be used.

Class 1 soils, occupying less than 2 percent of the surveyed areas, are the Avieme and the moderately well drained Hake soils. They are suited for a wide range of upland crops. Cover crops should be included in the rotation. Other measures, addition of crop residues and kraal manure, should be adopted to increase the soil organic matter content. Artificial fertilizers also should be used.

Roughly 4 percent of the area is covered by a shallow fresh water pond. This will be drained when the project flood control dikes and drainage channels are installed. The land will then become class 4d covered mainly by Tefle soils. Wetland rice can be grown here continuously with no risk of accumulating toxic substances if the drainage channels leading off excess surface water and lateral seepage from the adjoining areas and from the reclaimed areas are maintained in working condition. A limited range of upland crops, cotton, maize and vegetables, can be grown in the second rainy season. Areas in land class 2 would be more suited to these crops.

3.6 SUITABILITY OF PILOT AREA B

Pilot area B has a very gentle to almost flat topography. Slopes of less than 0.25 percent cover 70 percent of the area in the central portion stretching from east to west. The remaining area along the northern, northwestern and southeastern borders and an isolated hillock in the northwest have gentle slopes of 1-2 percent, occasionally reaching 2 percent.

The former, almost flat areas are occupied by Lupu and Tefle soils (Mapping Units V15 W3 and V45 W3 respectively) and their predicted suitability for arable upland crops is marginal to none (land subclasses 4sd and 4d respectively). These areas are most suitable for wetland rice under flood irrigation. Flooding by surface runoff from the surrounding high ground should be checked by interceptor drains. Deep drainage channels within the area are needed to promote leaching and to carry away excess water, both seepage and surface runoff from the area. Continuous rice cultivation or rotation with improved pasture appears to be the best land use.

Fertility is moderate but for cropping or with high yielding varieties, artificial fertilizers must be used. A limited range of upland crops like sugar cane, cotton, vegetables, cowpea can be grown on the Lupu soils (Mapping Unit V15 W3; land subclass 4sd) if a more elaborate system of deep and wide drainage channels are laid out and cultivation practised on raised beds or ridges. The drainage channels must be deep and wide enough to cope with large flash floods especially if they occur on soil recently saturated by rain or irrigation. These measures (drainage channels and raised beds) and the inclusion of a deep rooted leguminous cover crop like pigeon pea or cowpea in the rotation, will improve structure and permeability. In addition, pressure implements such as mould board ploughs, should be avoided as well as ploughing when very wet. If wetland rice under flood irrigation is also included in the rotation, improvements in soil structure and permeability will be temporarily arrested or even reversed. Under irrigated use, the soils are not expected to crack widely and deeply as they do under natural conditions, provided they are not allowed to dry out completely. Initial use of water at the beginning of a cropping season will be efficient, while leaching to prevent accumulation of soluble salts more effective if a surface soil mulch or trash mulch is maintained to minimise deep cracks.

Gently sloping areas are occupied by Akuse, Ashiaman, Agawtaw, Zipa and Amo soils. They are located along the proposed irrigation channels, parts of the area below it, and other parts above this level. The last mentioned will be indicated by the numeral 6 in addition to the otherwise expected land class or subclass symbol in parentheses, for example 6(2sd).

Irrigable parts have diverse potential. The Akuse (Mapping Units V10 W1 and 1V10B) and Ashiaman (Mapping Unit 1V11 W1) can give an adequate net farm income under irrigation with arable upland crops as indicated by their subclasses (2sd, 2st and 2sd respectively). Internal drainage is low to very slow when the soil has become saturated. Runoff is slow on the almost flat (0-2%) areas of subclass 2sd, but may be adequate on the sloping (usually 2-3%) areas of subclass 2st to minimize to an appreciable degree the restrictions of poor internal drainage. On all these areas, deep drains to facilitate leaching and carry away seepage and surface runoff are necessary. Crops that could tolerate very short periods of moisture saturation, like sugar cane, cowpea, cotton, maize, fodder crops and vegetables can be grown. Deep rooting leguminous cover crops should be included in the rotation to improve soil structure and permeability. Pressure implements and ploughing when the soil is wet must be avoided. Use of ridges or raised beds will help in the development of a granular soil structure. The accumulation of soluble salts must be prevented by provision of irrigation for effective leaching and drainage. Fertility is moderate but artificial fertilizers especially nitrogen and phosphorus should be used.

The second group of soils on the relatively higher ground are Zipa soil (Mapping Units M32B and V32 W1) and Amo soil (Mapping Unit M43 W1). They have only slight topographic or drainage restrictions. Potential for an adequate net farm income under irrigation with arable upland crops is indicated by their subclasses, 2t, 2d and 2d respectively. However, a greater part of these soils will be above the reach of irrigation water and will be designated when the irrigation channel layout is finalized as 6(2t) or 6(2d). The irrigable sections are suited for most arable upland crops as the project facilities will eliminate flooding hazards and since the soils have inherently a medium internal drainage and a medium runoff. Maize, cotton, sugar cane, cowpea, sisal, ginger, vegetables and tobacco can be grown. Deep rooting leguminous cover crops in the rotation, addition of household refuse, crop residues and kraal manure, and trash mulch wherever possible are recommended to increase the soils organic matter content. Artificial fertilizers also must be used.

The last group in the relatively higher ground are occupied by Agawtaw soils (Mapping Unit M20 W1). These have a low or marginal economic potential and upland crop adaptability range, as indicated by subclass 3sd. They are infertile, and are waterlogged in the wet season but become droughty early in the dry season. Structure and porosity are very poor being unfavourable for root development, water movement and storage. In this irrigation block, they occur along or close to the main irrigation channel and hence may be conveniently used. Deep ploughing and mixing can be adopted only after usefulness has been demonstrated in auxiliary farm No. 2. Till then, these soils can grow maize, groundnuts and sugar cane. Deep rooting leguminous cover crops and pasture can be included in the rotation. Other measures to increase organic matter content and improve soil structure and permeability are kraal manure, crop residues, household refuse, and trash mulch farming. Adequate deep drains to promote subsoil leaching and to carry seepage and runoff are necessary to avoid subsoil waterlogging and development of saline alkaline conditions at the surface. Wetland rice can be grown continuously or in the rotation. This will facilitate leaching of subsoil and prevention of accumulation of soluble salts at the surface.

Appendix 1

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Appendix 2

IRRIGATION SUITABILITY OF SURVEYED AREAS

PART I

THE BASIS OF LAND CLASSIFICATION FOR IRRIGATION SUITABILITY

The land classification system used has been devised to give classes and subclasses that have agronomic and economic significance. Nevertheless since experimental data or practical experience of the behaviour of these soils under irrigated agriculture is nonexistent except for the Akuse Series, the classes and subclasses have been defined in terms of differences in physical features that are expected to be of importance in determining their crop use and economic potential.

The major factors influencing crop adaptability and crop yields in the surveyed areas are: (i) soil characteristics such as texture, structure, depth, tilth, acidity, alkali, salinity, permeability and fertility; (ii) topographic characteristics such as land position, gradient and relief, and (iii) drainage. These factors also influence the annual costs of production since they determine irrigation pattern, workability, land preparation and farm drains. Factors influencing the cost of land development like density of tree cover and rough, tussocky micro-relief have not been included since the cost of land clearing and levelling will be a project cost.

Since crop requirements and tolerable limits of soil, topography and drainage characteristics vary widely between different kinds of crops like arable upland row crops, arable upland field crops, upland tree crops, pasture and wetland rice, no single classification scheme can attempt to predict the levels of suitability for all these groups. Differentiating characteristics for suitability levels for arable upland field and row crops, however, provide a broad range of subdivisions based on finer limits of soil, topography and drainage conditions than would have been needed for other kinds of crops. The subclasses thus defined can be reinterpreted for other crop uses. It is on this assumption and following the U.S. Bureau of Reclamation system of classification of 1953, that four levels of suitability based on different degrees of limitations due to soil, drainage, topography and their interactions have been defined. They provide a broad spectrum of groupings susceptible to more specific interpretations of crop adaptability and yields and of problems and costs of production when under conservational, sustained uses.

The specifications used for the irrigation suitability classification are given in Table 6. These specifications have been selected on the basis of their relevance to the agronomic and economic value of the lands under consideration. For each specification, the maximum or minimum limit allowable for a given class when the other conditions are at optimum is given. When one or more of these other conditions deviate from the optimum, the limits of the specification determining the land class will vary.

In practice, all the pertinent factors are considered and judgement of a proper balance between the compensating factors for qualifying for inclusion into a given class is made. Variations outside the permissible range of a given property often occur especially in alluvial soils and hence the classification is based on the most representative values for the mapped soil unit.

Class 5 is a tentative class to which lands whose irrigability, drainage or flood control in the projected scheme needs further study are assigned. Lands in this tentative class are finally placed under the proper arable class or class 6 prior to completion of the survey.

In the final map the areas that are not irrigable, because of either failure to meet the minimum requirements for the other classes of land, or not susceptible to delivery of irrigation water, or lacking provision of project land development for drainage or flood control, are included in class 6.

The subclasses within either class 2 or 3 are of approximately equal economic potential when under arable upland crops, although their adaptability range may vary widely from one subclass to another according to the kinds and degrees of limitations in the physical characteristics. For wetland rice or pasture, the levels of suitability implied in the land class or subclass numerical designation no longer apply; by the very definitions of the classification system, the suitability level and economic potential are applicable only to arable upland crops. Class 1, with drainage and other subclasses in classes 2, 3 and 4 assume new levels of suitability for wetland rice and dry season pasture. Similarly, the various subclasses of classes 2, 3 and 4 may assume other levels of suitability for tree crops. Tree crops are not considered in the present scheme since livestock production will play a major role in the development of the Accra Plains and any large scale production scattered through the region would tend to harbour tsetse flies.

Table 6

SPECIFICATIONS 1/ FOR IRRIGATION SUITABILITY
CLASSIFICATION OF LAND IN THE SURVEYED AREAS

	Land Characteristics	Class 1 for diversified crops-arable	Class 2 for diversified crops-arable	Class 3 for diversified crops-arable	Class 4 for diversified crops-arable
1	Surface soil (0-12 in)	fine sandy loam to friable clay loam	loamy fine sand to heavy, sticky (when wet) and hard, cloddy (when dry) clay	loamy fine sand to heavy, sticky (when wet) and hard, cloddy (when dry) clay	loamy fine sand to heavy, sticky (when wet) and heavy, cloddy (when dry) clay
2	Subsurface soil	sandy loam to permeable clay loam	loamy fine sand to dense or slowly permeable clay	very gravelly clay to loamy fine sand to very slowly permeable clay or claypan	very gravelly clay to loamy fine sand to very slowly permeable clay or claypan
3	Depth to very gravelly layer	more than 60in	more than 36in	more than 16in	more than 8in
4	Depth of almost fresh gneissic bedrock	more than 60in	more than 48in	more than 30in	more than 12in
5	pH in water (1:1)	5.5 to 8.2	4.5 to 8.5	4.5 to 8.5	4.5 to 8.5
6	Conductivity of saturation extract in mmhos/cm	less than 2	less than 4	less than 8	less than 8

1/ The specification limits of any given characteristics define the highest class in which it appears when all the other characteristics are near optimum. When two or three characteristics of a soil are at the minimal limits for a given class, the soil would be classified in the next lower class.

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Table 6 (Cont'd)

	Land Characteristics	Class 1 for diversified crops-arable	Class 2 for diversified crops-arable	Class 3 for diversified crops-arable	Class 4 for diversified crops-arable
7	Fertility	good to moderate	good to moderate	good to poor rapid	good to very poor
8	Permeability	moderate	rapid to slow	rapid to very slow	rapid to very slow
9	Water holding capacity	adequate	adequate to low	adequate to low	adequate to low
10	TOPOGRAPHY Slope	0.25-2%	0.25-5%	less than 5%	less than 5%
11	DRAINAGE Flooding	none to very slight	none to slight	none to moderate	none to severe
12	Internal drainage	medium	rapid to slow	rapid to very slow	rapid to very slow
13	Perched water table	none	none to prominent	none to prominent	none to prominent

PART II

INFILTRATION DETERMINATION

Intake rates were determined in the field. A pair of heavy, steel concentric cylinders, one 20 inches internal diameter and 24 inches high and the other 36 inches internal diameter and 10 inches high, were used. The annular space between the two cylinders installed concentrically and vertically into the ground serve as a guard ring to ensure vertical flow through the inner cylinder. The two cylinders were hammered vertically into the ground to a depth of 6 inches with minimum disturbance to the soil surface. The soil around the inner cylinder was restored to original compaction to ensure that there was no likelihood of water flowing in or out round the lower edge. The surface inside the inner cylinder was covered with cut grass weighted down by metal weights to prevent pudding of the soil. The water level was maintained at a height of around 6 inches and was planned not to deviate by more than an inch more or less from this mark. The level in the outer cylinder was kept continuously at 6 inches. The level in the inner cylinder was measured by an ordinary scale from a fixed mark on the upper part of the cylinder wall to the nearest twentieth (0.05) of an inch. The scale was point-shaped at the end touching the water to facilitate determination of the water surface and to avoid any meniscus or wetting effect. The water level in the inner cylinder was measured at frequent intervals. When the level reached near 5 inches at the time of measuring, water was rapidly added to bring the level to between 6 and 7 inches and the new level recorded immediately.

The drop in level in inches and the corresponding time interval in minutes were first calculated and from these the cumulative drop against total time was calculated and plotted. The base intake rate is the gradient of the terminal part of the curve when constant flow rate has been reached. The curves were prepared and the base intake rates were calculated for 26 different soils at a total of 81 different sites. The curves for ten representative soils are presented in this report.

Base intake rates, in general, closely agreed with the value that could be expected from an interpretation of the soil site, texture and structure. Numerous deviations from the expected values were encountered at auxiliary farm No. 1. The rather high values of many Amo and Hake soils in auxiliary farm No. 1 are probably due to the stratified layers of coarse texture frequently observed in the subsoil particularly of Hake. The high values of many Amo, Akuse, Lupu and Tefle sites are due probably to the prominent, wide, vertical cracks that have developed in the dry season. The consistently low values of Agawtaw and Nyigbenya soils are thus in accord with the absence of vertical cracks in these soils and the compact nature of the subsoil.

It will be useful to determine infiltration rates at auxiliary farm No. 1 at the end of the rainy season when the water table is high. (The determinations reported here were done at the end of the long dry season when the water table was low.) With a high water table, coarse textured substrata below the water table will not affect the values. The rates determined with a high water table will be closer to the rates that can be expected under irrigated agriculture.

Table 7

SUMMARY OF WATER INTAKE MEASUREMENTS

Soil	Location Area	Location Site	Period of observation	Sheet No.	Curve No.	Base Intake Rate (in/h)
Hake sandy clay loam, imperfectly drained phase	AF No.1 SA No.1	B	30/1 - 6/2 6/2 - 8/2 6/2 - 8/2 10/2 -14/2	1	1 2 3 4	1.48 3.65 3.25 3.95
Amo silty clay loam, imperfectly drained phase	AF No.1 SA No.1	D	10/2 -14/2 10/2 -14/2 10/2 -14/2	2	D1 D2	5.7 3.0
Hake sandy clay loam, moderately well drained phase	AF No.1 SA No.1	E	10/2 -14/2 10/2 -14/2	2	E1 E2	8.6 2.1
Hake heavy sandy clay loam imperfectly drained phase	AF No.1 SA No.1	F	15/2 -21/2 15/2 -19/2	3	F1 F2	4.8 6.5
Hake heavy sandy clay loam, poorly drained phase	AF No.1 SA No.1	G	15/2 -21/2 15/2 -21/2	3	G1 G2	6.2 8.5
Chichiwere sandy loam imperfectly drained phase	AF No.1 SA No.1	H	19/2 -21/2 19/2 -21/2	4	H1 H2	1.6 1.1
Hake sandy clay loam, imperfectly drained phase	AF No.1 SA No.1	K	15/2 -20/2 15/2 -19/2	4	K1 K2	6.8 4.6
Amo heavy silty clay, moderately well drained phase	AF No.1 SA No.1	L	21/2 -26/2 21/2 -26/2	5	L1 L2	7.5 3.6

Symbols: AF: Auxiliary Farm; SA: Selected Area; PA A: Pilot Area A; PA B: Pilot Area B.

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Table 7 (Cont'd)

Soil	Location Area	Site	Period of observation	Sheet No.	Curve No.	Base Intake Rate (in/h)
Amo silty clay loam, moderately well drained phase	AF No.1 SA No.1	M	21/2 - 26/2	6	M1	5.0
			21/2 - 26/2		M2	1.4
			21/2 - 26/2		M3	1.7
Amo silty clay loam, imperfectly drained phase	AF No.1 SA No.2	N	26/2 - 3/3	7	N1	1.5
			26/2 - 3/3		N2	6.9
			26/2 - 3/3		N3	4.6
Hake sandy clay loam, imperfectly drained phase	AF No.1 SA No.2	P	26/2 - 3/3	7	P1	3.5
			26/2 - 3/3		P2	6.0
Chichiwere sandy loam, moderately well drained phase	AF No.1 SA No.2	R	3/3 - 5/3	8	R1	6.4
			3/3 - 5/3		R2	4.6
			3/3 - 5/3		R3	3.5
Hake stratified moderately well drained phase	AF No.1 SA No.2	S	3/3 - 5/3	9	S1	2.9
			3/3 - 5/3		S2	1.0
Amo silty clay loam, poorly drained phase	PA A	Pit No.2	25/4 - 28/4	10	1	1.15
			25/4 - 28/4		2	0.36
			25/4 - 28/4		3	0.16
Hake sandy clay loam, imperfectly drained phase	PA A	Pit No.1	24/4 - 28/4	11	1	0.91
			24/4 - 28/4		2	0.51
			24/4 - 28/4		3	0.13
Tefle clay, very poorly drained	PA A	Pit No.6	28/4 - 4/5	12	1	0.21
			3/5 - 4/5		2	0.33
			3/5 - 4/5		3	0.05
			29/4 - 4/5	13	1	1.31
			1/5 - 4/5		2	1.84
			30/4 - 4/5		3	1.73
Amo heavy silty clay, poorly drained phase	PA A	Pit No.12	5/5 - 9/5	14	1	1.44
			5/5 - 10/5		2	0.96
			6/5 - 10/5		3	0.88
			5/5 - 10/5		4	0.23

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Table 7 (Cont'd)

Soil	Location Area	Location Site	Period of observation	Sheet No.	Curve No.	Base Intake Rate (in/h)
Lupu clay, very poorly drained	PA A	Pit No.20	10/5 - 16/5	15	1	3.57
			10/5 - 16/5		2	2.13
			10/5 - 16/5		3	2.13
Agawtaw sandy loam, moderately deep phase	PA B	Pit No.1	16/5 - 20/5	16	1	0.051
			17/5 - 20/5		2	0.022
			16/6 - 20/5		3	0.002
			16/5 - 20/5		4	0.011
Lupu clay, very poorly drained	PA B	Pit No.7	20/5 - 23/5	17	1	0.92
			20/5 - 23/5		2	2.02
			22/5 - 24/5		3	0.054
			21/5 - 24/5		4	0.11
Akuse clay	PA B	Pit No.3	25/5 - 28/5	18	1	0.31
			24/5 - 28/5		2	4.96
			24/5 - 28/5		3	0.51
			25/5 - 28/5		4	0.046
Agawtaw sandy clay loam, deep phase	AF No.2 SA	Pit No.7	28/5 - 30/5	19	1	0.046
			28/5 - 30/5		2	0.068
			28/5 - 30/5		3	0.048
			28/5 - 30/5		4	0.059
Nyigbenya (imperfectly drained variant) light sandy clay loam	AF No.2 SA	Pit No.2	31/5 - 3/6	20	1	0.854
			31/5 - 3/6		2	0.068
			31/5 - 3/6		3	0.788
			31/5 - 3/6		4	0.099
Agawtaw sandy clay loam	AF No.2 SA	Pit No.8	3/6 - 7/6	21	1	0.0054
			3/6 - 7/6		2	0.0036
			3/6 - 7/6	22	3	0.17
			3/6 - 7/6		4	0.34
Nyigbenya (imperfectly drained variant) light sandy clay loam	AF No.2 SA	Pit No.5	7/6 - 10/6	23	1	0.0577
			7/6 - 10/6		2	0.0505
			7/6 - 10/6		3	0.0200
Agawtaw(dark surface horizon variant)	AF No.2 SA	Pit No.3	11/6 - 16/6	24	1	0.0149
			11/6 - 16/6		2	0.0169
			11/6 - 16/6		3	0.0069
			11/6 - 16/6		4	0.0096

Appendix 3

PROFILE DESCRIPTIONS

I Information on the Site

Profile number: No. 3 Pilot Area B
Soil name and mapping unit symbol: Akuse, V10 W1
Higher category classification: Udic Chromustert
Date of examination: 17 June 1969
Author of description: S. Sivarajasingham
Location: FAO Irrigation Development Scheme in the Accra Plains of Ghana
Elevation: about 38 ft above mean sea level
Land form: gently sloping upland, lower slope
Slope: 1 percent
Vegetation or land-use: short grass and scattered trees
Climate: Coastal dry zone (savannah)

II General Information on the Soil

Parent material: garnitiferous hornblende gneiss
Soil drainage class: imperfectly drained
External soil drainage (runoff): moderate
Internal soil drainage: poor
Permeability: very slow
Moisture conditions in the soil: dry
Water table: probably more than 10 ft
Surface stones or rock outcrops: none
Evidence of erosion: none
Evidence of salt or alkali: none
Human influence: frequently burnt for grazing

III Brief General Description of the Profile

The Akuse Series is a deep, imperfectly drained, very dark grayish brown, heavy shrinking clay with weak horizon differentiation. The soil is very hard and cloddy when dry and very sticky and heavy when wet. It cracks to a depth of up to 40 inches in the dry season.

IV Description of Individual Soil Horizons

A11 0-5 centimetres (cm); very dark grayish brown (10YR 3/2) moist colour; silty clay; strong, fine, subangular blocky and medium, granular; hard, friable, very sticky, very plastic; common, fine and medium roots; clear, smooth boundary; laboratory sample number 417, pH 7.0; conductivity 0.22 millimho.

A12 5-27 cm; very dark grayish brown (10YR 3/2) to dark brown (10YR 3/3) moist colour; heavy clay; strong, fine, subangular blocky; very hard, firm, very sticky, very plastic; common, fine and medium roots; gradual, smooth boundary; laboratory sample number 416, pH 7.4 conductivity, 0.15 millimho.

A3 27-55 cm; dark brown (10YR 3/3) moist colour; heavy clay; strong, medium, subangular and angular blocky; very hard, firm, very sticky, very plastic; few, calcareous nodules; few, fine and medium roots; clear smooth boundary; laboratory sample number 415, pH 7.8, conductivity 0.63 millimho.

C11 44-128 cm; yellowish brown (10YR 5/4) moist colour with common, medium, distinct, dark brown (10YR 3/3) mottles; heavy clay; strong, medium, subangular and angular blocky; hard, very firm, very sticky, very plastic; many, calcareous nodules; few, fine roots; clear, smooth boundary; laboratory sample number 414, pH 7.8; conductivity 2.5 millimhos.

C12 128-181 cm; dark yellowish brown (10YR 4/4) moist colour with common, medium, distinct, brown (10YR 5/3) mottles; heavy clay, strong, medium, angular blocky; hard, very firm, very sticky, very plastic; laboratory sample number 413, pH 7.6; conductivity 2.3 millimhos.

I Information on the Site

Profile number: No. 7 Pilot Area B
Soil name and mapping unit symbol: Lupu, V15 W3
Higher category classification: Chromudic Pellustert
Date of examination: 21 June 1969 after recent rains
Author of description: S. Sivarajasingham
Location: FAO Pilot Irrigation Development Scheme in the Accra Plains of Ghana
Elevation: about 29 ft above mean sea level
Land form: broad valley
Slope: 0 percent
Vegetation or land-use: tall grass and Mitiagyna
Climate: Coastal dry zone (savannah)

II General Information on the Soil

Parent material: valley fill from adjoining uplands of material derived from black shrinking clays
Soil drainage class: very poorly drained
External soil drainage (runoff): very slow
Internal soil drainage: very poor
Permeability: very slow when wet
Moisture conditions in the soil: moist
Water table: probably more than 10 ft in the dry season
Surface stones or rock outcrops: none
Evidence of erosion: none
Evidence of salt or alkali: none
Human influence: frequently burnt for grazing

III Brief General Description of the Profile

The Lupu Series is a deep, very poorly drained, dark grayish brown heavy silty clay with weak horizon differentiation. The gleying is masked by the dark colours in the surface horizons. The soil cracks vertically to a depth of 40 inches.

IV Description of Individual Soil Horizons

A1 0-10 cm; dark grayish brown (10YR 4/2) moist colour with many medium, faint, very dark grayish brown (10YR 2/2) and very dark brown (10YR 2/2) mottles; clay; strong, fine, subangular and medium granular; hard, firm, very sticky, very plastic; common, fine and medium roots; laboratory sample number 458, pH 5.8; conductivity 0.31 millimho.

A3 10-31 cm; dark grayish brown (10YR 4/2) moist colour with many, medium, faint, dark brown (10YR 3/3) mottles, heavy silty clay; strong, fine, subangular blocky; hard, firm, very sticky, very plastic; common, fine roots; laboratory sample number 457, pH 5.6; conductivity 0.25 millimho.

C11 31-60 cm; dark gray (10YR 4/1) moist colour with many, medium, faint, very dark grayish brown (10YR 3/2) mottles; heavy silty clay; strong, medium, angular blocky; very hard, very firm, very sticky, very plastic; few fine roots; laboratory sample number 456; pH 7.2; conductivity 0.83 millimho.

C12 60-103 cm; olive gray (5Y 4/2) moist colour with many, medium, faint, olive (5Y 5/4) mottles; heavy silty clay; strong, medium, angular blocky with prominent slickenside-like basal surface; very hard, very firm, very sticky, very plastic; laboratory sample number 455; pH 7.6; conductivity 1.43 millimhos.

C13 103-150 cm; gray (5Y 5/1) with many, medium, prominent, olive yellow (5Y 6/6) and olive (5Y 4/4) mottles and few, fine manganese-rich nodules and traces of very fine, white, calcareous nodules; silty clay; strong, coarse, angular blocky with slickenside-like basal surface; very hard, very firm, very sticky, very plastic; laboratory sample number 454; pH 7.0; conductivity 5.8 millimhos.

I **Information on the Site**

Profile number: Pit No. 4, Auxiliary Farm No. 2
Soil name and mapping unit symbol: Agawtaw Series, 1M20 W1
Higher category classification: Albic Natraqualf
Date of examination: 10 June 1969; after several rains in the previous 2 weeks
Author of description: S. Sivarajasingham
Location: FAO Pilot Irrigation Development Scheme, in the Accra Plains of Ghana
Elevation: about 207 ft above mean sea level
Land form: gently sloping upland in the Accra Plains, middle slope
Slope: 0-2 percent
Vegetation or land-use: short grass and scattered short trees
Climate: Coastal dry zone (savannah)

II **General Information on the Soil**

Parent material: locally transported drift over layer containing laterite gravel or weathering acid gneiss
Soil drainage class: poorly drained
External soil drainage (runoff): slow
Internal soil drainage: very slow
Permeability: very slow
Moisture conditions in the soil: moist throughout
Water table: probably deep
Surface stones or rock outcrops: nil
Evidence of erosion: none
Evidence of salt or alkali: none except for any indication of the prismatic structure
Human influence: annual burning of grass accidentally or deliberately to remove the coarse vegetation and to allow the growth of tender shoots and leaves

III **Brief General Description of the Profile**

The Agawtaw Series is a shallow, poorly drained, very slowly permeable soil. The surface horizon is a very dark gray or very dark grayish brown, friable, sandy clay loam. The subsoil is an olive or light olive brown, dense, clayey hardpan and often containing a stone line of laterite gravel and quartz cobbles in the lower part. This overlies a friable clay or sandy clay or highly weathered bedrock.

IV **Description of Individual Soil Horizons**

A1 0-10 cm; very dark gray (10YR 3/1); heavy silty clay loam, moderate, medium, subangular blocky, friable, very sticky, plastic, many, fine, roots, clear smooth lower boundary; laboratory sample number 390; pH 6.8; conductivity 0.20 millimho.

A3 10-26 cm; dark grayish brown (10YR 4/2) and very dark grayish brown (10YR 3/2); heavy sandy clay loam, moderate prismatic breaking to moderate, medium, subangular blocky, friable, very sticky, plastic, common, fine roots, clear, smooth lower boundary; laboratory sample number 389; pH 7.0; conductivity 0.15 millimho.

B1 26–34 cm; dark brown to dark grayish brown (10YR 4/3); clay strong, very coarse prismatic breaking to strong medium subangular blocky; extremely hard, absorbs water very slowly, very sticky, very plastic; few fine roots; gradual, smooth lower boundary; laboratory sample number 388; pH 7.2; conductivity 0.25 millimho.

B2 34–58 cm; olive to olive gray (5Y 4/3–4/2); clay; strong, very coarse, prismatic with prominent basal cleavage and breaking to strong, moderate, prismatic; extremely hard, absorbs water very slowly; very sticky, very plastic; very few, fine roots; gradual, smooth, lower boundary; laboratory sample number 387; pH 7.6; conductivity 1.25 millimhos.

II B31 58–76 cm; dark grayish brown (10YR 4/2–2.5Y 4/2) with few, fine, distinct, reddish yellow (5YR 6/8) and common, fine, prominent black presumably manganese-rich mottles; very gravelly clay, the gravel being fine round, laterite concretions, manganese-rich, nodules and coarse angular quartz; very coarse, prismatic breaking down to strong, medium, prismatic, hard, friable, sticky, plastic; few fine roots; abrupt, wavy lower boundary varying from 40 cm to 88 cm depth within a distance of 100 cm; laboratory sample number 386, pH 7.8, conductivity 1.75 millimhos.

II B32 76–118 cm; gray (5Y 5/1) with many fine prominent, reddish yellow (5YR 6/8) mottles; very gravelly clay, the gravel being fine, round laterite; massive, dense gravel pan difficult to dig but clods removed are only slightly hard, sticky, plastic; no roots; laboratory sample number 385; pH 7.8; conductivity 2.50 millimhos.

III C1 118–160 cm; olive (5Y 5/4) with common, medium, white, calcareous and few, fine, black, presumably manganese-rich mottles; pockets of saprolotic material with brownish yellow (10YR 6/8), yellow (2.5Y 7/8) and yellowish brown (10YR 5/8) and greenish bands; light clay; strong, medium, angular blocky; slightly hard, sticky plastic; no roots; laboratory sample number 384; pH 8.0; conductivity 1.9 millimhos.

III D 160 cm; bedrock of hornblende schist, comes to within 120 cm at the position where the gravel layer also comes nearer the surface, at other places, the bedrock is even deeper than 160 cm.

I Information on the Site

Profile number: Pit No. 1, Auxiliary Farm No. 2
Soil name and mapping unit symbol: Nyigbenya Series, imperfectly drained variant, 2L25
Higher category classification: Oxic Tropustult, clayskeletal
Date of examination: 6 May 1969
Author of description: S. Sivarajasingham
Location: FAO Pilot Irrigation Development Scheme, in the Accra Plains
Elevation: approximately 203 ft above sea mean level
Land form: gently sloping upland in the Accra Plains; upper slope
Slope: 0–2 percent
Vegetation or land-use: short grass and scattered short trees
Climate: Coastal dry zone (savannah)

II General Information on the Soil

Parent material: locally transported material over country rock of acidic gneiss and basic gneiss
Soil drainage class: imperfectly drained
External soil drainage(runoff): moderate
Internal soil drainage: slow
Moisture conditions in the soil: dry
Permeability: slow
Water table: probably deep
Surface stones or rock outcrops: hard laterite surface, probably of a buried boulder exposed at surface about 20 ft away
Evidence of erosion: none
Evidence of salt or alkali: none
Human influence: frequently burned accidentally or deliberately to promote regrowth of tender grass for grazing

III Brief General Description of the Profile

The Nyigbenya Series, imperfectly drained variant, in a reddish brown, mottled, imperfectly drained sandy clay loam with a thick very gravelly subsoil, the gravel being mostly hard, well developed laterite concretions and occasional, angular quartz.

IV Description of Individual Soil Horizons

A1 0-11 cm; very dark gray to very dark grayish brown (10YR 3/2-3/1) moist colour; very fine sandy loam high in humus; weak; medium and fine, subangular blocky; hard, friable, slightly sticky, plastic; dense; slightly porous; many fine roots; abrupt, wavy boundary; laboratory sample number 287; pH 6.6; conductivity 0.29 millimho.

II A11 11-28 cm; very dark gray to very dark grayish brown (10YR 3/2-3/2) moist colour; very gravelly sandy clay loam, the gravel being very hard, fine round, laterite concretions; clods break into weak, fine, subangular blocky, granular and loose gravel; moderately hard friable, sticky, plastic; dense, slightly porous; many fine and medium roots; gradual, smooth boundary; laboratory sample number 286; pH 6.0; conductivity 0.10 millimho.

II A3 28-68 cm; reddish brown (5YR 4/4), red 2.5YR 4/6) and dark brown (10YR 3/3) moist colours in approximately equal amounts, very gravelly clay, the gravel occupying over 80 percent volume of the horizon and being very hard, fine and medium, round laterite concretions; very heavy and dense clods breaking into weak, fine, subangular blocky and loose gravel; moderately hard, friable, very sticky, very plastic; few, fine roots, clear, wavy boundary; laboratory sample number 285; pH 6.6; conductivity 0.13 millimho.

II B2 68–107 cm; dark reddish brown (2.5YR 3/4) with few, fine black stains and yellowish brown (10YR 5/6), laterite gravel and black manganese-rich gravel, very gravelly clay, the gravel occupying over 80 percent volume of the horizon and being many, very hard, fine and medium, round, laterite concretions and few, angular quartz and common, fine black, manganese-rich, nodules, very heavy and dense clods breaking into weak, subangular blocky and loose gravel, moderately hard, friable, sticky, plastic; few roots; clear, wavy boundary; laboratory sample number 284; pH 6.6; conductivity 0.10 millimho.

II B3 107–129 cm; red (2.5YR 4/6) with many, medium, distinct, pale brown (10YR 6/3) and many, medium distinct, light brownish gray (2.5Y 6/2) and few, medium, prominent, black mottles; very gravelly clay, the gravel occupying over 80 percent volume of the horizon and being composed of many fine, round and angular, laterite and manganese-rich nodules and few, fine, angular quartz gravel; heavy clods breaking into individual clay with a little clay adhering to give some weak, fine, subangular blocky; hard, friable, sticky, plastic, very few, fine, roots; abrupt, smooth boundary; laboratory sample number 283; pH 6.8; conductivity 0.09 millimho.

III C1 129–171 cm; yellowish red (5YR 5/6) to strong brown (7.5YR 5/6) with few, medium, prominent, black stains, many, medium, prominent, yellowish brown (10YR 5/6), and few, medium, prominent, red (2.5YR 4/8), many, medium, prominent olive yellow (2.5Y 6/8) and few, medium, distinct light yellowish brown (2.5Y 6/4) mottles; silty clay; strong, medium and fine, subangular blocky, moderately hard, friable, very plastic, very sticky, porous, light, saprolitic with many channels filled with grayish material; laboratory sample number 282; pH 6.8; conductivity 0.06 millimho.

I <u>Information on the Site</u>

Profile number: Pit No. 10, Pilot Area A
Soil name and mapping unit symbol: Aveime Series, L30
Higher category classification: Oxic Haplustalf
Date of examination: 29 April 1969, end of the long dry season
Author of description: S. Sivarajasingham
Location: FAO Pilot Irrigation Development Scheme, in the Accra Plains of Ghana
Elevation: about 38 ft above mean sea level
Land form: old river terrace about 20 ft above the surrounding area of recent alluvial deposit
Slope: middle position on a convex slope of 3 percent
Vegetation or land-use: dense low bush, grass and short trees
Climate: Coastal dry zone (savannah)

II General Information on the Soil

Parent material: alluvial deposit containing lenses of oyster shells at certain depths
Soil drainage class: well drained
External soil drainage (runoff): good
Internal soil drainage: good
Permeability: moderately rapid
Moisture conditions in the soil: dry throughout the profile
Water table: deep
Surface stones or rock outcrops: nil
Evidence of erosion: none
Evidence of salt or alkali: none
Human influence: probably cleared for bush-fallow farming more than 15 years ago

III Brief General Description of the Profile

The Aveime Series is a deep, well drained, moderately rapidly permeable, red coloured, porous, light textured soil with a good distribution of roots to a depth of more than 5 ft and much evidence of fanual activity. It occurs on the level and gentle slopes of old river terraces.

IV Description of Individual Soil Horizons

A1 0-12 cm; very dark grayish brown (10YR 3/2) moist colour; sandy loam; weak, fine, granular and single grain; soft, very friable, non sticky, non plastic, porous; many fine and medium roots; gradual, smooth lower boundary; laboratory sample number 252; pH 7.4; conductivity 0.16 millimho.

A3 12-54 cm; dark reddish brown (5YR 3/2-3/3) moist colour; loam, weak, medium subangular blocky; slightly hard, friable, non sticky, non plastic; porous; many medium and fine roots, pieces of old pottery at 40 cm and thin lens of oyster shells at 53 cm; gradual smooth lower boundary; laboratory sample number 251; pH 7.2; conductivity 0.07 millimho.

B2 54-86 cm; dark red (10R 3/6) to dark reddish brown (2.5YR 3/4) moist colour; light sandy clay loam, weak medium subangular blocky; hard, friable, slightly sticky, non plastic, porous due to many old root channels and insect burrow holes; thin patchy cutans; common, medium roots; gradual, smooth lower boundary; laboratory sample number 250; pH 7.2; conductivity 0.04 millimho.

B3 86-159 cm; red (2.5YR 4/8-10R 4/8) moist colour, loam weak, medium, subangular blocky; slightly hard, friable, slightly sticky, non plastic; porous due to many old root channels and insect burrow holes; old termite nests; thin patchy cutans as linings in pores; few medium roots; laboratory sample number 249; pH 7.0; conductivity 0.04 millimho.

I **Information on the Site**

Profile number: No. 15, Pilot Area A
Soil name and mapping unit symbol: Zipa Series, M31B
Higher category classification: Plinthic Typic Tropaquult
Date of examination: 1 May 1969
Author of description: S. Sivarajasingham
Location: FAO Pilot Irrigation Development Scheme in the Accra Plains of Ghana
Elevation: about 30 ft above mean sea level
Land form: old river terrace above the floodplain
Slope: 3 percent
Vegetation or land-use: medium grass and many trees
Climate: Coastal dry zone (savannah)

II **General Information on the Soil**

Parent material: alluvium deposited on an old river terrace
Soil drainage class: moderately well drained
External soil drainage (runoff): good
Internal soil drainage: poor to very poor
Permeability: very slow
Moisture conditions in the soil: dry
Water table: very deep
Surface stones or rock outcrops: none
Evidence of erosion: none
Evidence of salt or alkali: none except for any indication of the prismatic structure
Human influence: grass frequently burnt

III **Brief General Description of the Profile**

Deep, moderately well drained soil,compact, strongly mottled, slowly permeable.

IV **Description of Individual Soil Horizons**

A1 0-25 cm; light brownish gray (10YR 6/2) dry colour becomes dark brownish gray (10YR 4/2) on moistening, sandy loam, massive breaking town to single grains, and fine granules, very hard, soft, non sticky, non plastic, porous with granular material in cavities, few fine and medium roots, gradual, smooth boundary; laboratory sample number 270; pH 5.6; conductivity 0.08 millimho.

A3 25-63 cm; brownish gray (2.5Y 6/2) dry colour becomes grayish brown (10YR 5/2) and dark yellowish brown (10YR 4/4); sandy loam and sandy clay loam in parts with other many small sandy pockets; massive very hard, soft non plastic to sticky, non plastic to plastic, very few, fine roots, gradual, smooth boundary; laboratory sample number 269; pH 5.4; conductivity 0.08 millimho.

B1 63–82 cm; light brownish gray (10YR 6/2) moist colour with common, fine, distinct, yellowish brown (10YR 5/6) mottles; sandy clay; strong, coarse, prismatic breaking to moderate, medium prismatic with many basal 'cleavage planes' in turn breaking to moderate, medium angular blocky; very hard, very sticky, plastic, dense, few; fine roots; gradual smooth boundary; laboratory sample number 268; pH 5.8; conductivity 0.36 millimho.

B2 82–123 cm; light gray (5Y 7/1–7/2) to light brownish gray (2.5Y 6/2) moist colour with common, coarse, prominent red (10R 4/6–4/8) and common, fine, distinct yellowish brown (10YR 5/6) mottles; sandy clay loam, strong, coarse, prismatic breaking to moderate, medium, prismatic in turn breaking to moderate, coarse, angular blocky along horizontal weak planes giving smooth ped faces, very hard, sticky, plastic; dense, few fine pores, few fine roots; gradual smooth boundary; laboratory sample number 267; pH 5.2; conductivity 2.04 millimhos.

C11 123–158 cm; light gray (5Y 7/1–7/2) moist colour with common, coarse, prominent, dark red (10R 3/6) mottles and small, yellowish brown (10YR 5/6) sand fillings in cavities; heavy sandy clay; weak, coarse prismatic breaking to moderate, coarse, angular blocky; hard, firm, very sticky, plastic, dense, few pores, very few, fine roots, clear smooth boundary; laboratory sample number 266; pH 5.4; conductivity 3.5 millimhos.

C12 158–165 cm; light gray (5Y 7/1–7/2) moist colour with many, coarse, prominent, yellowish red (5YR 5/8) and red (2.5YR 4/8) mottles, gravelly, gritty sandy clay; weak coarse, subangular blocky, moderately hard, friable, very sticky, plastic, no roots, clear smooth boundary; laboratory sample number 265; pH 5.0; conductivity 2.7 millimhos.

C13 165–175 cm; light gray (5Y 7/1–7/2) moist colour with coarse, common, prominent, strong brown (7.5YR 5/8) mottles; gritty sandy clay; weak coarse, subangular blocky; heavy, dense, not porous; hard, very firm, very sticky, plastic; no roots; laboratory sample number 264; pH 5.0; conductivity 3.8 millimhos.

I <u>Information on the Site</u>

Profile number: No. 5, Auxiliary Farm No. 1
Soil name and mapping unit symbol: Chichiwere Series, L40
Higher category classification: Typic Dystropept
Date of examination: May 1968
Author of description: S. Sivarajasingham
Location: FAO Pilot Irrigation Development Scheme in the Accra Plains of Ghana
Elevation: about 44 ft above mean sea level
Land form: river levees
Slope: 1 percent
Vegetation or land-use: tall grass and many tall trees and bush
Climate: Coastal dry zone (savannah)

II General Information on the Soil

Parent material: alluvium from Volta River
Soil drainage class: moderately well drained
External soil drainage (runoff): slow
Internal soil drainage: moderately good
Permeability: moderately rapid
Moisture conditions in the soil: dry
Water table: probably deeper than 15 ft
Surface stones or rock outcrops: none
Evidence of erosion: none
Evidence of salt or alkali: none
Human influence: none

III Brief General Description of the Profile

Deep yellowish brown, loose sandy soil.

IV Description of Individual Horizons

A1 0-15 cm; very dark grayish brown (10YR 3/2); fine sandy loam; weak, fine, granular held together by common, fine and few, medium roots; soft, very friable, non sticky, non plastic, porous,clear, smooth boundary; laboratory sample number 75; pH 5.4; conductivity 0.16 millimho.

A3 15-45 cm; yellowish brown (10YR 5/6) with medium, faint dark yellowish brown (10YR 4/4) mottles; fine sandy loam to light fine sandy clay loam,moderate, fine, subangular blocky, soft, friable, slightly sticky, slightly plastic; porous; medium and fine roots; clear, smooth boundary; laboratory sample number 76; pH 5.4; conductivity 0.03 millimho.

B1 45-70 cm; dark yellowish brown (10YR 4/4) to brown to dark brown (7.5YR 4/4) with common medium, distinct, dark brown (10YR 3/3) and brownish yellow (10YR 6/8) mottles; light fine sandy clay loam to fine sandy loam; moderate, fine subangular, blocky, soft, friable, slightly plastic, slightly sticky; very porous; few, fine roots; clear smooth boundary; laboratory sample number 77; pH 5.4; conductivity 0.03 millimho.

B2 70-100 cm; yellowish brown (10YR 5/6) with few, medium, distinct, strong brown (7.5YR 5/6-5/8) and coarse, medium, distinct, dark brown (10YR 3/3) mottles; fine sandy loam; light fine sandy clay loam to fine sandy loam; weak fine, subangular blocky soft, friable, slightly sticky, slightly plastic; very porous; thin clay skins, few, fine roots, clear smooth boundary; laboratory sample number 7.8; conductivity 0.03 millimho.

C1 100-150 cm; yellowish brown (10YR 5/8) with common, medium distinct yellow (10YR 8/6) and dark brown (10YR 3/3) mottles, fine sandy loam, weak, fine, subangular blocky; soft friable, non sticky, non plastic; porous; laboratory sample number 7.9; pH 6.1; conductivity 0.03 millimho.

I Information on the Site

Profile number: No. 23, Pilot Area A
Soil name and mapping unit symbol: Hake Series, light textured variant, L42B
Higher category classification: Aquic-Typic Dystropept
Author of description: S. Sivarajasingham
Date of examination: 12 May 1969
Location: FAO Pilot Irrigation Development Scheme in the Accra Plains of Ghana
Elevation: about 30 ft above mean sea level
Land form: Floodplain
Slope: 3 percent
Vegetation or land-use: tall grass and scattered trees
Climate: Coastal dry zone (savannah)

II General Information on the Soil

Parent material: recent floodplain alluvium
Soil drainage class: moderately well drained
External soil drainage (runoff): good
Internal soil drainage: good
Permeability: moderately rapid
Moisture conditions in the soil: dry
Water table: deep, probably about 15 ft
Surface stones or rock outcrops: none
Evidence of erosion: none
Evidence of salt or alkali: none
Human influence: frequently burnt

III Brief General Description of the Profile

The Hake Series (light textured variant) is a deep, moderately well drained, yellowish red, moderately rapidly permeable moderately light textured soil with a light textured layer in the subsoil or substratum.

IV Description of the Individual Soil Horizons

A1 0-10 cm; dark grayish brown (10YR 3/2) moist colour; silt loam, weak medium, subangular blocky and granular; moderately hard, friable, slightly sticky, slightly plastic; many, fine and medium roots, clear, smooth boundary; laboratory sample number 319; pH 5.8; conductivity 0.10 millimho.

B1 10-33 cm; reddish brown (5YR 4/4) moist colour; silty clay loam, moderate coarse, prismatic breaking to moderate, coarse, angular blocky and in turn to weak, medium, subangular blocky; hard, friable, sticky, plastic; porous, few fine roots; clear, smooth boundary; laboratory sample number 318; pH 5.4; conductivity 0.07 millimho.

B2 33-70 cm; yellowish red (5YR 4/6) moist colour with many, medium, prominent, white (10YR 8/2) and common, medium, prominent, yellowish red (5YR 5/8) mottles; sandy clay loam; moderate, coarse, prismatic breaking to moderate, fine prismatic and in turn to moderate, medium subangular blocky, white parts are due to loose clean sand; very hard, friable, sticky, plastic, porous; few, fine roots; abrupt, smooth boundary; laboratory sample number 317; pH 5.2; conductivity 0.04 millimho.

II C1 70-113 cm; light gray (10YR 7/2) sand with yellowish red (5YR 5/6) relatively harder material of loam texture and occurring as many, medium, prominent mottles; weak coarse, prismatic breaking to weak, coarse, subangular blocky; the loose, clean sand occurs as pockets and interspersed fillings; the loamy parts are hard, friable, slightly sticky, non plastic; porous; few, fine and medium roots; clear, smooth boundary; laboratory sample number 316 (70-83 cm) and 315 (83-133 cm); pH 5.8 for both samples; conductivity 0.04 and 0.07 millimho respectively.

11 C2 113-178 cm; strong brown (7.5YR 5/6), with many, medium, prominent, white (10YR 8/2) mottles; sand; loose, soft, non sticky, non plastic; few, fine roots; laboratory sample number 314; pH 5.8; conductivity 0.001 millimho.

I Information on the Site

Profile number: Pit No. 1, Selected Area A of Auxiliary Farm No. 1
Soil name and mapping unit symbol: Hake Series, M43 W1
Higher category classification: Aquic Tropustultic Dystropept
Date of examination: 30 January 1969
Author of description: S. Sivarajasingham
Location: FAO Pilot Irrigation Development Scheme in the Accra Plains of Ghana
Elevation: about 43 ft above mean sea level
Land form: Floodplain
Slope: 0-2 percent
Vegetation or land-use: tall grass bush and scattered tall trees
Climate: Coastal dry zone (savannah)

II General Information on the Soil

Parent material: Recent floodplain alluvium
Soil drainage class: imperfectly drained
External soil drainage (runoff): slow
Internal soil drainage: imperfect
Permeability: moderately rapid
Moisture conditions in the soil: moist, due to recent rain
Water table: probably about 15 ft
Surface stones or rock outcrops: none
Evidence of erosion: none
Evidence of salt or alkali: none
Human influence: grass frequently burnt

III Brief General Description of the Profile

The Hake Series is a deep, imperfectly drained moderately rapidly permeable, medium textured, friable brownish yellow soil.

IV Description of Individual Soil Horizons

A11 0-8 cm; very dark grayish brown (10YR 3/2) to very dark brown (10YR 2/2) light loam; weak, fine subangular blocky and weak, medium and fine granular peds held together by many fine and common medium, and few coarse roots, soft, friable, slightly sticky, slightly plastic; porous; high in humus,clear smooth, lower boundary; laboratory sample number 201; pH 5.6; conductivity 0.67 millimho.

A12 8-15 cm; dark grayish brown (10YR 4/2) to very dark grayish brown (10YR 3/2) silt loam; weak, coarse, subangular blocky breaking to weak, fine and very fine, subangular blocky, soft, friable, slightly sticky, slightly plastic; porous, many fine and common medium roots; termites common; clear smooth, lower boundary; laboratory sample number 202; pH 6.8; conductivity 0.12 millimho.

A3 15-28 cm; brown (7.5YR 5/4), no mottles; loam, weak, coarse subangular blocky breaking to weak, fine subangular blocky, friable, slightly sticky, non plastic, many fine and medium pores, no clay skins on pore walls or ped faces; many fine and common medium roots, clear, smooth, lower boundary; laboratory sample number 203; pH 5.4; conductivity 0.05 millimho.

B2 28-40 cm; dark brown (7.5YR 3/2) ped exterior and brown to dark brown (7.5YR 4/4-4/2) ped interior with white (10YR 8/2) deposits in pores; loam to sandy loam; common pottery places and quartz pebbles; weak coarse subangular blocky friable, slightly sticky, non plastic; many fine pores, no clay skins on pore walls or ped faces; many fine pores, common, fine and medium roots; clear wavy lower boundary; laboratory sample number 204; pH 5.4; conductivity 0.05 millimho.

$A^{1}2$ 40-55 cm; dark brown (7.5YR 3/2) and brown (10YR 5/3) ped exterior and strong brown (7.5YR 5/6) ped interior white (10YR 8/2) filling in pores light fine sandy clay loam, the white deposits in the pores are clean sand grains washed free of all clay common pottery pieces and pieces of fresh garnetiferous rock; breaking into hard, strong, coarse angular blocky and friable weak, medium subangular, blocky peds; slightly sticky, slightly plastic; many, fine and medium pores; common fine and few medium roots; abrupt wavy lower boundary; laboratory sample number 205; pH 5.4; conductivity 0.08 millimho.

II B21 55-73 cm; dark brown to brown (7.5YR 4/4) with common, coarse, faint, dark yellowish brown (10YR 4/4) and few, fine distinct brownish yellow (10YR 6/8) and fine,prominent mottles on ped surface, and these and many, coarse, distinct grayish brown (2.5Y 5/2) and many, fine distinct greenish gray (5Gy 5/1) mottles in ped interior very sandy clay loam; hard, dense strong coarse, subangular blocky and fine soft weak, fine, subangular blocky; sticky, plastic, many fine pores, clay skins less prominent and less continuous than in underlying horizon,few, fine roots; clear, smooth, lower boundary; laboratory sample number 206; pH 7.0; conductivity 0.28 millimho.

II B22 73-113 cm; brown (7.5YR 5/4-5/2) ped surface with common, medium faint dark grayish brown (10YR 4/2) and few, medium, prominent, black mottles, and yellowish brown (10YR 5/6) ped interior; heavy silty clay; hard dense, strong, coarse subangular blocky breaking to friable moderate, fine subangular blocky with distinct ped faces; sticky plastic common, fine pores, clay skin on ped faces; few fine roots; many fine and medium old root channels filled with AI - like material; clear, smooth lower boundary; laboratory sample number 207; pH 7.4; conductivity 1.25 millimhos.

II C1 113-148 cm; brown (7.5YR 5/4) with common, medium, distinct, yellowish red (5YR 4/6) and few, medium, distinct, yellowish brown to strong brown (7.5YR 5/6-10YR 5/6), few fine, prominent, light gray (2.5Y 7/2) and few, fine, distinct black mottles; light silty clay; hard, dense, strong coarse subangular blocky breaking into friable weak, fine angular blocky sticky, plastic; few old root pores; few old root channels filled with A1 - like material, clay skins on ped faces; clear smooth lower boundary; laboratory sample number 208; pH 7.2; conductivity 2.5 millimhos.

II C2 148-180 cm; variegated with coarse, prominent mottles of yellowish ped light brownish gray (2.5YR 5/4) in approximately equal amounts and few, fine, distinct, black mottles; light silty clay; moderate medium, subangular blocky breaking to weak fine angular blocky; friable sticky, plastic, few, fine pores and few, thin skins on pore walls and ped faces, very few fine roots; laboratory sample number 209; pH 6.2; conductivity 1.97 millimhos.

Augured a further 120 cm (i.e. to a total depth of 300 cm), with depth grayish colours become more common and the texture changes through sandy loam to finally sand at about 300 cm; laboratory samples numbers 210 and 211; pH 7.4 and 7.2 respectively; conductivity 2.05 millimhos for both samples.

I <u>Information on the Site</u>

Profile number: Pit No. 2, Pilot Area A
Soil name and mapping unit symbol: Amo Series, M43 W2
Higher category classification: Tropaqueptic Typic Tropaqult
Date of examination: 27 April 1969
Author of description: S. Sivarajasingham
Location: FAO Pilot Irrigation Development Scheme in the Accra Plains of Ghana
Elevation: about 28 ft above mean sea level
Land form: Floodplain, lower slopes
Slope: almost flat (0-1%) slopes
Vegetation or land-use: tall grass and few scattered short trees
Climate: Coastal dry zone (savannah)

II General Information on the Soil

Parent material: recent floodplain alluvium
Soil drainage class: poorly drained
External soil drainage (runoff): slow
Internal soil drainage: poor
Permeability: slow
Moisture conditions in the soil: dry down to 111 cm
Water table: probably within 10 ft
Surface stones or rock outcrops: none
Evidence of erosion: none
Evidence of salt or alkali: none
Human influence: frequently burnt

III Brief General Description of the Profile

Amo Series is a deep, poorly drained brownish yellow soil with a friable silty clay loam surface soil commonly abruptly thin, strongly prismatic, very firm clay subsoil. The lower subsoil is angular blocky silty clay. Cracks extend vertically from the surface to a depth of about 108 cm.

IV Description of Individual Soil Horizons

A1 0–10 cm; very dark grayish brown (10YR 3/2) moist colour with few, fine, distinct dark yellowish brown (10YR 4/4) mottles, light silty clay loam, moderate, medium granular; soft, friable, slightly sticky, slightly plastic; porous, bulk density of 1.2 grammes (g), 1cc. many fine roots, clear smooth lower boundary; laboratory sample number 263, pH 5.2, conductivity 0.51 millimho.

A12 10–13 cm; white (10YR 8/2) dry colour and on moistering grayish brown (10YR 5/2) moist colour with many, fine distinct yellowish brown (10YR 5/4) and brown (7.5YR 5/4) mottles, silty clay loam; moderate coarse, angular blocky breaking to moderate, fine and medium subangular blocky; hard, friable, sticky; slightly plastic; porous, bulk density of 1.3 g/cc; few, fine roots, abrupt, smooth lower boundary; laboratory sample number 226; pH 5.4; conductivity 0.06 millimho.

B2 31–78 cm; light brownish gray (10YR 6/2) moist colour with medium fine, prominent, red (2.5YR 5/8) and common, fine prominent strong brown (7.5 5/8) mottles; clay; strong, coarse prismatic with inclined basal slickenside-like cleavage planes, very hard, very sticky, plastic, very dense, bulk density of 1.5 to 1.6 g/cc; few, fine roots, especially along the coarse and vertical ped faces; clear, smooth, lower boundary; laboratory sample number 225; pH 5.6; conductivity 0.29 millimho.

CII 78–111 cm; light brownish gray (2.5Y 6/2) moist colour with common fine, prominent red (2.5YR 4/8), yellowish red (5YR 5/8) and reddish yellow (7.5YR 6/8) mottles silty clay; moderate medium angular blocky with smooth ped faces; very hard, very firm, very strong, sticky, plastic; very dense, bulk density of 1.7 g/cc; very few, fine roots; clear smooth lower boundary; laboratory sample number 224; pH 6.0; conductivity 1.18 millimhos.

C12 111-133 cm; light brownish gray (2.5Y 6/2) moist colour with many coarse, prominent, strong brown (7.5YR 6/6) and few medium distinct yellowish brown (10YR 5/6) mottles; silty clay; moderate, medium angular blocky with smooth ped faces firm, very sticky, very plastic; very dense, bulk density of 1.7 g/cc; no roots; clear smooth boundary; laboratory sample number 223; pH 6.2; conductivity 1.86 millimhos.

C21 133-151 cm; light brownish gray (2.5Y 6/2) moist colour with many medium, prominent brown to dark brown (7.5YR 4/4) and few, medium distinct, yellowish brown (10YR 5/6) mottles; light silty clay moderate medium, angular blocky with smooth ped faces; very firm, very sticky, plastic, very dense, bulk density of 1.6 g/cc; clear smooth boundary; laboratory sample number 222; pH 6.6; conductivity 1.86 millimhos.

C22 151-172 cm; light brownish gray (2.5Y 6/2) moist colour with common medium, prominent, reddish yellow (7.5YR 6/6) and fine medium, distinct, yellowish brown (10YR 5/6) mottles; light silty clay to silty clay loam; moderate, medium angular blocky with smooth ped faces; firm, very sticky, plastic dense no roots; laboratory sample number 221; pH 6.8; conductivity 2.70 millimhos.

I Information on the Site

Profile number: Pit No. 12, Pilot Area A
Soil name and mapping unit symbol: Amo Series, Heavy Textured Variant, H43 W2
Higher category classification: Tropaquoptic Typic Tropaquult
Date of examination: 3 May 1969 at the end of a long, dry season
Author of description: S. Sivarajasingham
Location: FAO Pilot Irrigation Development Scheme, in the Accra Plains of Ghana
Elevation: about 20 ft above mean sea level
Land form: Floodplain, lower slopes
Slope: almost flat (0-1%) slope
Vegetation or land-use: tall grass and scattered short bushes
Climate: Coastal dry zone (savannah)

II General Information on the Soil

Parent material: recent floodplain alluvium
Soil drainage class: poorly drained
External soil drainage (runoff): slow
Internal soil drainage: poor to very poor
Permeability: slow to very slow
Moisture conditions in the soil: dry up to 61 cm; slightly moist up to 106 cm; and moist below 106 cm
Water table: probably within 10 ft
Surface stones or rock outcrops: none
Evidence of erosion: none
Evidence of salt or alkali: none
Human influence: frequently burnt

III Brief General Description of the Profile

The Amo Series, Heavy Textured Variant, is a deep brownish yellow poorly drained soil with a friable silty clay surface over a very firm, strongly prismatic clay subsoil.

IV Description of Individual Soil Horizons

A1 0-8 cm; light gray to gray (10YR 6/1) dry colour and very dark gray (10YR 3/1) moist colour; silty clay; strong, fine subangular blocky and strong, medium, granular, hard, friable, very sticky, plastic; very porous; many fine roots; clear smooth boundary; laboratory sample number 281; pH 5.4; conductivity 0.19 millimho.

A3 8-17 cm; dark gray (10YR 4/1) moist colour with many prominent strong brown (7.5YR 5/6) mottles; silty clay, strong fine subangular blocky and strong medium granular; hard to very hard, friable very sticky, very plastic; very porous, many fine and medium roots; clear wavy boundary; laboratory sample number 280; pH 5.4; conductivity 0.12 millimho.

B2 17-61 cm; gray (10YR 5/1) moist colour with few, fine, prominent strong brown (7.5YR 5/6) mottles; strong, very coarse, prismatic breaking down to strong, coarse, prismatic in turn breaking down in moderate coarse angular blocky; very hard, very firm, very sticky, very plastic dense, thick clay skins on ped faces and as channel linings, common, fine roots, gradual, smooth boundary; laboratory sample number 279; pH 5.6; conductivity 0.10 millimho.

B3 61-106 cm; light gray (5Y 7/1) moist colour with common, medium prominent, reddish yellow (7.5YR 6/5) mottles in ped interior and on slickenside-like faces, clay, strong coarse prismatic with prominent basal slickenside-like faces and breaking into weak; medium, prismatic and angular blocky; very hard to very firm, very sticky, very plastic; very few, fine roots, gradual, smooth boundary; laboratory sample number 278; pH 5.6; conductivity 0.93 millimho.

C11 106-143 cm; light gray (5Y 7/1) moist colour with many, medium, prominent yellowish brown (10YR 5/6) and reddish brown (10YR 5/6) mottles in ped interior; clay strong, medium prismatic with prominent basal slickenside-like faces and breaking into weak coarse angular blocky and in turn into medium angular blocky, firm, very sticky, very plastic, very few fine roots especially along the slickenside-like faces; gradual, smooth boundary; laboratory sample number 277; pH 5.4; conductivity 1.75 millimhos.

C12 143-179 cm; light gray (5Y 7/1) with moderate, medium, prominent yellowish brown (10YR 5/6) and strong brown (7.5YR 5/6) mottles in ped interior; clay strong coarse, angular blocky and prominent slickenside-like faces; very firm, very sticky, very plastic, very few fine roots; laboratory sample number 276; pH 5.2; conductivity 2.3 millimhos.

I Information on the Site

Profile number and location: Pit No. 6, Pilot Area A
Soil name and mapping unit symbol: Tefle Series, V45 W3
Higher category classification: Vertic Tropaquept
Date of examination: 30 April 1969, end of the long, dry season
Author of description: S. Sivarajasingham
Elevation:
Land form: Middle of broad valley floor in an area of recent alluvial deposits
Slope: less than 0.25 percent
Vegetation or land-use: tall grass and short trees mainly Mitragyna
Climate: Coastal dry zone (savannah)

II General Information on the Soil

Parent material: alluvial material from Volta River mixed with material washed from the adjoining area of garnetiferous hornblende gneiss
Soil drainage class: very poorly drained
External soil drainage (runoff): very slow to ponded
Internal soil drainage: very slow
Permeability: very slow
Moisture conditions in the soil: moist throughout
Water table: probably within 10 ft
Surface stones or rock outcrops: nil
Evidence of erosion: none
Evidence of salt or alkali: none, except for any indication of the prismatic structure
Human influence: annual burning of grass accidentally or purposely to replace the coarse grass with tender shoots

III Brief General Description of the Profile

The Tefle Series is a very poorly drained, deep, gray, mottled heavy clay with a strong, very coarse prismatic structure in the upper subsoil.

IV Description of Individual Soil Horizons

A1 0-7 cm; very dark gray (N 3/0) to black (W 2/0) moist colour, silty clay; strong, medium, granular and strong, fine, angular blocky held together by a dense mat of fine and medium roots; friable, sticky, very plastic, abrupt, smooth, lower boundary; laboratory sample number 263; pH 5.2; conductivity 0.51 millimho.

B2 7-41 cm; very dark gray (N 3/0) to dark gray (N 4/0) moist colour with common, fine, distinct, yellowish red (5YR 5/6) mottles along root channels, coarse, angular blocky, very firm, very sticky, very plastic, common, fine and medium roots and few, coarse roots; clear, smooth, lower boundary; laboratory sample number 262; pH 5.4; conductivity 0.32 millimho.

B31 41–87 cm; gray (5Y 5/1) interior with many, medium, prominent strong brown (7.5YR 5/6) mottles and gray (N 5/0) slickensides, clay; strong, coarse, prismatic breaking down to strong, coarse, angular blocky and medium, subangular blocky; very firm, very sticky, very plastic; strongly developed, inclined slickensides; few, fine and medium roots; gradual, smooth, lower boundary; laboratory sample number 261; pH 5.6; conductivity 0.36 millimho.

B32 87–125 cm; gray (5Y 5/1) interior with common, fine prominent, strong brown (7.5YR 5/6) mottles; gray (N 5/0) slickensides; clay weak, medium, subangular blocky; very firm very sticky, very plastic; many strongly developed inclined slickensides; few, fine roots mostly along slickensides; gradual, smooth, lower boundary; laboratory sample number 260; pH 5.6; conductivity 0.85 millimho.

B33 125–155 cm; gray (5Y 5/1) to dark gray (5Y 4/1) with common, fine, prominent, strong brown (7.5YR 5/6) mottles; clay; moderate, medium, subangular blocky; very firm, very sticky, very plastic; few slickensides; few, fine roots mostly along slickensides; gradual, smooth, lower boundary; laboratory sample number 259; pH 5.4; conductivity 0.72 millimho.

B34 155–180 cm; gray (5Y 5/1) to dark gray (5Y 4/1) with common, fine, prominent, strong brown (7.5YR 5/6) and few, fine, distinct, black, presumably manganese-rich, mottles; clay; strong, coarse, angular blocky and strong, medium, subangular blocky; very firm, very sticky and very plastic; few slickensides; few roots mostly along slickensides; laboratory sample number 258; pH 5.0; conductivity 2.9 millimhos.

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