SK

STICHTING VOOR BODEMKARTERING

WAGENINGEN

STI BO KA

A preliminary assessment of the (available) existing soil information of Nyankpala Agricultural Experiment Station (Tamale, Northern Ghana)

SOIL SURVEY INSTITUTE (STIBOKA)
P.O. Box 98
6700 AB Wageningen, Netherlands
Tel. 08370-19100

Project nr. 89.85.37
Rapport nr. 1912

A preliminary assessment of the (available) existing soil information of Nyankpala Agricultural Experiment Station (Tamale, Northern Ghana)

G. Serno
R.F. van de Weg

July, 1985

TABLE OF CONTENTS

Attached: Map: NAES, General soil information

1 BACKGROUND AND INTRODUCTION

The Nyankpala Agricultural Research Station (NAES), located approximately 12 km west of Tamale town, Northern Ghana, receives since 1977 technical and financial assistance from the "Deutsche Gesellschaft für Technische Zusammenarbeit", GTZ. Following the findings of the 1982 evaluation of the project (Evaluation Report, 1982), a soil fertility expert/agronomist, Dr. H. Tiessen, was posted in Tamale as from early 1984.
In the past, a detailed soil survey was carried out on the station (Adu, 1957), while additional soil survey information on Northern Ghana of varying detail was supposed to be available. However very little of this information is at present readily available in Ghana.
Keeping the above consideration in mind, Dr. Tiessen, through GTZ, requested the Netherlands Soil Survey Institute (STIBOKA) to assist in the collection of the existing soil information and "to re-interprete the existing survey information in terms of the Soil Taxonomy and to enable agronomist-users of the soil information to describe experimental sites and compare soils on and off the station. At the same time an understanding of the soil formation in the area should be acquired in order to identify recent impacts on the soils such as degradation and erosion".
Fortunately a topographical map at scale 1 : 10 000 of the station has been prepared recently (Amamoo-Otchere, 1984). Taking into account that a detailed soil map of the station exists (scale 1 : 12 500, Adu, 1957) and the fact that more soil information on the soils in the region was available, a complete new soil survey of the whole station did not seem appropriate at the moment, also in view of the high costs involved. It was therefore proposed to transfer the existing soil information (1957) to the new topographical station map (this was recently - November 1984 - done in Ghana), to check the reliability of the soil information, to make the soil information, contained in map legend and report, more accessible for the user and to classify the soil mapping units according to some internationaly accepted soil classification systems, as far as possible using the available laboratory data.
During his visit to the Netherlands, in November 1984, Dr. Tiessen and Stiboka decided on the following terms of reference for the consultancy:

1) collection of all soil maps and reports of Northern Ghana: photocopying of reports, reproduction of maps
2) assessment of available existing soil information of Nyankpala station, and "translation" of data in preliminary "Soil Taxonomy" soil classification nomenclature
3) assessment of representativeness of Nyankpala station for the Volta basin (in terms of soil conditions)
4) assessment of representativeness of "on farm sites" for the Northern and Upper regions (in terms of soil conditions).

Ad 1) Contacts were made with several soil-libraries and institutions. Dr. Tiessen visited in November 1984 the Soil Survey of Ghana, based in Kumasi. All available and relevant soil reports and maps were collected and, if relevant, photocopied resp. reproduced in the Netherlands. Copies of all relevant material were handed over to Dr. Tiessen. An inventory of available Northern Ghana natural resources information was made in particular at:

- Royal Tropical Institute, Amsterdam, the Netherlands
- International Soil Reference and Information Centre (ISRIC), Wageningen, the Netherlands
- Library, Land Resources Development Centre (LRDC), Surbiton, England
- Soil Resources Branch, AGLS, FAO HQ, Rome (See annex I)

Ad 2 and 3) In Chapter 8 the references are indicated which were available and have been used in the compilation of this report. These maps, reports and literature are available for reference at Stiboka, Wageningen resp. Nyankpala Station.

Ad 4) This item could only partially be covered as non-availability of more elaborate soil maps prevents a further elaboration (e.g. Tamale region, 1 : 250 000) of representativeness of certain areas.

The draft report (April, 1985) was handed over to Dr. H. Tiessen (NAES) for review and comments. His comments are incorporated in the final version of the report (July, 1985). His general comments based on field observations in the station are added as Annex II.

2 DESCRIPTION OF THE SOIL SERIES AT NYANKPALA AGRICULTURAL EXPERIMENT STATION (NAES)

In this section, descriptions are given of the soil series of the station, based on Adu, 1957 (Report on the detailed soil survey of the Central Agricultural Station, Nyankpala).
For every series a tentative classification using the Soil Taxonomy (1975) and the FAO Soil Map of the World Legend (1974) is added. The classifications are based on soil profile descriptions, with or without accompanying physical and chemical data, of soil series corresponding to the soil series found on the station.
Some of the profile descriptions and analytical data used for classification were available from sites on the station (in Obeng, 1970 and the I.S.S.C. Post Conference Fieldtour profiles, Adu, 1975); other soil profile descriptions and analyses used were mainly taken from FAO, Vol. III (1967).
The chemical and physical parameters used for classification are soil texture, base saturation and CEC, in addition to such soil characteristics as color, mottling and presence of clay cutans.

For additional information on vegetation, survey procedures, climate etc. one is referred to Adu (1957).

1. Tingoli series (4.7% of NAES station)

Well drained, shallow to moderately shallow[1], locally slightly deeper, profiles, consisting of approx. 15 cm brown to dark brown fine sand with locally small ironstone gravels, overlying (to approx. 60 cm depth) brown, fine sandy clay with moderate amounts of small ironstone concretions, overlying (to approx. 150 cm depth) tightly packed ironstone concretions in reddish-brown sandy clay, in places with abundant ferruginized sandstone fragments and with masses of soft ironstone (plinthite?[2]).
With increasing depth the ironstone concretions become more tightly packed. Below approx. 150 cm reddish-brown, sandy clay with sandstone fragments and partially weathered sandstone.

pH[3] : 0 - 60 cm: 6.6 - 6.9
60 - 150 cm: 5.1 - 5.5

Physiographic position: Summit and upper slopes.

Tentative soil classification:

- Ghana : Savannah Ochrosol.
- Soil Taxonomy: Paleustalf, sandy over clayey-skeletal phase
or Plinthustalf, sandy over clayey-skeletal phase
- FAO : Chromic Luvisol, petric phase[2]
or Plinthic Luvisol, petric phase[2]

N.B.

1) Soil depth refers to depth to ironstone, rock or tightly packed ironstone concretions.

2) The terms plinthite, petric and petroferric phase are defined in Appendix A.

3) pH = pH-H2O (Hellige-Truog Soil Reaction Tester).

2.a Tolon series (12.5%, incl. 2.b)

Well drained, shallow to moderately shallow profiles, consisting of up to 25 cm dark brown slightly humous fine sand, overlying (to 45-60 cm depth) orange-brown to brown sandy clay with masses of soft ironstone (plinthite?) and ferruginized sandstone fragments. Below approx. 150 cm gray and brown mottled clay with weathered sandstone and clay-shale fragments. Locally with gravel pavement and with ironpan exposures at the surface.

pH : 6.6 - 6.9

Physiographic position: Middle slopes.

Tentative soil classification:

- Ghana : Savannah Ochrosol.
- Soil Taxonomy: Paleustalf, sandy over clayey-skeletal phase or Plinthustalf, sandy over clayey-skeletal phase.
- FAO : Chromic Luvisol, petric phase or Plinthic Luvisol, petric phase possibly: Luvic Phaeozem, petric phase.

Remarks:

The difference between the Tingoli and Tolon series consists mainly of a redder soil matrix and a less well developed A horizon of Tingoli series.

2.b Tolon series, eroded phase

Well drained, very shallow sandy profiles with exposed sandstone. Below 50-90 cm depth brown and gray mottled clay with partly weathered sandstone and clay-shale fragments, overlying clay-shale bedrock.[1)]

pH : 5.1 - 6.0

Physiographic position: Slightly steeper upper slopes.

Tentative soil classification:

- Ghana : Savannah Ochrosol/Lithosol intergrades.
- Soil Taxonomy: Psamment, sandy skeletal (Lithic Ustipsamment?).
- FAO : Eutric Regosol.

3. Nyankpala series (53.7%)

Well drained, shallow, locally very shallow profiles; consisting of approx. 15-30 cm dark brown to pale grayish brown loamy fine sand, in places with scattered ironstone gravel and with a slightly humous topsoil, overlying approx. 150 cm of closely packed ironstone concretions in orange-brown to brown silty clay, with masses of soft ironstone (phinthite?). Below 180 cm mottled clay and weathered clay-shale.
Locally with gravel pavement and with ironpan exposures at the surface.

pH : 6.1 - 6.5

1) The soil depth class "very shallow" refers to the common large, exposed sandstone blocks at the surface.

Physiographic position: Upper slopes and crests.

- Ghana : Savannah Ochrosol.
- Soil Taxonomy: Plinthustalf, sandy over clayey-skeletal phase or Paleustalf, sandy over clayey-skeletal phase.
- FAO : Plinthic Luvisol, petric phase or Albic Luvisol, petric phase or Chromic Luvisol, petric phase.

4. Kumayili series (0.6%)

Well drained, moderately deep to deep profiles, consisting of approx. 30 cm dark brown, slightly humous fine sand, overlying (to 90-120 cm depth) orange-brown fine sandy clay, texture heavier with increasing depth, overlying fairly soft massive ironstone (plinthite?) to approx. 180-200 cm depth.

pH : 6.1 - 6.5

Physiographic position: Drainage grooves in middle slopes.

Tentative soil classification:

- Ghana : Savannah Ochrosol.
- Soil Taxonomy: Paleustalf, clayey or Plinthustalf, clayey.
- FAO : Orthic Luvisol or Plinthic Luvisol.

5. Kpelesagwu series (12.5%)

Imperfectly drained, shallow to moderately shallow profiles, consisting of 15-30 cm pale grayish brown fine sand, slightly humous at the surface, with scattered ironstone concretions, overlying (to approx. 60 cm depth) pale grayish brown or brown to orange-brown, loamy sand to sandy loam with some ironstone concretions, overlying (to approx. 150 cm depth) closely packed ironstone concretions in brownish gray sandy clay and with soft ironstone (plinthite?). Below approx. 150 cm silty clay with some ironstone concretions and clay-shale fragments.

Some general physical and chemical data on Kpelesagwu series, based on USOM (1959), Adu (1969), Adu and Stobbs (1981), Adu (1975), Brammer in Brian Wills (1962) and FAO (1967).
The soil reaction is usually slightly acid to slightly alkaline in the topsoil (6.3 - 7.2) and very acid to slightly acid in the subsoil (5.4 - 6.2). The organic carbon content is low (<1.5%)[1]. The clay content varies from 5-10% in the topsoil to 20-45% in the subsoil. The silt content is relatively high with values of 15-30%. The content of (mainly fine) sand varies from 60-85% in the topsoil to 40-60% in the subsoil. It should be noted that the textures described elsewhere for the B horizon of Kpelesagwu series range from sandy loam, sandy clay loam and silty clay loam to silty clay. Kpelesagwu series with a sandy clay texture were not found in the literature, other than in Adu (1957) for the NAES Kpelesagwu series. The total content of bases varies from 5-7 meq/100 g in the topsoil to 3-15 meq/100 g in the subsoil and is therefore low to medium.

The CEC is variable; in the topsoil it may have values of 4-6 meq/100 g and in the subsoil 4-20 meq/100 g. The base saturation is high in the topsoil (90-95%) and usually over 50% in the subsoil, although some profiles with lower values occur. The total P content is low to medium (50-300 ppm), but due to the acidic conditions considerable amounts of this may be fixed, especially in the subsoil.

	sand %	silt %	clay %	pH H_2O	org.C %	CEC meq/100 g	TEB	Base sat.%	Total P ppm
topsoil	45-75	15-45	5-10	6.3-7.2	0.8-1.4	3- 6	3- 6	90-95	70-150
subsoil	40-65	15-45	10-45	4.8-6.4	0.1-0.9	4-20	3-15	35-75	50-300

[1)] The inherent fertility of Ghana soils may, according to de Endredy in: Adu and Stobbs (1981), generally be categorized as followes:

	org. C %	CEC meq/100 g	base sat. %	total P ppm
very low	<0,7	0-3	<20	<100
low	0,7	3-5	20-50	100-250
medium	0,7-2,5	5-10	50-80	250-500
high	>2,5	>10	>80	>500

Physiographic position: middle and lower slopes.

Tentative soil classification:

- Ghana : Groundwater Laterite.
- Soil Taxonomy: Plinthustalfs, sandy over clayey-skeletal phase
  or Paleustalfs, sandy over clayey-skeletal phase
  possibly: Tropaqualfs, sandy over clayey-skeletal phase
  or Plinthaqualfs, sandy over clayey-skeletal phase.
- FAO : Plinthic Luvisol, petric phase
  or Gleyic Luvisol, petric phase
  or Albic Luvisol, petric phase
  in places Luvic Arenosol, petric phase.

6. Changnalili series (8.3%)

Poorly drained, shallow to moderately deep profiles, consisting of up to 25 cm pale brownish gray, slightly humous fine sand, possibly with some ironstone gravel, with rusty mottles, overlying (to approx. 50-90 cm depth) yellowish gray loamy fine sand to (silt) loam with brown and yellowish mottles, overlying massive ironstone, hard at the top but softer below.
Below approx. 120 cm green or gray mottled clay over clay-shale. Earthworms are abundant in this soil series.

Some general physical and chemical data on Changnalili soils based on Adu (1975), Adu and Stobbs (1981) and FAO (1967): The soil reaction is usually slightly to moderately acid (5.6-6.5), with the topsoil having somewhat higher values. Lower values can occur. The content of organic carbon is low (<1%). The clay content varies from 5-15% in the topsoil to 5-60% below. The CEC differs; low values of 2-5 meq and higher values of 7-15 meq/100 g may occur. The TEB is also rather variable. The base saturation is high in the topsoil (more than 90%) and variable in the subsoil, although generally above 50%. The total P content is low to medium (50-300ppm).

	sand %	silt %	clay %	pH H_2O	org.C %	CEC meq/100 g	TEB meq/100 g	Base sat. %	Total P ppm
topsoil	50-60	25-45	5-15	4.9-7.1	0.6-1.0	2- 8	2- 7	95-100	60-200
subsoil	25-60	15-50	15-60	4.4-6.3	0.1-0.7	3-18	2-17	35- 90	50-300

Physiographic position: edges of valley bottoms.

Tentative soil classification:

- Ghana : Groundwater Laterite.
- Soil Taxonomy: Tropaqualf, sandy or loamy over petroferric contact. In places: Aquic Quartzipsamment, sandy over petroferric contact.
- FAO : Gleyic Luvisols, petroferric phase or Albic Arenosols, petroferric phase.

Remarks:

1. Depth. Generally (FAO Vol. III, 1967, Adu and Stobbs 1981, Obeng 1970, I.S.S.C.-profiles) the Changnalili profiles are very shallow to shallow and appear shallower than those on the station.
2. The texture of the B horizon (40-70/120 cm) of the elsewhere described Changnalili series is usually sandy (clay) loam, clay loam, silty clay or silty clay loam.

7. Volta series (7.7%)

Poorly drained, deep to very deep profiles, consisting of approx. 30 cm dark gray, slightly humous silt loam with rusty mottles, overlying to a depth of approx. 60 cm, orange or yellow, gray mottled fine sandy clay to silty clay overlying (to approx. 120 cm depth) red and gray mottled, compact silty clay, possibly with thin ironstone layers.

Some general physical and chemical data on Volta series based on Adu (1969), Adu and Stobbs (1981), USOM (1959), Adu (1975) and FAO (1967):

Due to the alluvial nature of this series, with colluvial influence from the sides of the valleys, the texture is rather variable. Generally, the lower horizons are less sandy than the upper horizons. The silt content is relatively high, especially in the subsoil (15-50%).

The soil reaction is also rather variable in topsoils as well as in the subsoil: 4.3-6.2. The content of organic carbon is generally below 1%, although exceptions may occur.

The CEC and the TEB vary widely in the different profiles, but lie generally between 3 and 15 meq/100 g. The base saturation is above 50% in the upper horizons and is very variable in the lower horizons, both between profiles as within profiles. The content of total P is generally low, below 100 ppm, but in some profiles higher values may occur. These soils can be rated to have a low to medium fertility.

	sand %	silt %	clay %	pH H_2O	org.C %	CEC meq/100 g	TEB meq/100 g	Base sat. %	Total P ppm
topsoil	20-80	15-55	5-25	4.3-6.2	0.5-3.5	2-21	2-18	50- 95	50-360
subsoil	5-80	15-55	15-50	4.4-6.0	0.1-0.6	2-14	1-14	10-100	30-170

Physiographic position: Valley bottoms.

Tentative soil classification:

- Ghana : Savannah Gleisols.
- Soil Taxonomy: (Vertic) Tropaquepts, clayey.
- FAO : Eutric Gleysols or Dystric Gleysols.

Remarks:

1. The pH range is fairly similar to other Volta series descriptions given elsewhere.
2. The texture description resembles other Volta series descriptions given elsewhere.

3 SOIL SERIES CLASSIFICATION

3.1 Ghana soil classification system

Most of the soils of the Nyankpala Agricultural Station belong either to the Savannah Ochrosols, the Groundwater Laterites or the Savannah Gleisols.

3.1.1 The Savannah Ochrosols

The Savannah Ochrosols, as described in the East Dagomba Agricultural and Livestock Survey, USOM Survey Team, (1959), "are red to brown soils, relatively well drained, friable, porous, moderately permeable, neutral to slightly acid (pH 6.6 - 6.9) in reaction in the surface horizons, moderately acid (pH 5.6 - 6.0) below, commonly concretionary with an ironpan often in the subsoil. They have a relatively low base exchange and moisture holding capacity."
The Tingoli, Tolon, Kumayili and Nyankpala series belong to the Savannah Ochrosols, whereby the Tingoli series is slightly redder coloured than the other 3 series.
Apart from the descriptions of the series in Adu, (1957), only Brammer (1957) in "A note on the utilization of the soils of the station and their relationships to those of the Voltaian basin as a whole", refers to the Tingoli, Tolon, Nyankpala and Kumayili series. Specific chemical and physical data on these series were not found in the literature available.
Brammer mentions however, that the Tingoli, Tolon and Kumayili series are not well provided with organic matter (compare Adu, 1957: "the humous layers of the Tingoli series have largely been lost") and nitrogen and phosphorus are in short supply.
Obeng (1975. 2, page 13-14) and Obeng (1975), page 7, give also some general characteristics of Savannah Ochrosols: they have less than 2% organic matter in the A horizon, a CEC of 1-15 meq/100g soil throughout the profile and a base saturation of more than 50% in the A horizon and less in the lower horizons. An argillic B horizon is present and the predominant clay mineral is kaolinite. In the same two publications, the Nyankpala series is mentioned individually and is grouped under the moderately shallow to moderately deep Savannah Ochrosols. On the station the Nyankpala series is less deep. With respect to the base saturation being less than 50% in the B horizons is it doubtful whether this applies to the Savannah Ochrosols of the station. See also 3.2.2.

3.1.2 The Groundwater Laterites

The Groundwater Laterites, as defined by Charter in USOM (1959), page 14, are "pale colored sandy to silty soils overlying seepage ironpan, or massive highly concretionary unconsolidated soft ironstone. The pan, or concretionary unconsolidated pan, rests on relatively impermeable weathered bedrock. These soils occur on very gentle topography, are waterlogged in the wet season and droughty in the dry season.
The surface and horizons above the pan are pale gray in color, neutral to slightly acid in reaction (pH 6.6 - 6.9), porous, readily permeable, and low in plant nutrients."

The Kpelesagwu and Changnalili series belong to the groundwater laterites.

3.1.3 The Savannah Gleisols

"The savannah gleysols are typically deep, light gray to dark, grayish brown, mottled, soils of depressions and are seasonally to permanently waterlogged. They are not fertile. They are moderately to strongly acid (pH 5.1 - 6.0) with a lighter textured surface and a heavier subsoil and a relatively good waterholding capacity." (Charter in USOM, 1959, page 15).
The Volta series belongs to the Savannah Gleisols.

3.1.4 The Lithosols

"These are shallow to very shallow, pale brown to brown, stony soils, developed over bedrock on gentle to steep slopes.
The soils are droughthy" (Charter in USOM 1959, page 15).
The Tolon series, eroded phase belongs to the Lithosols/Ochrosols intergrade.

3.2 Soil Taxonomy Classification System

3.2.1 General

The classification of most of the 7 soil series of the NAES presents difficulties.
First, due to the virtual absence of physical and chemical laboratory data on the Tingoli, Tolon, Kumayili and Nyankpala series. Second, because of sometimes insufficiently detailed profile descriptions. The classifications must therefore be considered as tentative.

The Soil temperature regime of the area: isohyperthermic (see: van Wambeke, 1982).

The Soil moisture regime: ustic, for some soils aquic.

3.2.2 The Tingoli, Tolon, Kumayili and Nyankpala series

These series belong to the Savannah Ochrosols. Savannah Ochrosols are classified as:

- Typic Vetustalfs? (FAO, Vol. III, 1967, page 57, using the 7th Approximation)
- Paleustults and Rhodustults (Obeng, 1975. 2, page 13).
- Paleustalfs and Haplustalfs (FAO, 1981).
- Ultisols and Alfisols (Huizing in Hornetz, 1984, probably referring to Savannah Ochrosols and Groundwater Laterites).
- Paleustults, Rhodustalfs and Haplustalfs (Adu and Stobbs, 1981).

Based on the soil series descriptions in Adu (1957), and the limited other information available (especially Obeng 1975. 2, page 13-14) it is most likely that the Tingoli, Tolon, Kumayili and Nyankpala series must be classified as Alfisols. Interpreting the term "soft ironstone" as used by Adu (1957) meaning plinthite, the soils fall in the plinthic subgroup of Ustalfs.

In case there is no plinthite as such, they are classified as Paleustalfs.

It is however possible, that some of these soils have a sufficiently low base saturation of the (argillic) B horizon to qualify as Ultisols. This is more likely the case with the Tingoli and Tolon- series than with the Nyankpala series, as the Tingoli and Tolon series are developed over less clayey and more sandy bedrock than the Nyankpala series.

Some evidence for the classification as Ultisols is found when the Tingoli and Tolon series are compared with a in some respects similar soil series, the Sambu series, (developed over sandy shale) of which more data are available (FAO Vol. III, 1967, pages 23 and 46 and USOM 1959). The Sambu series has rather variable base saturation figures in the argillic horizon from 11-40% to more than 80%. Therefore only laboratory determinations of the Tingoli, Tolon and Nyankpala series on the station can provide reliable data for classification.

The strongly contrasting texture between upper and lower horizons of these soils is indicated with the particle-size class: sandy over clayey- skeletal. The term skeletal indicates the highly concretionary (>35 vol.%) nature of the lower horizons.

3.2.3 The Kpelesagwu and Changnalili series

The Kpelesagwu and Changnalili series belong to the Groundwater Laterites, which were by different authors classified as:

- Oxisols (Aquox and Idox), 7th Approximation Classification in FAO, Vol. III (1967).
- Oxisols (Obeng, 1970).
- Tropaqualfs (International Soil Science Conference field tour profiles no. 9 and no. 3, 1975).
- Ustalfs (Int. Soil Science Conference field tour profile no. 3 1975).
- Plinthaqualfs and Plinthustalfs (Adu and Stobbs, 1981).
- Eutropepts and Tropaquepts (Obeng, 1975. 2).
- Petrosols (Obeng, 1970).

The different classifications reflect, besides a possible range in profile characteristics the question:
- is there an argillic or oxic horizon in the profiles?

and further:
- is there plinthite in the lower horizons?
- how to classify the widely different textural characteristics of a sandy topsoil over a concretionary or indurated horizon?

The classifications made in this report were based on the following considerations:
1. The soils do not have an oxic horizon, because the CEC of the clay fraction is too high (see profile I.S.S.C. no. 3, Kpelesagwu series: CEC of the B horizon (16-174 cm) is 30-50 meq/100 g clay) and "the soils are high in total silica, generally more than 40% and may contain appreciable amounts of 2:1 lattice clays in lower horizons (Obeng 1970, pages 163-164).

2. The soils are not Ultisols, because the base saturation is too high (>50%).

3. Whether or not the soils have an argillic horizon is doubtful. Obeng (1970), page 164, gives some reasons why the ironpan soils are not Alfisols:
   a. they are too highly weathered and are devoid of primary minerals, but are rich in sesquioxides of Fe, Mn and Al
   b. they have no oriented clay cutans
   c. they are high in Fe-P and Red-P forms of phosphorus
   d. some ironpan soils have very low CEC

Obeng, thus having objected against the classification of the ironpan soils as Alfisols or Oxisols, proposes a new Soil Taxonomy order, the "Petrosols" and suggests definitions for great soil groups, subgroups and family levels (Obeng, 1970).

As this addition to the Soil Taxonomy has not been adopted (Obeng's "Petrosols" only seem to apply to soils with solid sheet ironpans, mainly the Changnalili series, and not to the more common highly concretionary soils without a completely indurated horizon) and as there is some evidence for the presence of clay cutans the Kpelesagwu and Changnalili series are in this report considered as having an argillic horizon and are thus classified as Alfisols.

Depending on the physiographic position and drainage conditions, the Kpelesagwu series is on the better drained, slightly higher positions classified as Paleustalf or Plinthustalf, resp. soils without and with sufficient plinthite within 125 cm from the surface.
On the lower, wetter locations the Tropaqualfs and Plinthaqualfs are found. The term "soft ironstone" from Adu's (1957) soil series descriptions was interpreted to mean plinthite, as with the Savannah Ochrosols. "Soft ironstone" occurs under a hardened horizon or a highly concretionary horizon, in some cases it is described as being mottled and it hardens upon exposure. Also Huizing in Hornetz (1984) and Brammer (1957) refer to the characteristic hardening of the lower horizons upon exposure of these soils.

The Changnalili series is classified as Tropaqualf, sandy or loamy over petroferric contact. The term "petroferric contact" refers to the ironpan usually found at variable depths in the profile.

In case of a thick sandy colluvial deposit directly overlying the ironpan, (Aquic) Quartzipsamments may be found.

3.2.4 The Volta series

The Volta series belongs to the Savannah Gleisols. These are classified as:

- Vertic Orthustents (FAO Vol. III, 1967, page 57)
- Aquepts (Adu and Stobbs, 1981)
- Ustents (Obeng, 1975. 2, page 18)
- Vertic Tropaquepts (Adu, 1981)

The Volta series as described by Adu (1957), on the NAES are classified as Inceptisols and are separated on the criterium of n-value <0.7[1)] from the Entisols.
Because they have an aquic moisture regime and the probable occurrence of vertic characteristics (FAO, Vol. III, 1967, page 10: "the soils of the Volta series crack extensively when dry"), they may belong to the Vertic Tropaquept family.

1) The n-value refers to the relation between the percentage of water under field conditions and the percentages of inorganic clay and of humus, i.e. it refers to the ripening of the soil. Soils in which the moisture content is periodically reduced below field capacity (f.i. the Volta series in the dry season) seldom have an n-value of 0.7 or more. Most of the soils that have been permanently saturated are likely to have a high n-value.

3.3 The FAO classification (Legend of the Soil Map of the World, 1974)

The Tingoli, Tolon, Kumayili and Nyankpala series are classified as Luvisols, petric phase. Depending on the presense of plinthite ("soft ironstone") within 125 cm of the surface they are classified as Plinthic Luvisols and in the absence of plinthite as Chromic Luvisols, especially the redder Tingoli and Tolon series. The less red Kumayili series is classified as Orthic Luvisol.
In places, the sandy topsoil of the Nyankpala series may be sufficiently pale to qualify as an albic E horizon (pale coloured eluviation horizon) and in the absence of plinthite within 125 cm of the surface can be classified as Albic Luvisol.

The Kpelesagwu, and Changnalili series are in most cases classified as Luvisols. The Kpelesagwu series may have hydromorphic properties within 50 cm of the surface on the lower, wetter locations (Gleyic Luvisols), it may have plinthite ("soft ironstone") within 125 cm of the surface (Plinthic Luvisols) or it may have an albic E horizon (Albic Luvisols). The Changnalili series is classified as Gleyic Luvisol. Expecially the Changnalili series may have in places a sufficiently thick sandy upper horizon (>50 cm) to qualify as Arenosol.

The Volta series is classified as Gleysol because of the hydromorphic properties of the soil. The argillic horizon is not very pronounced, if present at all. Based on laboratory data of Volta series (FAO vol. III, 1967, and I.S.S.C. 1975 profile no. 8) it is likely that Eutric and to a lesser degree also Dystric Gleysols occur in the area (resp. Gleysols with more than 50% and less than 50% base saturation).

4 REPRESENTATIVENESS OF THE SOILS OF THE NYANKPALA AGRICULTURAL EXPERIMENT STATION FOR THE VOLTA BASIN SOILS

4.1 Introduction

First of all, it has to be mentioned that this assessment of the representativeness of the soils of the NAES for the Voltaian Basin is a desk-study and is based on the soil information available (see Chapter 8). Then, the description of the soil series in the available reports is not always consistent, partly overlapping or incomplete. Especially about the upland soils relatively little information is available. A good key to the soil series as used by Charter in his classification system is unfortunately not available. This assessment should therefore be considered with the above-mentioned limitations in mind. In the following section, the FAO generalized soil association map of Northern Ghana, scale 1 : 500 000 (FAO, Vol. III, 1967, map 3) is compared with the 1 : 250 000 soil maps of the East Dagomba Survey (1959), the Nasia River Basin Soil Survey (1981), the Navrongo-Bawku area and the Bole-Bamboi area.

4.2 Comparison of the 1 : 500 000 FAO (1967) soil map with the 1 : 250 000 soil maps of the East Dagomba area, the Nasia River Basin, the Navrongo-Bawku area and the Bole-Bamboi area

It should be realized, that the FAO soil map (1967) is a exploratory soil map, scale 1 : 500 000. On such a small scale it is impossible to depict variations in soil conditions over short distances, especially in a landscape with quite different physiographic conditions, such as valley bottoms, gentle slopes and low summits. Therefore, the units on the map do not represent homogenuous soil units.
When the FAO (1967) map is compared with the soil map 1 : 250 000 of the East Dagomba Survey 1959, both making use of soil associations as mapping unit, some considerable differences are noticed. In general, on the East Dagomba 1 : 250 000 soil map, considerably more detail in soil conditions is shown than on the similar areas covered by the FAO (1967) map. Although this is to be expected from a larger scale map, there are rather extensive areas on the East Dagomba soil map having soils different from those indicated on the FAO (1967) map.
The most striking example is formed by FAO map unit 11 (Sambu-Pasga ass.), occupying nearly half of the East Dagomba survey area. On the corresponding areas of the East Dagomba soil map we find indeed small areas of the Sambu-Pasga ass., but much larger areas of the rather different, less well drained Kpelesagwu-Changnalili ass. and also of the Sang-Salam Kpong ass. The soil association patterns on the East Dagomba soil map seem not unlogical. With this difference between the two maps in mind, and as the East Dagomba soil map, published in 1959, was available to the FAO surveyors in 1964, one wonders why the soils information of the East Dagomba survey is not used in more detail for the compilation of the FAO (1967) map.

When comparing the FAO (1967) map with the soil maps 1 : 250 000 we find besides considerably more differentiation in the number of soil associations on the 1 : 250 000 soil maps, also considerable differences in the type of soils mapped in corresponding areas.
All maps use soil associations as mapping unit. As with the East Dagomba Survey soil map 1 : 250 000, the other soil maps 1 : 250 000 appear to give a more realistic picture of the soils in the respective areas than the FAO (1967) map. It is therefore advisable to use these soil maps in preference to the FAO (1967) map for verification purposes.

Some general remarks about the representativeness of the soils of the NAES are made by Brammer, (1957). "Although soils similar to those on the station occur extensively within a radius of some 10-20 miles of Tamale, conditions on the station are not entirely representative of those occurring over the 26.000 square miles which the V2-shales probably occupy elsewhere in the Northern Region and North Ashanti.
Relatively well drained soils such as Tingoli, Tolon and Kumayili appear to be rare elsewhere and even soils as relatively poorly drained as Nyankpala series have only occasionally been encountered. The most widespread soils over the Voltaian V2a beds resemble the Kpelesagwu and Changnalili ("probably nearly 50% of the Savannah zone covering the Northern Region and North Ashanti.")

4.3 Tingoli and Tolon series

In accordance with the statement of Brammer (1957) about the relative rareness of these soil series, no reference was found to these series in the maps and literature available. The Tingoli and Tolon series are well drained, while all upland soil series on the FAO (1967) map are imperfectly or moderately well drained[1] (on the Voltaian shales, mudstones and sandstones). However, with respect to physiographic position, amount of concretions, texture, soil depth and color, the Tingoli and Tolon series can be compared with the Techiman series (FAO (1967) map unit 14) as this series has a wide range in characteristics. There are also some differences between the Techiman and Tingoli-Tolon series. The Techiman series is developed over sandstone, while Tingoli and Tolon are developed over (sandy) shale.
In addition, the concretions in the B horizon of the Techiman series are loose, while those of the Tingoli and Tolon series are tightly packed. The Tingoli and Tolon series appear also more or less similar to the Sambu-Pasga association (FAO (1967) map unit 11), except for the yellow-red subsoil matrix and the loosely packed concretions in the Sambu-Pasga ass. and the slightly different physiographic position (middle slopes for

1) The heading on the FAO (1967) map "non-concretionary well drained upland soils developed on Voltaian sandstones", is incorrect and should read: "moderately well drained" etc. See FAO Vol. III (1967) page 25.

the Sambu-Pasga ass. against upper slopes and summits for the Tingoli-Tolon series). In the East Dagomba Survey area, the Tingoli and Tolon series may correspond to the Pasga series from the Pasga-Sambu-Gbane soil ass. (map unit 5).
In the Nasia River Basin Survey area the Bole-Bamboi and the Navrongo-Bawku areas no corresponding soil series were found.

4.4 Tolon series, eroded phase

This soil series is approximately similar to the Gushiago-Kasale ass. on the FAO (1967) map, unit no. 13.
In the East Dagomba Survey area this series corresponds most probably with the Gbane series in the Pasga-Sambu-Gbane ass. (map unit 5) and the Gushiagu-Kasale soils (map unit 3). In the Nasia River Basin Survey area this series corresponds with the Pigu ass. (map unit 13), and in the Navrongo-Bawku area it may correspond to the Kintampo series (map units 17 and 17a). In the Bole-Bamboi region it may correspond to the rocky parts of map unit 5 (Wenchi-Kintampo-Sambu complex).

4.5 Kumayili series

This series is different from all the soil series on the FAO (1967) map. Its extent is very small on the station, and it is to be expected that also outside the confines of the station the relatively deep, non concretionary soils in local colluvium are very localized in extent.
On the East Dagomba soil map soil series corresponding to the Kumayili series are not indicated. The Kumayili series may correspond more or less to the colluvial Murugu series of the Mimi association (map unit 3, Nasia River Basin, map unit 16 of the Navrongo-Bawku area, map unit 10 of the Bole-Bamboi region).

4.6 Nyankpala series

This series is not mentioned on the FAO (1967) map. The Sambu soil series, however, is with respect to parent material, soil depth, texture, color and amount of concretions more or less comparable to the Nyankpala series. The Sambu series is moderately well drained, however, and locally imperfectly, while Nyankpala series is well drained. But there are some doubts about the good drainage of Nyankpala soils on the station, as this series is located on a relatively level area where stagnation of rainwater in the rainy season seems likely. The concretions in Sambu series are loose, while those in the Nyankpala series are tightly packed. The Sambu series is mapped in association with the (not described) deeper Pasga series as map unit 11 on the FAO (1967) map.
In the East Dagomba and the Bole-Bamboi areas Nyankpala series may correspond to the Sambu series from the Pasga-Sambu-Gbane soil ass. (map unit 5). On the Nasia River Basin soil map the Nyankpala series corresponds to deeper parts of the Wenchi-Sambu ass. (map unit 14), these are limited in extent. In the Navrongo-Bawku area no corresponding series are mapped.

4.7 Kpelesagwu and Changnalili series

These soil series are mapped occupying extensive areas in the Volta basin, as map units 9 and 10 on the FAO (1967) map. Probably they cover also considerable portions of FAO (1967) map unit 11 (Sambu-Pasga ass.) in the East Dagomba Survey area and also of FAO (1967) map unit 11 in the Nasia River Basin area. With respect to the profile characteristics, these series correspond fairly well with the like-named series of the FAO (1967) soil map (units 9, 10), of the Navrongo-Bawku area (unit 20), of the Nasia River Basin (units 15, 17, 18) and of the East Dagomba area (units 2, 4, 8) though possibly these soils on the station are generally slightly less shallow than the soils of these series outside the station.
There is however a difference in the relative distribution of the Kpelesagwu and Changnalili series: On the station, the Kpelesagwu series occupies only a rather narrow (50-100 m) zone, limited in extent, between the upland soils (Nyankpala or Tolon series) and the lower slope or valley soils (Changnalili or Volta series). Generally, in the other survey areas, the Kpelesagwu series occupies the major part of the Kpelesagwu-Changnalili association and the extent of the Changnalili series is relatively limited.

4.8 Volta series

This soil series is comparable to the Volta series in the very frequently occurring, relatively narrow valley bottom soils, mapped as units 1 and 2 on the FAO (1967) map.
The associated Lima series in these map units is not described extensively in the FAO report, but represents according to the East Dagomba Survey Report (1959), page 15, the Savannah Vleisols. These are similar to the Volta series in color, depth, position and other profile characteristics, except that they are neutral to slightly alkaline (pH 7.1 - 7.5) in reaction in the subsoil, commonly have scattered calcareous concretions and may have an excess sodium content (Adu, 1969).
The Volta series of the NAES is comparable to the Volta series of the Nasia River Basin (map unit 20), the Navrongo-Bawku area (map unit 21), the East Dagomba area (map unit 1) and of the Bole-Bamboi area (map unit 12).

4.9 Conclusion

Strictly taken, most of the soil series of the NAES are not very representative for soils occupying large areas in the Voltaian basin, mainly because the drainage conditions of the upland soils appear better or the concretionary horizons are more tightly packed than in comparable soils outside the station.
The Changnalili and Kpelesagwu soil series appear however to be fairly representative of extensive areas.
The Volta series as described by Adu (1957) is representative for the Volta series of the narrow valley bottoms within the Voltaian shale, mudstone and sandstone areas. It is mapped as well in some valleysystems in the granite area.
When the drainage characteristics of the upland soils (the Tingoli, Tolon and Nyankpala series) are not interpreted too strictly, these soils appear more or less representative for

the Techiman-Tampu and Sambu-Pasga associations (FAO (1967) map units 14 and 11). However, these map units are depicted occupying rather extensive areas, but most likely the real extent of the upland soils within these map units is limited, due to the dominance of other soil series associations.
The Tolon series, eroded phase, may be representative for shallow, rocky and eroded soils, such as the large area with eroded soils in the northeastern part of the country (FAO map unit 13).
The Kumayili series has properties which are related to the colluvial soils of the Murugu series in the Voltaian V3 sandstone area.

Table 1 gives a summary of the series of the NAES and the corresponding series of other survey areas. Similar series names indicate quite similar soil conditions, different series names indicate approximately corresponding soil conditions.
The series marked* are developed over Voltaian V3 sandstones, instead of the V2 Voltaian shales, mudstones, siltstones and argillaceous sandstones found at the NAES

Table 1

NAES series	FAO (1967) Northern Ghana		Nasia River Basin		Navrongo-Bawku area		East Dagomba area		Bole-Bamboi area	
	series	unit	series	unit	series	unit	series	unit	series	unit
Tingoli	Techiman* Pasga	14 11	-		-		Pasga	5	-	
Tolon	Techiman* Pasga	14 11	-		-		Pasga	5	-	
Tolon, eroded	Gushiagu-Kasale Kintampo	13 12-1	Pigu	13	Kintampo*	17,17a	Gbane Gushiagu-Kasale	5 3	Kintampo*	5
Kumayili	parts of Mimi* ass.	15	Murugu*	3	Murugu*	16	-		Murugu*	10
Nyankpala	Sambu	11	Nyankpala	14	-		Sambu	5	Sambu	5
Kpelesawgu	Kpelesawgu	9,10	Kpelesawgu	15,17	Kpelesawgu	20	Kpelesawgu Wulasi*	2,4 8	-	
Changnalili	Changnalili	9,10	Changnalili	15,17,18	Changnalili	20	Changnalili	2,4	-	
Volta	Volta	1,2	Volta	20	Volta	21	Volta 1		Volta	12

4.10 Comparison of the soils of the NAES with the soils developed on granite

When comparing the soils of the NAES with the soils developed over granites, as described in FAO, Vol. III (1967), there are several characteristics in common and a few differences.
The similarities are the abrupt increase in clay content in the profiles i.e. a fairly light textured A horizon (5-10% clay or less), overlying a medium textured B horizon (20-50%

clay), in the granitic soils at a depth of 40-50 cm and the dominant soil series on granite (FAO 1967 map units 19, 20 and 21) are also highly concretionary (usually with over 50 vol. % concretions) or have an ironpan at variable depths.
Further similarities are the relatively high base saturation of more than 50% and the low organic matter content, while also the soil colors and the pH-range are more or less similar. The differences consist of the lower CEC of the granitic soils (CEC-clay 10-15 meg/100 g against 20-50 meg/100 g for Kpelesagwu and Changnalili); the considerably higher content of coarse sand in the soils on granite (30-50% coarse sand against 5-15% for Kpelesagwu and Changnalili) and the concretions are not as tihgtly packed in the granitic soils compared with the soils on Voltaian shales, making root penetration easier on the granitic soils. In addition, the nutrient content is lower on the soils over granite than on the soils on shales.
The agricultural suitability rating on map 5 of FAO, Vol. III (1967), indicates a class III suitability for the upland soils around Tamale, corresponding with the Tingoli and Tolon series. With exception of the highly eroded areas, the granitic soils have suitability rating IV. Class V covers areas where the Kpelesagwu and Changnalili series and the Sambu-Pasga ass. (corresponding with the Nyankpala series) are dominant.
Summarizing it can be said that, despite several similarities, there are also considerable differences in soil conditions and taken together with the resulting differences in agricultural potential, it is unlikely that the soils of the NAES can be considered representative for the (concretionary) soils developed over granites.

5 SOME REMARKS ON THE OCCURRENCE AND GENESIS OF THE SOILS OF THE NYANKPALA AGRICULTURAL EXPERIMENT STATION

The soils are developed on the Voltaian (V2b) shales, mudstones and argillaceous sandstones, probably of Ordovician age (FAO Vol. III, 1967, page 4).
Well drained to moderately well drained, shallow to moderately shallow, red-brown to orange-brown clayey to loamy soils are found on the summits and upper slopes, usually with iron concretions in the subsoil and locally with ironstone pans. Deeper in the profile "soft ironstone"* is often found, overlying partly decomposed shales and sandstones in a mottled, clayey matrix. The soils have in general a brown to gray, sandy topsoil, 15-30 cm in thickness.

On the middle and lower slopes imperfectly to poorly drained, grayish to grayish-brown or brown, shallow to moderately shallow, clayey to loamy soils are located, highly concretionary and especially on the lower slopes often with massive ironpans at variable depths in the profile.
The concretions do not restrict root penetration altogether, except when there is a clear ironstone pan (FAO, Vol. III, 1967, page 18). The profiles can have rusty, gray or brown mottles due to hydromorphic conditions, while lower in the profiles, except in the really wet profiles close to the valleys, also reddish mottles can occur in relation with the presence of plinthite-like material.
A sandy topsoil is present with a thickness of some 15-30 cm, locally up to 90 cm thickness, especially on the lower slopes. Decomposed shales and mudstones or sandstones in a mottled clayey matrix are found lower in the profile at variable depths below 100 to 200 cm.

The valley soils consist of colluvial, poorly drained, deep, grayish, mottled loamy to clayey profiles. The clay content increases usually with increasing depth. Sometimes ironstone layers are found at varying depths in the profile. The sandy topsoil is not very pronounced or absent.

With exception of the valley soils, the clay content of the soils increases often sharply from approx. 5-10% in the sandy upper horizon, to approx. 20-60% in the underlying B horizons. Although usually within the B horizon clay content increases gradually with depth, in some cases the clay content varies irregularly with depth, as in Adu (1975), profile no. 3, (Kpelesagwu series):

0 - 16 cm	8.8% clay
16 - 46 cm	22 - 24 % clay
46 - 74 cm	11 - 14 % clay
74 - 174 cm	14 - 24 % clay

* nomenclature according to Adu (1957).

Micromorphological studies of samples of Kpelesagwu and Changnalili profiles of Nyankpala Agricultural Station, revealed evidence of the presence of oriented clay cutans in the B horizons of the profiles (personal information Dr. Sevink). This, in combination with the available chemical and physical data of analysed profiles, suggests that there is an argillic horizon present within the B horizon of the soils.
However, clay cutans have not been indicated in the available profile descriptions.

Adu (1957) is of the opinion that the soils of the station are not directly developed from the Voltaian shale, sandstone and mudstone (V2b), but from the initial weathering-products of this parent material, namely the ironstone concretions or ironstonepans or the ferruginized sandstone fragments.
He postulates that from this secondary parent material by subsequent weathering the present clay soils are formed i.e. a polygenetic profile development. He does not explain the abrupt increase in clay content between the upper (A) horizon and the lower (B) horizons.
With regard to this, Dr. Sevink agrees with the poly-genetic profile development and considers the heavier textured B and C horizons (of the non-colluvial profiles) to represent parts of a former profile, of which the upper horizons have been truncated by erosion. This explains the abrupt textural change between A and B horizon.
The sandy horizon is thought to result from the weathering of upper-slope sandstones as well as from the erosion products of the upper-slope profiles. The clayey erosion products are transported downslope towards the valleys, when the highly permeable sandy horizon, overlying the slowly permeable B horizon becomes saturated with rainwater in the rainy season.
In some cases part of the clay may accumulate on lower slopes (Changnalili series) immediately above the ironstone pan (Obeng, 1972).
The sandy upper horizon is very susceptible to erosion (Brammer, 1957), Huizing (in Hornetz, 1984) (Adu, 1981)(Obeng, 1975. 2). During the rainy season, this horizon becomes in saturated condition easily subject to downslope transport, even on gentle slopes. The upper A horizon, containing most nutrients, is eroded first.
With decreasing thickness of the sandy horizon the water storage capacity decreases as well, thus leading to an ever accelerated erosion- process.
It is very important to stop this process by taking the appropriate soil conservation measures.

The clay in the ironpans and the concretionary profiles is dominantly kaolinitic (Obeng 1970, page 148), but especially lower horizons may contain appreciable amounts of illite and its associated 2 : 1 lattice clays (Obeng 1970, page 164). Besides this vertical differentiation, there is also a lateral differentiation in clay mineralogy. In FAO, Vol. III (1967), page 105, it is mentioned that "the lower slopes are apparently

more illitic than the middle slope soils. This seems to be a rather general feature in the soil pattern of Northern and Upper Ghana".
This can be explained by the lateral downward movement of illitic clay from lower horizons of upper-slope profiles.

Obeng (1970, page 153) also gives some information about the composition of the ironpan in the ironpan soils.
Fe in the form of goethite is the principal mineral present in the ironpan horizons. It may be the principal mineral responsible for the hardening process.
The Al-containing minerals (a.o. gibbsite) are significantly prominent within the ironpan horizons of the well-drained, high-level ironpan soils and there is evidence that the aluminium-containing minerals are less prominent in the imperfectly and poorly drained soils.
It is probable that in analogy with the drainage-related differences in mineralogical composition between the summit-levels and the lower slopes, such differences occur also, although less pronounced, between upland soil types with different drainage conditions.
On the station we see such differences between the brownish coloured Nyankpala series, with imperfect internal drainage (Adu, 1957) developed over shales and the Tingoli and Tolon series, both well drained, reddish-brown to orange-brown in color, developed over more permeable sandy shale.
Possibly, these relativety small differences in mineralogy and drainage will be reflected in agricultural productivity.

6 SOME REMARKS ON THE SOIL MAP 1 : 10 000 AND ACCOMPANYING REPORT OF NYANKPALA AGRICULTURAL EXPERIMENT STATION

When comparing the soil series description (Adu, 1957) with the soil series map 1 : 12 500 (Adu, 1957) and the soil series map 1 : 10 000 (Nov., 1984), it appears that the soil series boundaries form a logical pattern. However, a few comments must be made. See also Annex II.

A There seems to have occurred a southward shift of approx. 0,5 cm of the soil boundaries in relation to the contourlines around the valley in the southwestern part of the station. It appears as if the valley-floor Volta series is located halfway between the valley and the neighbouring summit, while the Kpelesagwu series normally occupying the lower slopes, is located partly in the valley. The supposedly correct position of the soil series boundaries is indicated "on the transparant overlay" (Appendix B).

B In the same valley in the southwestern part of the station, the westernmost end of the Kpelesagwu soil boundary could possibly be located further northward. At present the boundary crosses the contourlines in a rather unlikely way. A more probable position of the boundary is indicated near point A on Appendix B. Further field observations are required to find the correct position of the boundary.

C When comparing the soil depth map (Adu, 1957) with the description of the soil series in the report, it was observed that for a number of soil series there is a certain discrepancy concerning the soil depth criterium (depth to ironstone or rock or tightly packed ironstone gravel).
In general, on the soil depth map the soil depth is indicated as deeper than indicated in the descriptions. This is especially the case with the Kpelesagwu, Tolon and Tingoli series.
The areas where the soil depth on the map and in the descriptions do not coïncide are indicated on the soil series map (Appendix C).
The difference in depth is usually not more than one depth class. Only field observations can ascertain whether the information on the soil depth map or in the soil series descriptions is correct. See also Annex II.2.

D The drainage class of Nyankpala series, well drained, is more likely to be moderately well drained, due to the position of this soil series, with a shallow sandy surface horizon overlying heavier textured horizons with imperfect internal drainage (Adu, 1957), mostly on an almost level summit. This is believed to easily induce water stagnation in the rainy season.

E Not all textural classes as given in Adu (1957), are described in standard terminology (f.i. silty sand in Nyankpala series). It was attempted to "translate" Adu's textural classes in standard textural classes where necessary.
Further, Adu uses frequently the "sandy clay" texture class in his soil series descriptions. In the comparable soil series

descriptions in the literature available this texture class was seldom or not found. More common however are (silty) clay loams, silt loams and sandy clay loams.

F The color description in Adu (1957) is not given according to the Standard Munsell Soil Color charts. This results in some cases in difficulties with the classification of the series according to the Soil Taxonomy and the FAO Soil Map of the World Legend.

7 ASSESSMENT OF THE SOILS OF THE ON-FARM SITES

7.1 Introduction

In this Chapter an assessment is given of the soils of the villages of Nakpa, Nakpanduri, Namburugu, Nakpala, Wantugu and Binduri. For every village the major soil series are described and where possible some general information on chemical and physical soils properties is given. The soils are tentatively classified following the Ghana classification system, the USDA Soil Taxonomy and the FAO Soil map of the World Legend.
The agricultural suitability is described for the major soil series, taken from USOM (1959), Adu (1969), Adu and Stobbs (1981) and Brammer (in Brian Wills, 1960). Further some remarks are given on the representativeness of the soil series for Northern and Upper Ghana.

It should be realised, that the soil maps scale 1 : 250 000 and 1 : 500 000 use broad soil associations as mapping units. The soil conditions of the on-site farms may show local deviations from the general characteristics of the constituent soils of the associations. It is advisable to ascertain that the soils of every site in reality fit the descriptions given for the major soil series for that particular area.

7.2 Nakpa village

Location	:	approx. 30 km northwest of Bimbila, East Dagomba.
Geology	:	V2b sandstone
Elevation	:	-
Landuse	:	moderately intensely cultivated (FAO, 1967).
Geomorphology	:	long, gentle slopes of 2-3%; some short slopes of 4-5%.
Soil series	:	Nankpayeri-Wulasi association, transitional to the Kpelesagwu-Changnalili association.

Soils.

On the East Dagomba soil map 1 : 250 000 (USOM 1959) can be seen that the soils around the village belong to the Nankpayeri-Wulasi association (map unit 8). This map unit is rather limited in extent and is surrounded by map unit 2, the Kpelesagwu-Changnalili association. Assuming that not all the arable fields are located close to the village, it is likely that the soils of some of the more remote fields belong to the Kpelesagwu-Changnalili ass. On the FAO (1967) soil map 1 : 500 000 all soils of the area around Nakpa are indicated as belonging to the Sambu-Pasga association (map unit 11).
The Nankpayeri-Wulasi soils are not described in detail in the USOM (1959) report. They include well drained (Nankpayeri series) to imperfectly drained (Wulasi series) concretionary soils, somewhat similar to respectively the Sambu and Kpeleswagu series, but have darker horizons. They are associated with the deep, well drained soils of the Dogbam series, which is also not described in detail, but which is comparable to the Pasga series. These soils form a catena with the Pasga series on the summits, Sambu on the lower summit and upper slopes and Kpeleswagu,

Changnalili (and the Volta series, less relevant here) on the lowest parts of the catena. The Sambu series occupies about 60% of the association.
For a description of Sambu and Pasga series see below; descriptions of Kpelesagwu and Changnalili series can be found in Chapter 2.

Descriptions of the agricultural suitability of the Sambu, Pasga, Kpelesagwu and Changnalili are given; for completeness also for Volta series.
It should be kept in mind that the Nankpayeri, Wulasi and Dogbam soils are developed over Voltaian sandstones and that the soils which have more or less similar characteristics (respectively the Sambu, Kpelesagwu and Pasga series) are developed from Voltaian mudstones, siltstones, sandy shales and clay shale. This difference may a.o. be reflected in a somewhat higher nutrient content of these last group of soils.

7.2.1 Sambu series

These series comprise well drained to moderately well drained, shallow to moderately shallow concretionary soils. The A horizon is a dark brown to (yellowish) brown, mostly concretion free, porous sandy loam, with a crumb structure and a thickness of 15-25 cm. The upper 5-10 cm are slightly humous. The A horizon overlies a (yellowish) to (orange) brown sandy clay loam or silty clay loam, with a varying degree of reddish mottling and with 60-80 volume percent ironstone concretions and ironstone boulders. This horizon may harden upon exposure.
The concretions are loosely packed and can be dug.
Some profiles may have a hard vesicular ironstone pan.
The profile is underlain by decomposed sandy shale or sandstone below 150-250 cm.
The subsoil drainage conditions vary; some profiles show signs of impeded drainage or poorly drained conditions in lower horizons. Areas with frequent exposures of ironstone boulders occur.

The soil reaction varies from slightly acid (6.1-6.7) in the topsoil to very acid-moderately acid (5.1-5.7) in the subsoil. The clay content is 5-10% in the A horizon and increases to 20- 40% in the B horizon; the amount of sand (mainly fine sand) is 75-85% in the topsoil and decreases to 45-60% below. The CEC is 3-8 meq/100 g soil in the topsoil and increases to 3-13 meq/100 g soil in the lower horizons. The total content of exchangeable bases varies: FAO (1967) gives higher values (3-10 meq/100 g), mainly due to high values of Ca and Mg, than the corresponding horizons of the profiles analysed in the USOM (1959) report (1-4 meq/100 g soil). The base saturation is also variable, in the topsoil values of 65-100% occur while in the lower horizons values of 40-70% are common, in some cases even lower values. The content of organic matter is low.

	sand %	silt %	clay %	org.C %	pH H_2O	CEC meq/100 g	TEB meq/100 g	Base sat. %
topsoil[1]	75-85	5-12	5-10	0.4-1.0	6.1-6.7	3- 8	6- 8	65-100
subsoil[2]	45-60	6-15	20-40	0.2-0.6	5.1-5.7	3-13	2-10	11- 70

1) upper 5-15 cm
2) approx. 40-100 cm depth

Tentative classification:

Ghana	: Red Savannah Ochrosols
Soil Taxonomy	: Plinthustalfs, sandy over loamy-skeletal
	or Haplustalfs, sandy over loamy-skeletal
if base sat. <35%:	Plinthic Paleustults, sandy over loamy-skeletal
	or Plinthic Haplustults, sandy over loamy-skeletal
FAO	: Plinthic Luvisols, petric phase
	or Chromic Luvisols, petric phase
if base sat. <50%:	Plinthic Acrisols, petric phase
	or Orthic Acrisols, petric phase

Agricultural suitability:
The soils are moderately susceptible to erosion and will need conservation measures such as contour ploughing, strip cropping and construction of graded small terraces or ridges [3] if cultivation on a moderate scale is undertaken.
The fertility is low and they have a low to medium nutrient storage content. The application of farmyard manure would aid in reducing erosion, by increasing the infiltration rate, increasing the waterholding capacity and the fertility and improve the plant soil moisture relationship. Preliminary trials on comparable soils conducted at the NAES indicate that the application of chemical fertilizers, P, N and S will nearly double current yields when adequate moisture is available (USOM 1959).
Split application of chemical fertilizers is recommended.
The soils may be saturated with water in the rainy season, but dry out rapidly at the onset of the dry season and become droughty.
These soils are not very suitable for mechanical tillage due to their stoniness, but if mechanical ploughing is undertaken, disk ploughing is recommended. Cultivation has to be carried out

3) USOM (1959) gives some detailed soil conservation measures descriptions; as these may be applicable to most upland soils of Northern Ghana, they are quoted here:
"All tillage, whether by hoe or by bullocks, should be laid out on the approximate contour.

In as much as so-called "shift", or "patch-farming", has been carried on in the area to such an extent that it is now the custom, it is recommended that these patches or small fields be not over 50 feet in width with the slope, and should there be several fields down the slope, these fields should be separated by a strip of native grass not less than 20 feet in width on the contour on a one percent slope. The width of these native grass strips should be increased by 5 feet with each degree increase in slope. For example, on a one percent slope the minimum width should be not less than 20 feet, on a 2% percent slope the minimum width should not be less than 25 feet, etc. Broadcast crops of small grain and sorghums may be substituted for native grass strips. The purpose of these strips is to help in erosion control and for cover and food for beneficial birds."

carefully in order not to expose the subsoil, which can lead to irreversible hardening. Adu and Stobbs (1981) recommend these soils for the growing of groundnut and cereals.

Representativeness of Sambu-Nankpayeri series:
The Nankpayeri series seems to occur very infrequent: in the East Dagomba area the Nankpayeri-Wulasi association occupies only 3% of the area. In the Nasia River Basin, the Navrongo-Bawku soil survey and the Bole-Bamboi soil survey this series does not occur, nor on the FAO (1967) soil map 1 : 500 000. The related Sambu series however is more common. On the FAO (1967) soil map the Sambu-Pasga association (map unit 11) covers relatively large areas, although parts of this unit may be occupied by less well drained soils.
The Sambu series occupies presumably the major part of the unit no. 11.
In the Nasia River Basin the Sambu series occupies a small area. It forms a minor part of the Wenchi-Sambu association (map unit 14).
The Sambu soils are not mapped in the Navrongo-Bawku soil survey.
In the Bole-Bamboi region the Sambu soils form part of the map unit no. 5, the Wenchi-Kintampo-Sambu complex, which occurs in the eastern part of the area.

7.2.2 Pasga series

This series consists of well drained, moderately deep to deep, concretionary upland soils without cemented ironpan.
The soils have an approx. 10 cm thick, brown to dark brown A-horizon of loamy fine sand with some ironstone concretions, overlying a yellowish brown to strong brown fine sandy loam B-horizon, in some cases loamy fine sand, with frequent loose ironstone concretions and some ironstone builders to a thickness of approx. 120 cm. Below 120 cm red to light red, fine sandy loam to sandy clay with tightly packed ironstone concretions is found, at a depth of 250-300 cm overlying the sandstone bedrock.

The soil reaction is slightly acid to slightly alkaline (6.4-7.2) in the topsoil and moderately to slightly acid (5.6-6.2) in the subsoil. The organic carbon content is low. The CEC and the TEB are low to medium. The base saturation is high in the topsoil and medium to high in the subsoil. The fertility is low to medium.

	sand %	silt %	clay %	org.C %	pH H_2O	CEC meq/100 g	TEB	Base sat. %
topsoil	-	-	-	1.1	6.4-7.2	6	6-7	85-100
subsoil	-	-	-	0.3-1.0	5.6-6.2	3-8	3-7	55- 95

Tentative classification:

Ghana : Red Savannah Ochrosols
Soil Taxonomy : Plinthustalfs, sandy over loamy-skeletal
or Paleustalfs, sandy over loamy-skeletal

FAO : Plinthic Luvisols, petric phase
or Chromic Luvisols, petric phase

Agricultural suitability:
These soils belong to the better soils for agricultural production. The soil is rated as class 1 for (rainfed) agricultural production by USOM (1959), relative to the other soils of the East Dagomba area.
This soil is moderately susceptible to erosion, and therefore erosion control measures are necessary as described for the Sambu series. The soil offers less restrictions to mechanical cultivation than the Sambu series, because it is deeper and less stony. The moisture holding capacity is slightly higher than for Sambu series. Also here application of farmyard manure and chemical fetrilizers are recommended for higher production.

The agricultural production of Dogbam series is basically similar to that of Pasga series.

Representativeness of Pasga-Dogbam series:
Of the reports available now, the Dogbam series is only mentioned in the East Dagomba soil report. It forms part of the very small Nankpayeri-Wulasi association (the deeper soils of this association) and it forms also part of the Bimbila-Dogbam-Ejura association (map unit 6). This last association occupies only approx. 5% of the East Dagomba area and therefore the Dogbam series is not at all a commonly occuring soil series.
Also the related Pasga series does not occur frequently: it is mapped together with the Sambu series on the FAO map as unit 11, Sambu-Pasga association, but Pasga forms the lesser part of this association. In the Navrongo-Bawku, the Nasia River Basin and the Bole-Bamboi regions this series is not mapped at all.

7.2.3 Kpelesagwu series

Agricultural suitability of Kpelesagwu series. The soils are liable to be waterlogged in the wet season, thus restricting root development and the crops tend to be drowned in the rainy season. However, attempts at improving the drainage by open ditches or subsoil drains tend to increase the irreversible hardening of the subsoil. Possibly the construction of shallow, grassed waterways might be more applicable for improving drainage. The soil dries out quickly in the dry season due to the low moisture holding capacity. The fertility is low. The soils are susceptible to erosion. Erosion control measures should be applied, such as contouring, strip cropping and the construction of graded terraces.
Mechanical cultivation is generally not advisable because of the presence of boulders which lie near the surface.
Given the many limitations, these soils seem best adapted to the production of grass and some early crops and possibly upland rice. Yam and cereals are grown in some localities but the yields are low (Adu and Stobbs 1981, USOM 1959, Brammer 1957).
The agricultural suitability of Wulasi series follows that of Kpelesagwu series.

Representativeness of Wulasi-Kpelesagwu series:
The Wulasi series is confined to the Nankpayeri-Wulasi association in the East Dagomba area. In the other reports Wulasi series was not mentioned anywhere.
For the representativiness of the related Kpelesagwu series see Chapter 4.

7.2.4 Changnalili series

Agricultural suitability of Changnalili series:
Changnalili soils are generally rated unsuitable for agriculture, as they are saturated with water during the rainy season and are very droughty during the dry season. They are generally too stony and too shallow for arable agriculture and support poor pasture which is available for grazing during the early part of the wet season and the early part of the following dry season (Adu, 1969).
Representativeness of Changnalili series: see Chapter 4.

7.2.5 Volta series

For a description and classification of the Volta series see Chapter 2. An assessment of the representativeness of Volta series can be found in Chapter 4.

Agricultural suitability of Volta series:
These valley bottom soils have a potential for intensive agricultural development within the V2 shale formation. They are comparatively better supplied with nutrients than the associated Kpelesagwu soils, they are deep and they occur on relatively flat land on sites where conditions are suitable for mechanized tillage and where there are possibilities of water control.
These soils are liable to seasonal flooding or waterlogging, but become thoroughly dry during the dry season.
At present some areas are used for dry-season grazing, but they appear to provide opportunities for large-scale rice cultivation and dry season vegetable growing.
Rice growing is not generally worthwile if the crop has to rely on the irregular rainfall and run-off. It is essential if satisfactory yields are to be obtained, to provide for complete water control structures and to improve and maintain the fertility of the soils by the regular use of artificial and organic fertilizers (Adu 1969).

7.3 <u>Nakpanduri village</u>

Location	:	on the divide between the Nasia River Basin and White Volta Basin, along the Gushiegu-Misiga road.
Geology	:	V3 Upper Voltain sandstones
Elevation	:	approx. 460 m

Landuse (1964): in immediate vicinity of the village compound farming [1]); approx. 1 km from the village transition to compound farming with land rotation or bush farms [2]).
Geomorphology : Divide.
Soil series : Mimi, Murugu, Nalerigu and Kintampo.

Soils.
The on-site farms are indicated as occurring in two groups. One group is located to the north-east of the village; the soils of this area belong to the shallow, stony soils of the Kintampo consociation (map unit 17a of the 1 : 250 000 soil map of the Navrongo-Bawku area, Adu 1969).
The farms of the other group lie to the south-west of the village. The soils here belong to the Mimi association (map unit 3 of the Nasia River Basin soil survey, Adu and Stobbs 1981). The FAO (1967) soil map 1 : 500 000 indicates the Mimi-association (map unit 15) in the whole of the Nakpanduri area.

7.3.1 The Kintampo series

The Kintampo series consists of excessively drained, very shallow to shallow soils, with a thin (0-5 cm) slightly humous sandy loam topsoil, overlying 15-25 cm of brown fine sandy clay or sandy loam with ferruginized sandstone fragments and some ironstone concretions, and reddish brown, massive, fine sandy clay with frequent ironstone concretions and frequent sandstone fragments. Massive sandstone rock may be found at a depth of approx. 40 cm. Many areas expose bare rock outcrops.

Tentative classification:

Ghana : Lithosols
Soil Taxonomy : Lithic Ustorthents
FAO : Lithosols
or Dystric/Eutric Cambisols

Agricultural suitability:
Due to the very shallow nature of these stony soils, they have little agricultural value. They are droughty and poorly provided with nutrients. They may best be left under savannah or may be assigned to wildlife preserve (Adu 1969).

[1]) Compound farming: agricultural production is practised continually on small areas, approx. 2 acres in size, near the dwellings. Fertility is maintained by household refuse and livestock droppings. Main crops grown: okro, tobacco, gourds, melons, tomatoes, peppers, sweet potatoes etc. Also planted: early millet, sorghum, maize, cowpeas, bambarra beans and groundnuts. (Adu and Stobbs, 1981).

[2]) Bush farms: farms several kilometers from the village, approx. 3 acres in extent, where land rotation is practised and fertility is maintained by fallowing. Main crops grown: sorghum, late millet, maize, some upland rice, yams and groundnuts. (Adu and Stobbs, 1981).

Representativeness of Kintampo series:
These soils are mapped as units 2, 4 and 6 in the Nasia River Basin. In unit 2 (the Kintampo consociation) Kintampo series occupies the major part of the unit; in units 4 and 6 (Kintampo-Mimi and Nalerigu-Kintampo ass.) about half of the units. Taken together Kintampo series occupies considerable areas in the northern half of the basin.
In the Navrongo-Bawku area, the Kintampo series forms part of the Kintampo ass. (map unit 17) and of the Kintampo consociation (map unit 17a). These units are located in a 10-20 km wide zone at both sides of the White Volta River. Unit 17a occurs only to the south of the river, along the divide.
In the Bole-Bamboi region comparable Lithosols form part of the Wenchi-Kintampo-Sambu complex (map unit 5) in the eastern part of the area.
On the FAO (1967) soil map the Kintampo series forms part of map unit 12 (Wenchi-Kintampo ass.) and the dominant part of unit 12-1 (Kintampo ass.). These units are mainly located along the scarps of the Gambaga highlands, along the Larbanga scarp in the North-Gonja area and in the area around the scarp north of the Black Volta.

7.3.2 Mimi association

The Mimi association consists of the Mimi series, (occupying about 60% of the association) on the upper and middle slopes, and on the lower slopes passing into the colluvial Murugu series. Lower on the slopes the Nalerigu series are found, (seepage ironpan soils) and these give way to the alluvial soils of the valley bottoms (the Yarayiri and Bombi series). As the village of Nakpanduri is located on the divide, it is likely that the alluvial soils of the association do not occur here; they are therefore not described here.

7.3.2.1 Mimi series

These are deep, well drained non-concretionary soils, with a profile consisting of approx. 30 cm grey-brown, porous, loamy fine sand, with a crumb structure, overlying 120 cm or more of red to yellowish red, porous, sandy (clay) loam with a medium angular blocky structure or loamy sand. Rock fragments and ironstone concretions may be found at lower depths. At sites where steep slopes have been eroded and near rockoutcrops, the shallow phase of the Mimi series is encountered with a depth of approx. 60-120 cm.

The organic carbon content is low (<1%). The soil reaction is slightly acid to neutral (6.4-7.0) in the topsoil and very acid to slightly acid (5.1-6.2) below. The CEC is low to very low. The nutrient-content is low (1-7 meq/100 g). The base saturation is 90-100% in the topsoil and drops to 30-60% in the lower horizons. The P content is low to very low (below 160 ppm). In general the Mimi series has a low fertility.

topsoil	org.C %	pH H_2O	CEC meq/100 g	TEB	Base sat. %	Total P ppm
topsoil	0.5-0.7	6.4-7.0	3-4	3-4	90-100	70-100
subsoil	0.1-0.4	5.1-6.2	2-7	1-5	30- 60	40-160

Tentative classification:

Ghana : Red Savannah Ochrosols
Soil Taxonomy : Typic Rhodustalfs, loamy
or Oxic Rhodustalfs, loamy
or Oxic Paleustalfs, loamy
or Arenic Paleustalfs, sandy over loamy
if base sat. <35%: Rhodic Paleustults, loamy
FAO : Chromic Luvisols
or Orthic Luvisols
if base sat. <50%: Orthic Acrisols

Agricultural suitability:
Adu and Stobbs (1981) mention that the main limitations for agricultural production of the Mimi series are the tendency to be droughty, because of water losses through evaporation and rapid run-off during rainstorms; the low fertility due to the low nutrient content of the soil related to the poor nutrient content of the parent rock, and the susceptibility to erosion. Contour ploughing and strip cropping and the construction of graded terraces would be necessary to minimize the risks of sheet and gully erosion.
The soil is rated suitable for the production of yams, guinea corn, millet and tobacco, although a wide range of cash crops, requiring soils with good drainage, can be grown successfully on these soils. The productivity can be considerably increased by the provision of organic matter, cover crops and fertilizers, particularly nitrogen and phosphorus.

Representativeness of the Mimi series:
The soils of the Mimi series occupy in the Nasia River Basin the major parts of map unit 3 (Mimi ass.) and about half of unit 4 (Kintampo-Mimi ass.) and thus the Mimi series is covering considerable areas in the northern half of this basin. In the Navrongo-Bawku area the Mimi series forms the main part of the Mimi ass. (map unit 16) in the southern part of the area. This unit does not cover extensive areas. In the Bole-Bamboi region the Mimi series forms together with the Murugu series the Mimi-Damango ass. (map unit 10), covering small areas in the southern and the eastern part of the survey area. In the East Dagomba area no corresponding series are mapped. On the FAO (1967) soil map the Mimi series forms the dominant part of the Mimi ass. (map unit 15, presumably together with the Murugu series). This unit occupies fairly extensive areas in a 15-40 km wide belt in the west and north of the Voltaian sandstone and shale formation, bordering the granites.

7.3.2.2 Murugu series

The Murugu series are less deep, less well drained and less red colored soils compared with the associated Mimi series. These soils are moderately well drained, moderately deep to deep; they have a dark brown, slightly humous A horizon with a texture of loamy fine sand and a thickness of approx. 25 cm and a weak crumb structure, overlying 60-90 cm of (reddish) yellow, in places mottled, porous, loamy sand to sandy (clay) loam, overlying mottled rock fragments and ironstone concretions.

The organic carbon content is low (<1%). Both the content of nitrogen and phosporus is low to very low. The soil reaction in the topsoil is slightly acid to neutral (6.6), but in the lower horizons it is slightly to moderately acid (5.5-6.4). The CEC is low. The base saturation is generally above 50%.

	org.C %	pH H_2O	CEC meq/100 g	TEB	Base sat. %	Total P ppm
topsoil	0.5-0.7	6.6	4	1-4	80-100	40- 70
subsoil	0.1-0.5	5.5-6.4	2-6	<1-3	30- 75	50-130

Tentative classification:

Ghana : Yellow Savannah Ochrosols
Soil Taxonomy : Haplustalfs, loamy
if base sat. <35%: Haplustults, loamy
FAO : Orthic Luvisols
if base sat. <50%: Orthic Acrisols

Agricultural suitability:
This series has a low fertility. This can be raised by the application of organic and mineral fertilizers, especially N and P. These soils are more susceptible to erosion than the Mimi series, so appropriate erosion conservation measures are necessary.
The soils are suited for the cultivation of yam, guinea corn, millet and tobacco, as they are relatively well drained and relatively deep, with a reasonable waterholding capacity (except the more sandy profiles). (Adu 1969)

Representativeness of Murugu series:
The Murugu series occurs in close association with the Mimi series and therefore reference is made to Mimi series.

7.3.2.3 Nalerigu series

This series consists of imperfectly drained, shallow to moderately shallow soils, consisting of up to 12 cm of brown, slightly humous, fine sandy loam, overlying frequent to abundant ironstone concretions in a porous, reddish brown to yellowish red, fine sandy (clay) loam matrix, at a depth of 50-70 cm overlying a soft or hard seepage ironpan.

The soil reaction is moderately acid in the topsoil and in the subsoil strongly to very strongly acid (5.0-5.2).

Tentative classification:

Ghana : Groundwater laterites

Soil Taxonomy: Plinthaqualfs, sandy over loamy-skeletal
or Tropaqualfs, sandy or loamy over petroferric contact
FAO : Gleyic Luvisols, petroferric phase
or Plinthic Luvisols, petric phase

Agricultural suitability:
This soil becomes waterlogged to the surface at the height of the rains, but dries out early in the dry season, due to the low waterholding capacity. The presence of the ironpan and the ironstone concretions provide adverse conditions for both mechanized tillage and root growth. The soil is susceptible to erosion. Very little farming is practised on this soil. It may be suitable for grazing early in the wet season and at the onset of the dry season. (Adu 1969)

Representativeness of Nalerigu series:
The Nalerigu series occupies major parts of the map unit 6 (Nalerigu-Kintampo ass.) in the Nasia River Basin and it forms a minor part of the Mimi ass. (map units 3 and 4). In the Navrongo-Bawku area it forms also a minor part of the Mimi ass. (map unit 16). It is not mentioned whether the Nalerigu series forms part of the Mimi ass. in the FAO (1967) soil map nor of the Mimi-Murugu ass. of the Bole-Bamboi region. This series is not mapped in the East-Dagomba area.

7.4 Namburugu village

Location	: approx. 30 km northwest of Gushiegu, Nasia River Basin
Geology	: V2a Lower Voltaian sandy shales, clay shales and mudstones
Elevation	: approx. 300 m
Landuse	: compound farming with land rotation or bush farms
Geomorphology	: gently undulating area
Soil series	: Kpelesagwu and Changnalili series

Soils.
According to the soil map 1 : 250 000 of the Nasia River Basin (Adu and Stobbs 1981) and the FAO soil map 1 : 500 000 the soils belong to the Kpelesagwu association, map units 15 and 9, respectively.
The Kpelesagwu association is dominated by the Kpelesagwu series, occupying the upper, middle and lower slopes. On the lower slopes it passes into the Changnalili series, and the Volta series occupies the valleys. Areas occupied by the Kpelesagwu series may also include small patches of Wenchi series (very shallow brownish ironpan soils on occasional flat summits), Sambu series and Nyankpala series. The description of the Kpelesagwu and Nyankpala series in Adu and Stobbs do not differ substantially from the descriptions in Adu (1957) (see Chapter 2), with the exception of the depth of the upper limit of the horizon with abundant ironstone concretions of the Kpelesagwu series. This limit varies in the Nasia River Basin Kpelesagwu soils between 25 and 100 cm depth; 60 cm is

given by Adu (1957) for the Kpelesagwu soils at the Nyankpala Agricultural Station.

For the classification of Kpelesagwu series the reader is referred to Chapter 2. A discussion of the agricultural suitability can be found under the assessment of the soils of Nakpa village in this Chapter. The representativeness of Kpelesagwu series is discussed in Chapter 4.

Changnalili series.
According to the data in Adu and Stobbs (1981) the Changnalili series in the Nasia River Basin is shallower than on the NAES and consists of imperfectly drained, shallow to very shallow soils, with a yellow-gray or brown, mottled, fine sandy loam topsoil of 15-25 cm thickness, overlying a massive, compact, manganiferous ironstone pan. Layers below the pan often comprise ironstone and manganese concretions in a matrix of gray and yellow mottled, silty clay, which overlay decomposing shale or mudstone. Usually, eroded areas have outcrops of massive ironpan.
For the classification of Changnalili series see Chapter 2; for the agricultural suitability see under Nakpa village in this Chapter. The assessment of the representativeness is found in Chapter 4.

7.5 Nakpala village (on the map designated as Nakpok)

Location	: approx. 10 km west of Sawla, Bole-Bamboi region
Geology	: granites and granodiorites
Elevation	: -
Landuse	: moderately intensely cultivated (FAO, 1967)
Geomorphology	: -
Soil series	: Varempere, Tafale and Tanina series.

Soils.
The village of Nakpala occupies map unit 6.1/6.2 on the 1 : 250 000 soil map of the Bole-Bamboi region. The soils of this unit are described as moderately shallow to moderately deep, colluvial soils, occurring at upper to middle slopes. They are reddish brown to brown and have a light texture and overly an incipient pan or ironstone pan. The soils are mapped as Varempere and Tafali series and their shallow phases, and in some places the shallow phase of the Tanina series.
As the above is all the information there is on these soils on the legend of the Bole-Bamboi soil map (the report is not available), additional information on the Varempere, Tafale and Tanina series is taken from FAO (1967) and Adu (1969). The Varempere ass. consists, according to Adu (1969), of the following series. On the summits the very shallow, concretionary and stony Wenchi series is found; the red, moderately deep to deep, in situ developed Varempere series is found on the upper slopes, while on the middle slopes the colluvial, moderately deep to deep Tafale series is found. On the lower slopes occur the shallow, pale-coloured Gulo series, consisting of loamy fine sand overlying a seepage ironpan at approx. 30 cm depth. In the valleys the gray, poorly drained clays of the Kupela

series and the deep colluvial, sandy Berenyasi series are found.
On the FAO (1967) soil map the soils of the area around Nakpala are indicated belonging to the Tanina ass. (map unit 19) and not to the Varempere ass. Apparently, FAO (1967) considered the predominant soils in the area sufficiently concretionary to be mapped as the Tanina ass.
Below follows a description of the Varempere, Tafale and Tanina series. In the field can be checked which of these descriptions correlates most with the actual on-farm soil conditions. See also Annex II.

7.5.1 Varempere series

The Varempere series occur on summits and upper slopes where the slope gradients range between 0-5% with an average of 2%. Varempere series are moderately well to well drained, moderately deep to deep soils, with a yellowish brown to brown, coarse sandy loam or coarse loamy sand surface horizon to a depth of 20-40 cm. This topsoil has a weak crumb structure and the upper 7-10 cm is slightly humous. It overlies yellowish red to (reddish brown) or red, coarse sandy (clay) loam with abundant fine quartz gravel and some occasional ironstone concretions, with a weak medium blocky structure and a lower limit which varies between 90 and 150 cm.
Often a hard vesicular pan with mottling is found below 90-150 cm depth.
Below the subsoil there is usually 90-120 cm of strongly weathered parent material, consisting of red and yellow or brown, mottled coarse sandy clay.
The clay content may increase from as low as 6-10% in the topsoil to 40% in the subsoil. The soil reaction does not vary much between topsoil and subsoil, usually being slightly to moderately acid (6.0-6.4). The soil has a good moisture holding capacity. The organic carbon content is low (<1.5% in the topsoil). The CEC is low, 2-4 meq/100 g in the topsoil, increasing to 6 meq/100 g in the subsoil. The TEB content varies from 1 to 5 meq/100 g. Both P and N levels are very low, total P is around 45-100 ppm. The base saturation is medium to high: over 85% in the topsoil and over 70% in the subsoil.

	sand %	silt %	clay %	org.C %	pH H_2O	CEC meq/100 g	TEB meq/100 g	Base sat. %	Total P ppm
topsoil	80-90	4- 8	4- 5	0.4-1.1	6.3-6.7	2-4	1-4	85-100	40- 75
subsoil	45-80	5-16	10-40	0.1-0.6	6.0-6.4	1-6	1-5	70- 90	50-100

Tentative classification:

Ghana : Savannah Ochrosols
Soil Taxonomy: Plinthustalfs, loamy or loamy over petroferric
Typic Haplustalfs, loamy or loamy over petroferric
FAO : Plinthic Luvisols
Chromic Luvisols

Agricultural suitability:
As the soil is moderately deep to deep and not stony it offers freedom of root development. The subsoil will remain moist for long periods due to the relatively high moisture holding capacity, but the topsoil may dry out in the dry season. The fertility is very low, but the productivity of the soil is easily improved by the application of fertilizers. Good responses to the application of superphosphate and "kraal" manure have been reported by Djokoto and Stevens (1961) in Adu (1969) from fertilizer trials conducted on Varempere soils at Manga Agricultural Research sub-station. Most crops also responded well to the application of sulphate of ammonia.
The Varempere soils are suitable for almost all the traditional crops commonly grown in the region: millet, guinea corn, maize, groundnuts, bambarra beans, cowpeas and tobacco, which is grown as an additional cash crop (Adu 1969).
The soil is however somewhat susceptible to erosion and appropriate soil conservation measures such as strip cropping, contour ploughing and the application of organic manure are necessary when the soil is cultivated continuously.
The eroded, shallow phases and the concretionary variants are also suitable for cropping but hand or bullock ploughing is recommended. These soils are more freely draining and have a lower moisture holding capacity, and the surface horizons easily become droughty in the dry season. They are more susteptible to erosion and soil conservation measures are necessary.

Representativeness of Varempere-Tafale series:
There exists a considerable difference between the FAO (1967) soil map and the 1 : 250 000 soil maps of the Bole-Bamboi and the Navrongo-Bawku areas concerning the extent of this association. On the FAO (1967) soil map the deep soils of the Varempere-Tafale ass. cover only a very limited area, mainly west of Bole in the western part of the country. On the Bole-Bamboi soil map however, the Varempere-Tafale ass. is shown covering quite extensive areas (map units 6.1 and 6.2). It is however not clear from the legend of the Bole-Bamboi soil map whether unit 6.1 represents the deep phases of Varempere and Tafale and unit 6.2 the shallow phases and concretionary soils, or that unit 6.1 includes both deep and shallow soils and unit 6.2 deep, shallow and concretionary (Tanina series) soils. The FAO (1967) soil map instead of Varempere-Tafale series, indicates highly concretionary soils predominating in large parts of the granite area, mapped as units 19 and 20 (Tanina and Kolingwu associations).
In the Navrongo-Bawku area the soils of the Varempere ass. (thus including the Tafale, Gulo, Wenchi and Berenyasi and Kupela series) occupies (map unit 1) a fairly extensive area in the eastern part of the basin. Also the FAO (1967) soil map indicates the Varempere- Tafale ass. for this location, but the area covered is considerably smaller. Part of it is occupied by the Tanina ass.
In the Nasia River Basin and the East Dagomba area, soils developed over granite do not exist.

7.5.2 Tafale series

This series is developed in colluvium. It occurs at a lower site than Varempere series, on slope gradients of 1-5%, averaging 2%.
They are moderately deep to deep, moderately well drained soils, with a profile consisting of 15-25 cm pale brown to brownish gray loamy coarse sandy topsoil, with a weak crumb structure overlying 90-120 cm of light brown to reddish yellow coarse sandy loam to coarse sandy clay. Below 120 cm a weak seepage ironpan is usually found, consisting of gravel and ironstone concretions cemented by iron.

Tentative classification:

Ghana : Savannah Ochrosols
Soil Taxonomy: Plinthustalfs, loamy-or clayey (over petroferric)
or Typic Haplustalf, loamy-or clayey (over petroferric)
FAO : Plinthic Luvisols
or Chromic Luvisols

Agricultural suitability:
The Tafale series has a slightly lower moisture holding capacity than Varempere series and it is more easily eroded. Owing to the absence of stones or ironstone concretions or pans it is easy to cultivate and offers a good growing medium to both root and tree crops. Like Varempere series the productivity of the soil is easily improved by the application of organic and inorganic fertilizers, especially nitrogen and phosphate (Adu 1969).
Erosion control measures are strictly necessary in order to maintain the production capacity of the soil.

Representativeness of Tafale series:
The Tafale series occurs in close association with Varempere series; therefore reference is made to Varempere series.

7.5.3 Tanina association

The Tanina association consists of moderately well drained, dark brown to reddish brown, sandy (clay) loams or sandy clays, which are highly concretionary. The ironstone concretions occupy generally over 50 volume %, up to 90% in the subsoil. The A horizon, which may be concretionary to a depth of 25-40 cm, usually has a coarse sandy texture. The concretions are loosely packed to a depth of 60-90 cm, and root penetration is still possible to this depth.

The clay content in the topsoil is 5-10%, increasing to 30-50% in the subsoil. The organic carbon content is low (<1%). The soil reaction is slightly to moderately acidic (6.0-6.7). The CEC and TEB are low (2-6 meq/100 g). The base saturation is fairly high, usually over 70%.
The fertility is low.

	sand %	silt %	clay %	org.C %	pH H_2O	CEC meq/100 g	TEB meq/100 g	Base sat. %
topsoil	80-90	5-10	5-10	0.5-0.7	6.5	3-4	3-4	90-100
subsoil	40-65	5-15	15-50	0.1-0.4	6.0-6.7	2-6	2-6	70-100

Tentative classification:

Ghana : Savannah Ochrosols
Soil Taxonomy : Plinthustalfs, sandy over loamy-or clayey-skeletal
Haplustalfs, sandy over loamy-or clayey-skeletal
FAO : Plinthic Luvisols, petric phase
Chromic Luvisols, petric phase

Agricultural suitability:
The Tanina series has a limited potential for agricultural production. The fertility is low, it is very stony and the moisture holding capacity is low resulting in droughtiness in the dry season. It may be susceptible to erosion. It is not suitable for mechanical tillage.

Representativeness of Tanina series:
There is a discrepancy between the areas covered by Tanina as indicated on the FAO (1967) soil map and the soil maps of the Bole-Bamboi and Navrongo-Bawku area.
On the FAO map, the Tanina ass. covers extensive areas in the western and northwestern part of the country, including the Bole-Bamboi region. However, on the Bole-Bamboi sheet, the Tanina series covers only parts of map units 6.2 and 1.1. In the Navrongo-Bawku area, the Tanina series (map unit 19) on the FAO soil map covers an fairly extensive area, which for about 50% coïncides with the (western) part of the area occupied by the Varempere ass. (map unit 1) on the Navrongo-Bawku soil map.
Which one of the maps shows the correct situation can only be ascertained by field observations.

7.6 Wantugu village

From this village, it is only known that the soils are designated as the Sambu-Pasga association (map unit 11) on the FAO (1967) 1 : 500 000 soil map.
For a description, classification and agricultural suitability of these soils is referred to the soils of Nakpa village.

7.7 Binduri village

Location : approx. 10 km southwest of Bawku, Navrongo-Bawku area.
Geology : Pre-Cambrian granites and granodiorites; immediately east of the village Pre-Cambrian Birrimian rocks (argillaceous sedimentary and/or volcanic series) or mixed granitic and Birrimian rocks.
Elevation : -
Landuse : -
Geomorphology: Slopes 0-2%, locally 2-5% east of Binduri 0-2% increasing towards 9-12%.

Soil series : - around, south and west of Binduri. Varempere association (consisting of Varempere, Tafale, Wenchi and Gulo series and Berenyase and Kupela series near and in valleys).
- east of Binduri: Yagha association (consisting of Yagha, Nangodi, Sapeliga and Kalini series) and/or Dorimon-Pu complex, consisting of the Nangodi and Kolingu associations.

Soils

The village of Binduri occupies map unit 1 (Varempere association) on the 1 : 250 000 soil map of the Navrongo-Bawku area (Adu, 1969). The soils of this unit are developed over granites. The soil series show a definite relationship with the relief. On the summits and upper slopes the moderately well to well drained, moderately deep to deep Varempere series is found. On some of the summit areas the very shallow, concretionary and stony Wenchi series may be found, on the middle slopes the colluvial, moderately deep to deep, moderately well drained Tafale series occurs and on the lower slopes of the association the shallow, seepage-pan Gulo series is found.

The association is made complete by the moderately deep to deep, imperfectly and poorly drained soils of the valley bottoms and adjoining areas (Kupela and Berenyase series).

For the description of Varempere, Wenchi and Tafale series is referred to pages 44-47.

Directly east of the village of Binduri, we find the soils belonging to map units 13 and/or 15 (soils developed over Birrimian rocks or over mixed Birrimian and granitic rocks). It is not clearly indicated on the soil map 1 : 250 000 (Adu, 1969) which of these untis is dominant in the area. But, as several of the series of unit 13 form part of unit 15, they are described as belonging to one topo-sequence. This is in agreement with fig. 6 in Adu (1969). Generally, on the upper slopes the shallow, stony or concretionary Kolingu, Nangodi or (locally) the Doriman series are found.

On the lower slopes dominate the deep, colluvial clayey Yagha series. In the valleys the moderately deep Kalini series occur with locally, on the banks of major streams, the deep to very deep clayey Sapeliga series. It is however questionable whether Sapeliga series is of importance in the Binduri area.

Agricultural suitability.
Soils around, west and south of the village. From an agricultural point of view, the Varempere and Tafale series are most important in this area. These series have the highest agricultural potential because of their depth and relative lack of concretions. Besides, they cover the major part of the prevailing association in this area, map unit 1. The Gulu and Wenchi series are too shallow and stony to be of much agricultural importance, except for some rough grazing and they are of limited extent. Berenyase and Kupela series are of limited importance; they are

too wet in the rainy season and too dry in the dry season. They have however some potential after improvements are made, such as water-, erosion control measures and application of organic manure.

Soils east of the village.
Of the soil series prevailing east of Binduri, Nangodi series is at present mainly used for agricultural operations, because of the fertility of the soil and the good rooting conditions, despite the stoniness of the soil and the relatively steep slopes. Yagha series has the greatest potential of the soil series in this area: not only because of its large extent but also because the soil is fertile and relatively level and not stony. Therefore, it is considered suitable for mechanized farming operations. For hand operated tillage the texture of this soil is however too heavy, which is related to the vertic characterisics of this series.

The Kolingu and Dorimon series are of very limited importance agriculturally; they are shallow and stony with poor moisture retention. Kalini series has a high fertility, but as with Yagha series hand tillage is difficult, due to poor physical characteristics, such as extreme hardness in the dry season and waterlogging in the wet season.

More detailed information concerning the agricultural suitability of the series can be found in Adu (1969). Below follows a brief description of the soil series. A tentative classification is given for the agriculturally most important series.

7.7.1 Soils west and south of the village

7.7.1.1 Gulo series

This series occurs on slopes of 0-2%, on physiographic positions below Tafale series, but above the valleybottom soils. Gulo series occupies the flanks of streams and depressions, similar in position to the Kpelesagwu and Changnalili series. Gulo series are imperfectly drained, shallow ground water laterites, consisting of approx. 5-7 cm of a very pale brown loamy coarse sandy topsoil, overlying approx. 15-25 cm of (yellowish) brown loamy coarse sand. At a depth of 20-30 cm on indurated or incipient pan is found.
Representativeness: This soil is likely to occur quite frequently on the lower slopes within the areas occupied by mapping unit 1 of the Navrongo-Bawku soil map (Adu, 1969).

7.7.1.2 Berenyase series

This imperfectly drained series occupies low, imperfectly drained sites adjoining the valley floors. The slope gradiënt is usually 1-2%. The profile consists of gray, strongly mottled brown loam with medium hard crumbs, overlying approx. 90 cm of whitish gray mottled reddish yellow, fine sandy or coarse sandy loam to loamy fine or coarse sand.
Locally, layers of clay may be found in the profile.
Representativeness of Berenyase series: This series occurs within

the mapping units 1, 3, 4 and 8 of the Navrongo-Bawku 1 : 250 000 soil map (Adu, 1969).

7.7.1.3 Kupela series

This poorly drained series occupies the nearly level (0-1%) valley bottoms in the granitic areas. The soil is more fine textured than Berenyase series. It consists of approx. 5-8 cm of gray, humous, silty fine sandy clay, with hard crumb structure, overlying approx. 25 cm of brownish gray, silty to fine sandy clay. The subsoil consists of gray, silty or fine sandy clay with yellow or brown mottles. Calcium carbonate concretions may be found occasionally deeper in the profile.
Representativeness of Kupela series: This series occurs on the valleybottoms within mapping units 1, 3, 4 and 8 of the Navrongo-Bawku soil map (Adu, 1969).

7.7.2 Soils east of Binduri village

7.7.2.1 The Kolingu association

The Kolingu association is for the major part composed of the Kolingu series. This series consists of a moderately eroded, shallow soil, occurring on middle to upper slope sites, with gradients of 2-3%.
This series consists of approx. 20 cm of pale brown, loamy coarse sand with frequent fine quartz gravel, stones or ironstone concretions, overlying approx. 15 cm of very pale brown, coarse sandy clay with very frequent quartz gravel, occasional stones and frequent pieces of decomposed granite.
The horizon with a depth of approx. 30-60 cm consists of yellow brown, mottled coarse sandy clay with abundant quartz gravel and ironstone concretions. It is underlain by decomposed granite. Shallower and more stony variations within this series do occur locally.
Representativeness of Kolingu series: The map unit 3, Kolingu association, is fairly extensive on the granitic areas in the Navrongo-Bawku area. The Kolingu ass. corresponds with the map unit 20 on the FAO (1967) soil map.

7.7.2.2 The Nangodi association

Component soils of the Nangodi association are the Nangodi, Dorimon, Yagha and Kalini series. The last 2 series are discussed separately. Nangodi series occurs on the footslopes of steep hill ranges of Birrimian rocks. The dominant slope percentage of Nangodi series is 9-12%.
This series is very stony and consists of greenstone fragments with some quartz stones in a matrix of brown to reddish brown silty clay. With depth the rock fragments increase in size and overly weathering greenstone at a depth of 60-90 cm.

Tentative soil classification:

- Ghana : Lithosols
- Soil Taxonomy: Typic Ustorthents, clayey, skeletal
- FAO : Eutric Regosols
or Eutric Cambisols

Dorimon series
This welldrained series occurs locally on upper slopes and summit sites in areas predominantly occupied by Nangodi series. The profiles consist of 5-8 cm of dark brown, humous, crumbly fine sandy loam overlying 30-45 cm of porous, yellowish red, mottled silty clay loam with frequent to abundant rock fragments and ironstone concretions, overlying gray and red mottled silty clay with pieces of partly weathered greenstones. This series is not very extensive.
Representativeness of Nangodi association: This association (map unit 12) is not very widespread in the Navrongo-Bawku area. The Nangodi association corresponds with soil map unit 20.2 the Nangodi association, on the FAO (1967) soil map.

7.7.2.3 The Yagha association

The Yagha association consists for approx. 60% of the imperfectly drained, deep to very deep Yagha series, with Nangodi series around local outcrops of greenstones. On river bank levees locally the Sapeliga series is found.
Soils of small valley bottoms are formed by the dark coloured, heavy textured Kalini series.

Yagha series.
This series occurs on long piedmont slopes with gradients less than 2%. It is developed in colluvial material derived from upslope Nangodi soils. Locally greenstone outcrops are encountered. Yagha series consists of 0-7 cm of dark grayish brown, humous silty clay, with a medium blocky structure, overlying approx. 25 cm of dark grayish silty clay, with a medium subangular blocky structure, overlying 120-150 cm of light olive brown clay. This clay cracks on drying, but is plastic when moist. This layer overlies weathering greenstones.
Frequent quartz stones may occur at the surface. The texture may be lighter by admixture of sand in areas where the soils come into contact with those of granite origin. The soil has self-mulching characteristics.

Tentative soil classification:

- Ghana : Tropical Brown Earths
- Soil Taxonomy: Typic Chromusterts, clayey
- FAO : Chromic Vertisols

Representativeness of Yagha series: This series forms the major part of map unit 13 on the Navrongo-Bawku soil map (1 : 250 000), as well as on the more gently sloping areas of the Nangodi association (map unit 12).

7.7.3.2 Sapeliga series

This moderately well drained, deep clayey soil occurs locally on levees along the major streams within the Yagha association.
As the area east of Binduri is located at the upper part of the watershed, major streams with levees are unlikely to occur.

7.7.3.3 Kalini series

This series occurs on small, nearly level (slopes 1-5% or less) valley bottoms. This poorly drained, moderately deep to deep series is alluvial in origin and consists of 7-10 cm of very dark gray clay, overlying 45-60 cm of black (silty) clay with a medium blocky structure with some ironstone concretions, overlying dark gray clay, also with some ironstone concretions. Below 60-120 cm depth gray, mottled clay derived from decomposing greenstone is found.

Representativeness of Kalini series: This series occurs in the valley floors of the Nangodi and Yagha associations (map units 12 and 13) of the Navrongo-Bawku soil map 1 : 250 000.

village	series	FAO (1967) Northern Ghana		Nasia River Basin		Navrongo-Bawku area		East Dagomba area		Bole-Bamboi area	
		series	unit	series	unit	series	unit	series	unit	series	unit
Nakpa	Nankpayeri	Sambu*	11	-		-		Nankpayeri	8	Sambu*	5
	Sambu	Sambu	11	-		-		Sambu	5	Sambu	5
	Pasga	part S.-P.ass.	11	-		-		Pasga	5	-	
	Dogbam	part S.-P.ass.	11	-		-		Dogbam	7	-	
	Wulasi	Kpelesagwu*	9,10	Kpelesagwu*	15,17	Kpelesagwu*	20	Wulasi	8	-	
Namburugu	Kpelesagwu	Kpelesagwu	9,10	Kpelesagwu	15,17	Kpelesagwu	20	Kpelesagwu	2,4	-	
	Changnalili	Changnalili	9,10	Changnalili	15,17,18	Changnalili	20	Changnalili	2,4	-	
	Volta	Volta	1, 2	Volta	20	Volta	21	Volta	1	Volta	12
Nakpanduri	Kintampo	Kintampo	12,12-1	Kintampo	2, 4, 6	Kintampo	17,17a	Gushiagu-Kasale*	3	Kintampo	5
	Mimi	Mimi	15	Mimi	3, 4	Mimi	16	-		Mimi	10
	Murugu	part Mimi ass.?	15	Murugu	3, 4	Murugu	16	-		Damongo	10
	Nalerigu	part Mimi ass.?	15	Nalerigu	3, 6	Nalerigu	16	-		part Mimi ass.?	10
Nakpala	Varempere	Varempere	17,17-1	-		Varempere	1	-		Varempere	6.1, 6.2
	Tafale	Tafale	17,17-1	-		Tafale	1	-		Tafale	6.1, 6.2
	Tanina	Tanina	19	-		-		-		Tanina	1.1, 6.2

* corresponding series developed on different parent material.

8 LITERATURE AND MAPS AVAILABLE FOR REFERENCE AT STIBOKA, WAGENINGEN

Adu, S.V. 1957. Report on the detailed soil survey of the Central Agricultural Station, Nyankpala.

Adu, S.V. 1969. Soils of the Navrongo-Bawku area, Upper Region, Ghana. Memoir no. 5, Soil Research Institute, Kumasi.

Adu, S.V. 1975. The use of aerial photographs in the mapping of savannah soils in Northern Ghana. Conference paper no. 40 of Conference on Earth Resources Technology Satellite Remote Sensing. Kumasi.

Adu, S.V. 1975. Field tour profile descriptions of I.S.S.C.-profiles no. 3, 8, 9, 11, 5, 4, 1, 2, 10, 6 and stop 1 and 3. Post conference tour no. III. Int. Society of Soil Science Conference of Savannah soils of Africa and their management. Kumasi.

Adu, S.V. 1981. The geomorphology, soils, water resources and land use potential of the Nasia River Basin, Ghana. In: I.T.C. Journal 1981-4. Enschede.

Adu, S.V. 1981. Land evaluation and management in Ghana on the basis of physical and chemical properties. World Soil Resources Report no. 55. pp. 26-33. FAO, Rome.

Adu, S.V. and Stobbs, A.R. 1981. Soils of the Nasia River Basin, Northern Region. Memoir no. 6, Soil Research Institute, Kumasi.

Ahn, P. 1970. West African Soils. Laterite formation. pp. 98-106, and General classification of West African Soils, pp. 202-213. Oxford University Press.

Brian Wills, J. (Ed.) 1962. Agriculture and land use in Ghana. Oxford University Press. London.

Brammer, H. 1957. A note on the utilisation of the soils of the station and their relationship to those of the Voltarian basin as a whole. In: Adu, 1957.

Evaluation Report, 1982. Agricultural Experiment Station Nyankpala. GTZ, Eschborn.

FAO, 1967. Land and Water Survey in the Upper and Northern Regions. Ghana. Volume III. Soil Surveys. Rome.

FAO-Unesco, 1974. Soil map of the World. Volume I, Legend. Paris.

FAO-Unesco, 1977. Soil map of the World. Volume VI, Africa. Paris.

FAO, 1981. Cinquième réunion du sous-comité Ouest et Centre Africain de corrélation des sols pour la mise en valeur des terres. Lomé. World Soil Resources report. no. 55 FAO-Rome.

Hornetz, B. 1984. Agrarklimatologisches Gutachten in Rahmen des GTZ-projektes "Mischkulturen". (Nyankpala/Ghana) (unpublished) Heidelberg.

Obeng, H.B. 1970. Characterization and classification of some ironpan soils of Ghana. Iowa State University, Iowa (unpublished, available at ISRIC-Wageningen).

Obeng, H.B. 1970. Ghana. Twenty-five years of Soil Survey and Classification in Ghana. In: World Soil Resources Report no. 40 (Kumasi). FAO, Rome.

Obeng, H.B. 1970. Soils which present problems in use and management in West-Africa. In: World Soil Resources Report no. 40. pp. 93-97. (Kumasi). FAO, Rome.

Obeng, H.B., Acquaye. D.K. and Bampoe-Addo, A. 1971. Ironpan geomorphic surfaces and associated soils of Ghana. Paper presented to the Conference on Agricultural Research and Production in Africa. Kumasi.

Obeng, H.B. 1972. Soil formations in sandstone and clay shale areas. World Soil Resources Report 44. pp. 25-29. (Accra) FAO, Rome.

Obeng, H.B. 1972. Early trends in the correlation and classification of the soils of Ghana. World Soil Resources Report 44. pp. 108-112. (Accra) FAO, Rome.

Obeng, H.B. 1975. Soils of the interior savannah zone of Ghana, their problems and management. pp. 4-12. West African Soil Correlation meeting, Dakar. Unpublished. FAO-Rome.

Obeng, H.B. 1975.2. Soils of the savannah zones of Ghana - their physico-chemical characteristics, classification and management. Keynote paper in: Proceedings of the Joint commissions, I. IV, V, and VI of the International Society of Soil Science Conference on Savannah Soils of the sub-humid and semi-arid regions of Africa and their management. pp. 11-23. Tema, Ghana.

Sijs, C. 1975. Savannah soils of Central Africa - their classification and management. In: Proceedings Savannah Soils of the sub-humid and semi-arid regions of Africa and their management. pp. 53-57. Tema, Ghana.

USOM/G. Survey Team. 1959. East Dagomba Agricultural and Live Stock Survey - Northern Ghana. Ghana.

Wambeke, van. A. 1982. Soil moisture and temperature regimes. Soil management Support Services. Technical Monograph no. 3. Soil Conservation Service. USDA Ithaca.

Young, A. 1975. Weathered ferralitic soils: their properties, genesis and management. In: Proceedings Savannah Soils of the sub-humid and semi-arid regions of Africa and their management. pp. 171-174. Tema, Ghana.

Soil map of the Bole-Bamboi Region, 1 : 250 000 (soil survey) of Ghana. Map only.

APPENDIX A

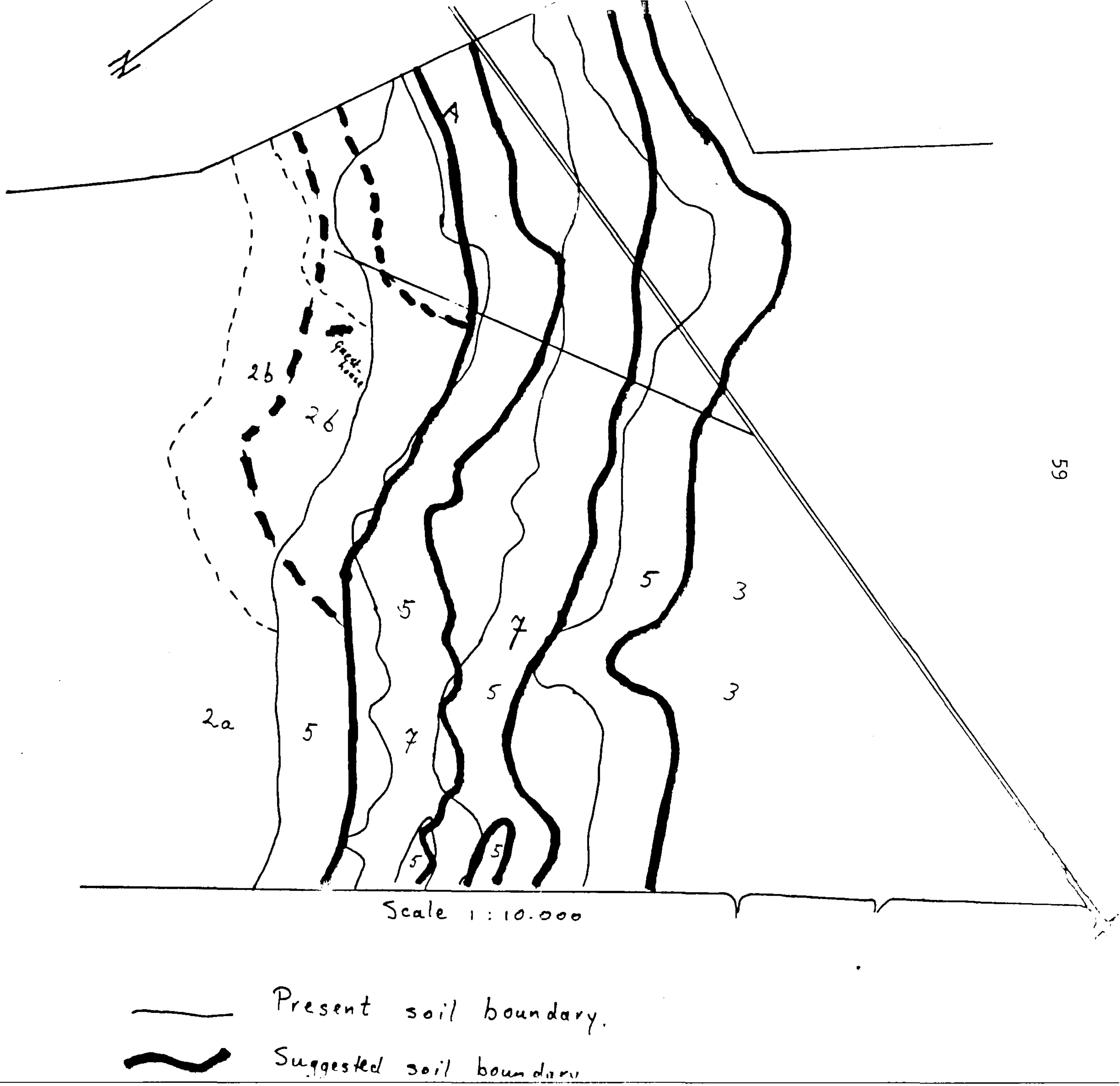
The following definitions can be found in the FAO Soil Map of the World Legend (1974).

- Petroferric phase. Soils in which the upper part of the petroferric horizon occurs within 100 cm of the surface. The petroferric horizon is a continuous or fractured layer of indurated material, in which iron is an important cement and organic matter is absent, or present only in traces.
  The indurated layer is continuous or is fractured with the lateral distance between fractures of 10 cm or more.

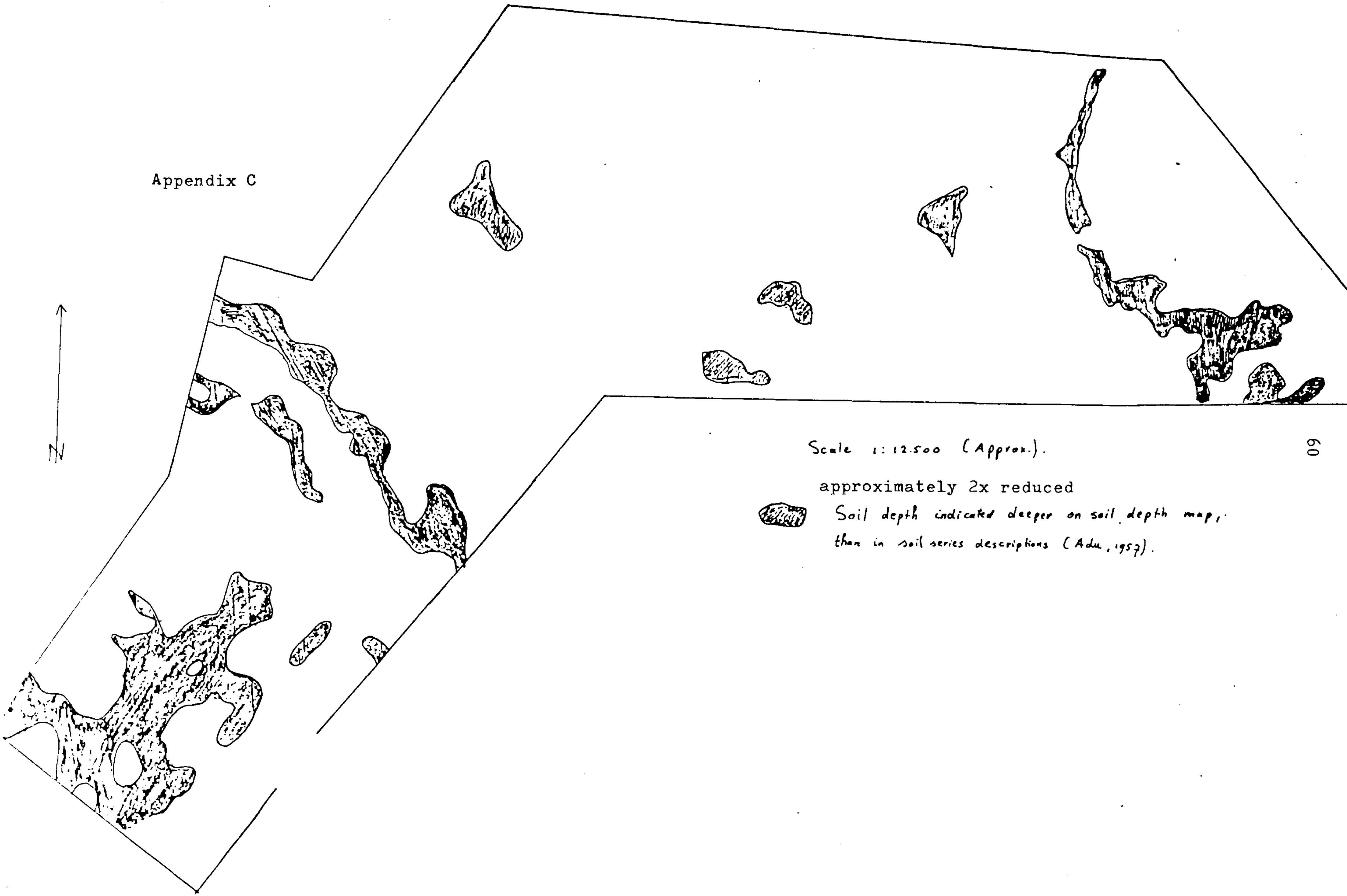
- Petric phase. Soils with a layer consisting of 40% or more by volume of oxidic concretions or of hardened plinthite or ironstone or other coarse fragments with a thickness of at least 25 cm, the upper part of which occurs within 100 cm of the surface. The difference in the petroferric phase is that the concretionary layer of the petric phase is not continuously cemented.

- Plinthite. Plinthite is an iron-rich, humus-poor mixture of clay with quartz and other materials, which commonly occurs as red mottles in certain patterns and which changes irreversibly to an ironstone hardpan or to irregular aggregates on exposure to repeated wetting and drying. In a moist soil, plinthite is usually firm, but it can be cut with a spade. When irreversibly hardened the material is no longer considered plinthite, but is called ironstone.

Appendix B


N
A
Guest house
2b
2b
2a
5
5
7
7
5
5
5
5
3
3
Scale 1:10.000
Present soil boundary.
Suggested soil boundary

Appendix C


Scale 1:12.500 (Approx.).
approximately 2x reduced
Soil depth indicated deeper on soil depth map, than in soil series descriptions (Adu, 1957).

ANNEX I.1

Literature on Ghana Land Resources available at the Royal Tropical Institute, Amsterdam.

Literature available at the Royal Tropical Institute, Amsterdam. no's: 631.0 - 631.9 (115).

Charter, C.F. 1949. Papers on soil survey. Report of the Cocoa conference.
Purnell, M.F. 1954. Preliminary report on the proposed pineapple area, Ashalaja. Kumasi.
Brammer, H. 1955. Detailed Soil survey of the Kpong Pilot irrigation area. Kumasi.
Adu, S.V. 1957. Report on the detailed soil survey of the Central Agricultural Station, Nyankpala. Kumasi.
Akutor, A.K. 1959. Report on the detailed soil survey of Ejura agricultral station, ed. by H. Brammer. Kumasi.
Brammer, H. 1958. Ho-Keta plains, Trans-Volta/Togoland. Kumasi.
Hammon, J.B. 1950. Report to the Gov. of Ghana on the irrigation problems of the Accra plains. FAO.
MacKinnon, E. 1958. Report to the Gov. of Ghana on agronomic aspects of the Kpong pilot irrigation scheme. FAO.
Ahn, P. 1959. The soils of Buaku cocoa station. Sefuri district, Western region. Kumasi.
Brammer, H. 1959. The tropical black earths of Ghana. Kumasi.
Brand, B. and H. Brammer. 1959. Provisional grassland associations of the interior and coastal savannah zones of the Gold Coast. Kumasi (map not available).
U.S. Operation Mission in Ghana. 1959. East Dagomba agricultral and livestock survey, Northern Ghana. Accra.
Mensah-Ansah, J.A. 1959. Report on a detailed soil survey of Poana cocoa Station. Kumasi.
Roy, B.N. 1959. Report on the detailed soil survey of the medium Security Prison Farm, Nsawam, Eastern Region. Kumasi.
Heath, R.G. 1961. Report to the Gov.'t of Ghana on crop production possibilities under conditions of irrigation in the Volta flood plain area. FAO.
Manshard, W. 1961. Die geographischen Grundlagen der Wirtschaft Ghana's unter besonderer Berücksichtigung der agrarischen Entwicklung. Wiesbaden.
Adu, S.V. 1960. The soils of Manga agricultural station. Kumasi.
Ahn, P.M. 1962. The soils of the proposed 1000-acre cocoa estate, Ahafo, Ghana, Kumasi.
USAID 1962. Report on soil and agricultural survey of Sene-Obosum river basins, East Brong-Ahafo and Ashanti regions.
Adu, S.V. 1963. The soils of Tono state farm. Kumasi.
Adu, S.V. and Jungerius, P.D. 1963. Report on the detailed survey of Mampong agricultural station, Ashanti. Kumasi
U.S. Operations Mission to Ghana. 1959. Report on the soil survey of N.W. Ashanti, Tain Basin, by C.L. Coultas. Completion of assignment report N.W. Ashanti survey; conditions of aid possibilities for livestock production by J.R. Neale. Accra.

Stobbs, A.R. 1959. Report on the detailed soil survey of Wenchi Agricultural station, Wenchi. Sunyani district, Ashanti, Kumasi.

Ahn, P.M. 1960. The soils of Aiyinasi agricultural station and their relationship to the soils of Nzima, Western Region. Kumasi.

U.S. Operations Mission to Ghana. 1960. North Gonja Agricultural and livestock survey. Accra.

Adu, S.V. 1961. The soils of Zuarungen agricultural station. Upper Region. Kumasi.

Ahn, P.M. 1961. Soils of the Lower Tano Basin, S.W. Ghana. Kumasi.

Jordan, D. 1963. The use of cover crops with special reference to the forest region of Ghana. Kade.

Mensah-Ausah, J.A. 1963. Report on the detailed soil survey of Juaso Cocoa station, Ashaniti. Kumasi.

Obeng, H.B. and Aina, J.T. 1963. The suitability of the soils of Mangoase co-operative farm for large-scale cultivation of avocado pears. Kumasi.

FAO, 1963. Report on the Survey of the Lower Volta river flood plain, U.N. Special fund project. Rome.

Vol. I General report
II Soil survey and classifications
III Agronomical considerations
IV Engineering designs and estimates
V Economic appraisal.

Scott, J.M. 1963. Soils of the Dodowa co-operative farm. Kumasi.

Brammer, H. 1967. Soils of the Accra plains. Kumasi.

FAO, 1967. Report of the W.F.P. mission on the appraisal of the Volta river resettlement in Ghana in regard to W.F.P.-assistance. Rome.

FAO, 1968. Report to the Gov.'t of Ghana on applied agronomic research on field food crops in Northern Ghana, based on the work of Y.E.A. Azab. Rome.

FAO, 1968. Report to the Gov.'t of Ghana on irrigated agriculture in the upper and northern regions; based on the work of S.N. Kaul. Rome.

Eshuis, E. and P. de Veth. 1969. Education and farming; a survey among middle school leavers, middle-school teachers and parents in Central Region, Ghana, about occupational aspirations and attitudes towards farming and education. Amsterdam.

Amatekpor. J.K. 1970. Some investigations on soils, agricultural landuse, insect pests and plant diseases in the drawdown area of the Volta lake. Accra.

Remy, G. 1972. Donsin - les structures agraires d'un village Mossi de la region de Nobere (Cercle de Manga). Paris.

FAO, 1972. Report to the Gov.'t of Ghana on farm mechanization in the Northern and upper regions. Rome.

FAO, 1973. Pilot irrigation dev. scheme, Asutsuare, Ghana farm management and settlement. Rome.

Guide to the production of some crops in Ghana. Kumasi. 1974.

FAO, 1974. Increased farm production through fertilizer use. Ghana: agronomic experimentation and extension work in the Volta, Central and Ashanti- Brong-Ahafo regions. Rome.
FAO, 1974. Increased farm production through fertilizer use, Ghana: Soil chemical and soil classification studies in relation to soil fertility and fertilizer recommendations. Rome.
FAO, 1976. Report. Second, on the protection of maize in farm storage, based on the work of R. Taylor. Rome.
Klingshirn, A. 1977. UNFPA-FAO study mission on the involvement of women in cooperatives connected with food production and distribution and related population activities in Zaire and Ghana. 26 Oct. - 31 Dec. 1976. FAO, Rome.
Soils of Ghana (covering the published literature for 1946-1974). Herpenden 1977.
Crop improvement in Ghana: proceedings of a symposium held in Univ. of Ghana. 1978.
Gyasi, E.A. 1975. A comparative geographical analysis of maize production in Ghana. Wisconsin.
Obeng, H.B. 1978. Characterization and classification of some ironpan soils of Ghana. Iowa State Univ.
Korem, A. 1979. Influence of indiscriminate burning on desiccation and desertification - observations in Northern Ghana. Zandvoort.
Konings, P. 1981. Peasantry and state in Ghana: the example of the Vea irrigation project in the upper region of Ghana. Leiden.
Ardayfio-Schandorf, E. 1982. Rural dev. strategies in Northern-Ghana - problems and prospects for reaching the small farmer. Norwich-Geo books.

no.: 632 - 639 (115)

Leather, R.I. 1959. Diseases of economic plants in Ghana other than cacao. Accra.
Bray, F.R. 1959. A study of yam farming in North Manpong. Ashanti. Legon.
Blair, I.J. 1960. Int. development of grazing and fodder resources.
Mc Ewen, J. 1961. Raising of cereal yields in Northern Ghana. Accra.
Blair, I.J. 1963. Report to the Gov.'t of Ghana on production from grassland. Rome, FAO.
Coursy, D.G. and A. Aidoo, 1966. Ascorbic acid levels in Ghanaian yams.
Forsyth, J. 1966. Agricultural insects of Ghana. Accra.
FAO, 1970. Food research and dev. unit. Ghana. Conditions for the expansion of fruit and vegetable processing. Rome.
FAO, 1972. Report to the Gov.'t of Ghana on 1970 Census of agriculture and improvement of agricultural statistics. Rome.
Okoso-Amaa, K.K. 1971. Rice marketing in Ghana: an analysis of Gov.'t intervention in business. Uppsala.
Innes, R.R. 1977. A manual of Ghana grasses (with a key to species). Surrey, England.
Winch, F.E. 1976. Costs and returns of alternative rice production systems in Northern Ghana; implications for output, employment and income distribution. Ann Arbor.

Hartog, A.P. den, 1969. Some observations on the use of palm oil in Northern Ghana for a campaign of popularisation of palm oil. Rome, FAO.

Ghana 33.

Ramsay, J.M. and Rose Innes, R. Some quantitative observations on the effects of fire on the Guinea savannah vegetation of Northern Ghana over a period of eleven years.

Ramsay, J.M. and Rose-Innes, R. 1964. Studies on browse plants in Ghana. Chemical comp.

Obeng, H.B. 1971. The major soil groups of Ghana and their potential for agric. development. 4 pp.

Foggie, A. 1962. Conservation of natural resources in Ghana.

Nye, P.H. 1958. The relative importance of fallows and soils in staring plant nutrients in Ghana.

The ecology of peasant farming systems in Ghana. Legon, 1974. "Bush-fallow and shallot farming system."

Hänsel, H. 1972. Zu fragen der Wirtschaftlichkeit bei der Übernahme neuer Verfahren: Mineraldüngung in Ghana. Afrika Spectrum.

Benneth, G. 1973. Population, food production and nutrition in a northern savannah village of Ghana.

Kumar, H. 1963. Land clearing techniques. Ghana Farmer 7.

Cervinka, V. 1967. Tropical farm mechanisation. Ghana's experience.

Halm, A.T. and Bampoe-Addo, A. 1972. Available phosphorus as related to inorganic phosphate fractions in some Ghana soil series.

Acquaye, D.K. and Oteng, J.W. 1972. Factors influencing the status of phosphorus in surface soils of Ghana.

Obeng, H.B. et al. 1973. Ironpan geomorphic surfaces and associated soils of Ghana.

Nyanteng, V.K. 1971. Shifting cultivation: the Ghanaian farmers answer to weed and soil fertility problems.

Soil Reports etc. available at: Land Resources Development Centre (ODA), Tolworth Tower, Surbiton, Surrey, England.

LRDC PAMPHLET 631.67(667) 008390

KAUL, S.N.

Report to the Government of Ghana on irrigated agriculture in the Upper and Northern Regions.

FAO/UNDP Report no. TA 2484. 1968

AGRICULTURE-GENERAL
ADVISORY SERVICE/ DEVELOPMENT/ FOOD AND AGRICULTURE ORGANISATION/ FOOD SCIENCE/ GHANA/ HYDROLOGY/ IRRIGATION/ IRRIGATION PLANNING/ LAND IRRIGABILITY/ NORTH-COUNTRY/ PILOT FARM/ PLANNING/ TOMATO/ WETLAND FARMING/

LRDC BOOK 711.11(667) 004870

FOOD AND AGRICULTURE ORGANISATION, FAO

Ghana. Land and water survey in the upper and northern regions. Final report. Volume 1. General.

Rome: Food and Agriculture Organisation 1968

AGRICULTURE-GENERAL,FORESTRY-GENERAL,WATER RESOURCES-GENERAL
AGRICULTURAL SYSTEM/ CLIMATOLOGY/ CROP YIELD/ DOMESTIC ANIMAL/ FOOD AND AGRICULTURE ORGANISATION/ FORAGE/ FOREST RESERVATION/ GHANA/ HYDROLOGICAL STUDY/ HYDROLOGY/ IRRIGATION/ IRRIGATION PLANNING/ LIVESTOCK NUMBER/ MAP/ NORTH-COUNTRY/ PLANTATION-FOREST/ SOIL SURVEY/ SURVEY/ VEGETATION ZONE-CLIMATIC/

LRDC BOOK 711.11(667) 004870

FOOD AND AGRICULTURE ORGANISATION, FAO; UNITED STATES DEVELOPMENT PROGRAM

Land and water survey in the Upper and Northern regions of Ghana. Final report. Volume 5. Water resources development and soil conservation.

Rome: Food and Agriculture Organisation 1967

PEDOLOGY-GENERAL,WATER RESOURCES-GENERAL
BIBLIOGRAPHY-GREATER THAN 50 REF/ COMMUNICATION/ DAM/ DEVELOPMENT/ FISH/ FOOD AND AGRICULTURE ORGANISATION/ GHANA/ HYDRAULIC DESIGN/ HYDROELECTRIC POWER/ IRRIGATED FARMING/ IRRIGATION PLANNING/ IRRIGATION STRUCTURE/ LAND CONSERVATION/ MAP/ NORTH-COUNTRY/ RIVER/ SOIL FERTILITY/ SOIL MAPPING/ STREAM CONTROL STRUCTURE/ UNITED NATIONS/ VALLEY/ WATER RESOURCE ASSESSMENT/ WATER RESOURCE DEVELOPMENT/

FOOD AND AGRICULTURE ORGANISATION, FAO

Report to the Government of Ghana on applied agronomic research on field food crops in Northern Ghana, based on the work of Y.E.A. Azab.

FAO UNDP TA Report no. 2596. 1968 Abstract in: Tropical Abstracts 25, abs. 1509.

AGRICULTURE-GENERAL,CROP SCIENCE-GENERAL
ABSTRACT/ ASSESSMENT/ FERTILISER/ FERTILISER APPLICATION/ GHANA/ GROUNDNUT/ MILLET/ MULTIPLE CROPPING/ NORTH-COUNTRY/ RESEARCH/ SESAME/ SORGHUM-FORAGE/ SORGHUM-GRAIN/ ZEA MAYS/

LRDC BOOK 63(667) 006369

HUNTING TECHNICAL SERVICES LIMITED

A pilot survey for agricultural census in northern Ghana.

Borehamwood: Hunting Technical Services Ltd. 1960

AGRICULTURE-GENERAL
AERIAL PHOTOGRAPHY/ CARTOGRAPHY/ GHANA/ LAND RESOURCE/ NORTH-COUNTRY/ PHOTOGRAM INTERPRETATION/ STATISTICS-RECORDS/ SURVEY/

LRDC BOOK 91(6)

HUNTER, J.M.

Population pressure in a part of the west African savanna: A study of Nangodi, northeast Ghana.

In: People and land in Africa south of the Sahara. Readings in Social Geaography. Prothero, R.M. editor. pp 152-162.

London: Oxford University Press 1972

SOCIAL SCIENCE-GENERAL
DEMOGRAPHY/ ETHNOGRAPHY/ GHANA/ MIGRATION/ NORTH-COUNTRY/ POPULATION PRESSURE/

LRDC BOOK 711.11(667) 004870

FOOD AND AGRICULTURE ORGANISATION, FAO

Land and water survey in the Upper and Northern Regions, Ghana. Final Report. Volume 6. Economic considerations.

FAO SF: 31/GHA.

Rome: Food and Agriculture Organisation 1967

WATER RESOURCES-GENERAL,AGRICULTURE-GENERAL
AGRICULTURAL MANAGEMENT/ BIBLIOGRAPHY-LESS THAN 50 REF/ COST BENEFIT ANALYSIS/ ECONOMICS/ FOOD AND AGRICULTURE ORGANISATION/ GHANA/ IRRIGATION PLANNING/ LAND RESOURCE/ LAND USE-CURRENT/ NORTH-COUNTRY/ PLANNING/ POTENTIAL LAND USE/ PROFITABILITY/

LRDC BOOK 711.11(667) 004870

FOOD AND AGRICULTURE ORGANISATION, FAO

Land and water survey in the Upper and Northern Regions, Ghana. Final Report Volume 2. Surveys, climate and hydrology.

Rome: Food and Agriculture Organisation 1967

ATMOSPHERIC SCIENCE-GENERAL,WATER RESOURCES-GENERAL
BIBLIOGRAPHY-LESS THAN 50 REF/ CLIMATOLOGY/ EROSION/ FLOOD/ FOOD AND AGRICULTURE ORGANISATION/ GHANA/ GROUNDWATER/ HYDROLOGICAL STUDY/ MAP/ METEOROLOGY/ NORTH-COUNTRY/ RAINFALL DATA/ RAINFALL DATA ANALYSIS/ RIVER/ RUNOFF/ SEDIMENTATION/ SURVEY/ WATER QUALITY/ WATER SUPPLY/

LRDC REPORT 581.9(667) 004760

RAMSEY, J.M.; ROSE INNES, R.

Some quantitative observations on the effects of fire on the Guinea Savanna vegetation of Northern Ghana over a period of eleven years.

African Soils 8(1), 41-85. 1963

BOTANY-GENERAL
BIBLIOGRAPHY-LESS THAN 50 REF/ BUSH CONTROL/ GHANA/ LAND CLEARING/ NORTH-COUNTRY/ PLANT ASSOCIATION/ SAVANNA/ VEGETATION ABUNDANCE/

LRDC BOOK 711.11(667) 004870

FOOD AND AGRICULTURE ORGANISATION, FAO

Land and water survey in the Upper and Northern Regions, Ghana. Final Report. Volume 4. Agronomy and sociology.

FAO/SF: 31/GHA.

Rome: FAO 1967

SOCIAL SCIENCE-GENERAL,WATER RESOURCES-GENERAL,ANIMAL SCIENCE-GENERAL,AGRICULTURE-GENERAL
ANIMAL HUSBANDRY/ BIBLIOGRAPHY-LESS THAN 50 REF/ CATTLE/ DIPTERA/ DISTRIBUTION/ FOOD/ FOOD AND AGRICULTURE ORGANISATION/ FOREST MANAGEMENT/ GHANA/ GRAMINEAE/ IRRIGATION/ MANAGEMENT/ MAP/ NORTH-COUNTRY/ PASTORAL FARMING/ PLANTATION-FOREST/ POTENTIAL LAND USE/ SOCIOLOGY/ SURVEY/ VEGETATION DISTRIBUTION-HORIZONTAL/ VEGETATION STRUCTURE/

LRDC PAMPHLET 711.14(667) 002540

BRAMMER, H.

Agricultural potentialities of the northern savanna regions of the Gold Coast.

Departmental Paper, Department of Soil and Land Use Survey, Gold Coast, no.7
1954

AGRICULTURE-GENERAL,BOTANY-GENERAL
AGRICULTURAL PRACTICE/ BIBLIOGRAPHY-GREATER THAN 50 REF/ CROP SEQUENCE/ DEVELOPMENT/ ENVIRONMENT/ GHANA/ NORTH-COUNTRY/ POTENTIAL LAND USE/ SAVANNA/ VEGETATION ZONE-CLIMATIC/

LRDC PAMPHLET 711.3(667) 024784

ARDAYFIO-SCHANDORF, E.
SWANSEA, UNIVERSITY COLLEGE, CENTRE FOR DEVELOPMENT STUDIES.

Rural development strategies in northern Ghana: problems and prospects for reaching the small farmer.

Occasional Paper no.18

Norwich: Geo Books. 1982 0860941191 32pp; bibl.

SOCIAL SCIENCE-GENERAL
BIBLIOGRAPHY-LESS THAN 50 REF/ GHANA/ NORTH-COUNTRY/ RURAL DEVELOPMENT/

LRDC JOURNAL 5 69

HILTON, T.E.

The landforms of north eastern Ghana.

Journal of the West African Science Association 11, 136-149. 1966

GEOSCIENCE-GENERAL
EAST-COUNTRY/ GEOMORPHIC CYCLE/ GEOMORPHOLOGY/ GHANA/ IRONSTONE/ LANDFORM/ NORTH-COUNTRY/ PLAIN/

LRDC PAMPHLET 631.8(667) 000978

NYE, P.H.

A survey of the value of fertilisers to food farming areas of the Gold Coast. II The granitic soils of the far north.

Empire Journal of Experimental Agriculture 21(84), 262-274.

CROP SCIENCE-GENERAL
BIBLIOGRAPHY-LESS THAN 50 REF/ CROP YIELD/ FERTILISER/ GHANA/ NORTH-COUNTRY/ SUBSISTENCE FARMING/ SURVEY/

LRDC BOOK 617.7(66) 017894

UNITED NATIONS DEVELOPMENT PROGRAMME, UNDP; FOOD AND AGRICULTURE ORGANISATION OF THE UNITED NATIONS, FAO; INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT, IBRD, WORLD HEALTH ORGANISATION,WHO

Onchocerciasis control in the Volta River Basin area. Annex VI-2.B - Background data and proposed integrated rural development project in North Eastern Ghana.

Geneva: World Health Organisation 1973 57pp; bibliography

AGRICULTURE-GENERAL,SOCIAL SCIENCE-GENERAL
AGRICULTURAL DEVELOPMENT/ ANALYSIS/ CONTROL/ DEVELOPMENT/ EAST-COUNTRY/ ECONOMICS/ FOOD AND AGRICULTURE ORGANISATION/ GEOGRAPHY/ GHANA/ HUMAN DISEASE/ LAND SETTLEMENT/ MAP-WITH TEXT/ METHODOLOGY/ NORTH-COUNTRY/ UNITED NATIONS/

LRDC BOOK 631.47(667) 12471

ADU,S.V.
GHANA MINISTRY OF AGRICULTURE,SCIENTIFIC SERVICES DIVISION

The soils of Zuarungu Agricultural Station, Upper Region

Technical Report No. 54

Accra; Ghana Ministry of Agriculture, Sceintific Services Division 1961

VEGETATION-GENERAL,PEDOLOGY
CLIMATE/ GEOGRAPHY/ GHANA/ LAND CAPABILITY/ LAND USE-CURRENT/ NORTH-COUNTRY/ SOIL CONSTITUENT/ SOIL FERTILITY/ SOIL MAPPING/ SOIL PARENT MATERIAL/ SOIL SURVEY/

LRDC ABSTRACT ONLY HELD BY LRDC 911.3:3

ENGMANN,E.V.T.

Migration and population pressure in Northern Ghana: a note on methodology.

Bulletin of the Ghana Geographical Association 17, 38-55. 1975 Abstract in: Geo Abstracts 1977D(4), abs. 1354.

GENERAL SCIENCE
CLASSIFICATION/ DEMOGRAPHY/ DEVELOPMENT/ DISTRIBUTION/ GEOGRAPHY/ GHANA/ LAND RESOURCE/ MAP-WITH TEXT/ METHODOLOGY/ MIGRATION/ NORTH-COUNTRY/ PLANNING/ POPULATION PRESSURE/ REGION/ SAVANNA/ SERIAL ARTICLE/

ODA SERIAL NOT HELD BY LRDC 985.96

BUAMAH,T.F.

Nutritive evaluation of range pasture in the Northen Ghana savanna belt.

Ghana J. of Science Vol. 2, No. 1 27-40 1971

ANIMAL SCIENCE-GENERAL
BIBLIOGRAPHY-LESS THAN 50 REF/ CHEMICAL ANALYSIS/ FODDER/ FODDER DIGESTIBILITY/ FODDER NUTRITIVE VALUE/ GHANA/ NORTH-COUNTRY/ YIELD/

LRDC BOOK 631.47(667) 12445 71

STOBBS,A.R.;

Report on the semi-detailed soil of Pong Tamale Veterinary Station, Dagomba District, Norther Ghana

Technical Report No. 38

Kumasi Ghana:Ghana Ministry of Food and Agriculture, Scientific Services Division, Soil and Land-Use Survey Branch 1960

VEGETATION-GENERAL,PEDOLOGY
BIBLIOGRAPHY-GREATER THAN 50 REF/ CLIMATE/ FORAGE/ GEOMORPHOLOGY/ GHANA/ GRAMINEAE/ MAP-WITH TEXT/ NORTH-COUNTRY/ SOIL CLASS BY FORMATION/ SOIL DESCRIPTION-MORPHOLOGY SURVEY AND MAPPING/ SOIL SURVEY/

DIRECTORATE OF OVERSEAS SURVEYS 528.7

ADU, S.V.

The geomorphology, soils, water resources and land use potential of the Nasia River Basin, Ghana. Their relevance to the "Middle Belt" of West Africa.

ITC Journal 1981-4, 498-525

AGRICULTURE-GENERAL,GEOSCIENCE-GENERAL,PEDOLOGY-GENERAL,WATER RESOURCES-GENERAL
BIBLIOGRAPHY-LESS THAN 50 REF/ EAST-COUNTRY/ GEOMORPHOLOGY/ GHANA/ LAND CAPABILITY/ NORTH-COUNTRY/ POTENTIAL LAND USE/ SERIAL ARTICLE/ SOIL DESCRIPTION-MORPHOLOGY SURVEY AND MAPPING/ SOIL SURVEY/ WATER RESOURCE ASSESSMENT/ WATER RESOURCE DEVELOPMENT/

LRDC BOOK 631.47:634.0(667) 19441

GHANA, SOIL RESEARCH INSTITUT

Report on the detailed soil survey of the proposed Buipe Forestry Plantation

Technical Report no.75

Kumasi: Ghana Academy of Sciences 1967 17pp 4 maps

VEGETATION-GENERAL,PEDOLOGY
ENVIRONMENT/ GHANA/ LAND CAPABILITY/ LAND CLASSIFICATION/ LAND USE-CURRENT/ NORTH-COUNTRY/ SOIL CLASSIFICATION/ SOIL DESCRIPTION-MORPHOLOGY SURVEY AND MAPPING/ SOIL PROFILE/ SOIL SURVEY/

ADU,S.V.

The soils of Tono State Farm

Technical Report No. 58

Kumasi Ghana: Agricultural Research Institure, Soil and Land-Use Survey 1963

VEGETATION-GENERAL,PEDOLOGY
CLIMATE/ DRAINAGE-NATURAL/ GEOLOGY/ GEOMORPHOLOGY/ GHANA/ LAND CAPABILITY/ LAND USE-CURRENT/ NORTH-COUNTRY/ PLANT ECOLOGY/ SOIL DESCRIPTION-MORPHOLOGY SURVEY AND MAPPING/ SOIL DESCRIPTION-MORPHOLOGY SURVEY AND MAPPING/ SOIL HYDROGEN ION CONCENTRATION/ SOIL PARENT MATERIAL/ SOIL PROFILE/

BENNEH,G.

The response of farmers in Northern Ghana to the introduction of mixed farming: a case study.

Geografiscka Annaler 54 B(1972)2 pp 95-1Ø3

AGRICULTURE-GENERAL
AGRICULTURAL DEVELOPMENT/ AGRICULTURAL OPERATION/ ASSESSMENT/ CASE STUDY/ CHANGE/ GHANA/ MIXED FARMING/ NORTH-COUNTRY/ ORGANIC FERTILISER/ PEASANT/ POPULATION PRESSURE/

GRENZEBACH,K.VON.

Nutzflachen Kartierung als Grundlage agrarraumlicher analyse, dargestellt an Beispielen aus Tropisch-Afrika. (Land use mapping as a basis for spatial rural analysis represented in examples from Tropical Africa). Entwicklung der Landuntzung in der tropen undihre Auswickungen, p15-38 (with English summary)

Giessener Beitrage zur Entwicklungs Forschung, Reiche, 1, Band 2, Tropeninstitut Giessen 1976

SURVEY SCIENCE-GENERAL,AGRICULTURE-GENERAL
AERIAL PHOTOGRAPHY/ ANALYSIS/ ANGOLA/ ASSESSMENT/ BIBLIOGRAPHY-LESS THAN 5Ø REF/ EAST-COUNTRY/ GHANA/ KENYA/ LAND CAPABILITY/ LAND USE-CURRENT/ MAP/ NIGERIA/ NORTH-COUNTRY/ PHOTOGRAM INTERPRETATION/ SOUTH-COUNTRY/ SURVEY/ WEST-COUNTRY/ ZAMBIA/

LRDC PAMPHLET 631.6.02(667) 15450

BILLES,D.J.

The planning of land use and soil and water conservation in the northern territories, Gold Coast. Document 90, Section III B

2nd Inter-African Soils Conference - Leopoldville, 1954.

AGRICULTURE-GENERAL
DAM/ EROSION CONTROL/ GHANA/ NORTH-COUNTRY/ PLANNING/ POTENTIAL LAND USE/ SMALL SCALE/ SOIL EROSION/ WATER CONSERVATION/

LRDC BOOK 631.4(667) 12430

OBENG,H.B.

The major soils of the Seilo-tuni land planning area, Northwestern Ghana, West africa.

A paper submitted to the 3rd Inter-african soils conference, Dalaba, guinea, November 1959.

Kumasi Ghana: Ministry of Food and Agriculture, Scientific Services Division, Soil and Land-Use Survey Branch 1961

PEDOLOGY
BIBLIOGRAPHY-LESS THAN 50 REF/ GHANA/ LAND CAPABILITY/ NORTH-COUNTRY/ SOIL CLASS BY FORMATION/ SOIL CONSTITUENT/ SOIL FERTILITY/ SOIL HYDROGEN ION CONCENTRATION/ SOIL MAPPING/ SOIL PARENT MATERIAL/ SOIL PARENT ROCK/ SOIL SURVEY/ WEST-COUNTRY/

LRDC BOOK 711.3(6/213) 22057

SHEPHERD,A.

Agrarian change in northern Ghana: public investment, capitalist farming and famine

In: Rural development in tropical Africa. Heyer J, Roberts P and Williams G eds. London: Macmillan, pp 168-192 1981 033284488

AGRICULTURE-GENERAL,SOCIAL SCIENCE-GENERAL
AGRICULTURAL DEVELOPMENT/ BIBLIOGRAPHY-LESS THAN 50 REF/ CAPITAL/ FINANCE/ GHANA/ HUMAN NUTRITION/ NORTH-COUNTRY/ PEASANT/ POLITICAL IDEOLOGY/

LRDC BOOK 631.47:639.311(667) 19442

TENADU,D.O.; ADU,S.V.
GHANA, SOIL RESEARCH INSTITUTE

Soils of the proposed national fish pond culture centre at Yapei, near Tamale, Northern Region

Technical Report no.106

Kwadaso-Kumasi: Council for Scientific and Industrial Research 1977 24pp 5 maps

PEDOLOGY
ENVIRONMENT/ FISH/ GHANA/ MAP-WITH TEXT/ NORTH-COUNTRY/ SOIL ANALYSIS/ SOIL CLASSIFICATION/ SOIL DESCRIPTION-MORPHOLOGY SURVEY AND MAPPING/ SURVEY/

LRDC BOOK 631.47:633.18(667) 19440

ABLORH,F.S.
GHANA, SOIL RESEARCH INSTITUTE

Report on the detailed soil survey of the Mencilo farm at Yapei for large-scale cultivation of rice

Technical Report no.76

Kwadaso-Kumasi: Council for Scientific and Industrial Research 1969 14pp bibl 2 maps

PEDOLOGY
BIBLIOGRAPHY-LESS THAN 50 REF/ ENVIRONMENT/ GHANA/ LAND CAPABILITY/ LAND CLASSIFICATION/ MAP-WITH TEXT/ NORTH-COUNTRY/ RICE/ SOIL CLASSIFICATION/ SOIL DESCRIPTION-MORPHOLOGY SURVEY AND MAPPING/ SOIL SURVEY/

LRDC REPORT 338.984:616.98(667) 19658

STOBBS,A.R.; LESSLIE,A.; AKROYD,D.
GREAT BRITAIN, MINISTRY OF OVERSEAS DEVELOPMENT, LAND RESOURCES DEVELOPMENT CENTRE.

Project appraisal of the proposed ODM Onchocerciasis Survey Unit in Ghana. (Preliminary - for discussion)

Unpublished Project Report 68

Tolworth: Land Resources Development Centre. 1979 131pp

AGRICULTURE-GENERAL
ADVISORY SERVICE/ AGRICULTURAL DEVELOPMENT/ ANIMAL HUSBANDRY/ ASSESSMENT/ COST/ CROP MARKETING/ FINANCE/ GHANA/ LAND RESOURCES DIVISION/ LAND USE-CURRENT/ MINISTRY OF OVERSEAS DEVELOPMENT/ NORTH-COUNTRY/ POTENTIAL LAND USE/ PROJECT/ RESEARCH/ SURVEY/

ODA NOT HELD BY LRDC

SCOTT,E.P.

Land use change in the harsh lands of West Africa

African Studies Review 22(1), 1-24 1979

GENERAL SCIENCE-GENERAL
AFRICA/ ANIMAL MIGRATION/ ARABLE FARMING/ ARID CLIMATE/ BIBLIOGRAPHY-LESS THAN 50 REF/ CHAD/ CLIMATE/ DAHOMEY/ GHANA/ MALI/ MAURITANIA/ MIXED FARMING/ NIGER/ NIGERIA/ NOMADISM/ NORTH-COUNTRY/ ORGANIC FERTILISER/ PASTORAL FARMING/ PLANT ECOLOGY/ SAVANNA/ SERIAL ARTICLE/ SOIL DEGRADATION/ TOGO/ UPPER VOLTA/ VEGETATION ZONE-CLIMATIC/

LRDC BOOK 19292

ANSELL,D.J.
BARCLAYS BANK INTERNATIONAL

Mechanised rice production in Northern Ghana

London: Barclays International 83pp

AGRICULTURE-GENERAL
AGRICULTURAL MECHANISATION/ CROP PRODUCTION/ GHANA/ NORTH-COUNTRY/ RICE/

LRDC BOOK 631.4(667-17) 15543

ADU,S.V.
GHANA,COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

Soils of the Navrongo - Bawku area, Upper Region, Gana

Memoir No.5.

Kwadaso-Kumasi: Council for Scientific and Induatrial Research, Soil Research Indtitute 1969

PEDOLOGY
GEOGRAPHY/ GHANA/ INTRUSIVE ROCK/ LAND CAPABILITY/ MAP-WITH TEXT/ NORTH-COUNTRY/ SOIL CLASS BY PARENT ROCK/ SOIL DESCRIPTION-MORPHOLOGY SURVEY AND MAPPING/ SOIL FERTILITY/

LRDC SERIAL 711.3

DUE,J.M.

Efficiency of resource use - the case of the Ghanaian State rice farms.

Eastern African Journal of Rural Development 4(2), 77-93. 1971

AGRICULTURE-GENERAL
AGRICULTURAL MANAGEMENT/ ARABLE FARMING/ EAST-COUNTRY/ EFFECTIVENESS/ GHANA/ NORTH-COUNTRY/ POST MORTEM/ RICE/

LRDC BOOK 631.47(667) 12457

OBENG,H.B.

Soils of the Seilo-Tuni land planning area Wala District, Near Wa, Upper Region.

Kumasi,Ghana: Agriculture Research Institute (Ghana Academy of Sciences)

Kumasi, Ghana: Agriculture Research Institute (Ghana Academy of Sciences)
1973

PEDOLOGY
GEOGRAPHY/ GHANA/ LAND CAPABILITY/ MAP-WITH TEXT/ NORTH-COUNTRY/ SOIL CLASSIFICATION/ SOIL SURVEY/

LRDC BOOK 631.47(667) 12486

BRAMMER,H.

The soils of the Lawra District Agricultural Station, Babile, Northern Territories.

Technical Report no. 17.

Kumasi, Gold Coast: Department of Soil and Land Use Survey 1956

PEDOLOGY
GHANA/ ISOPTERA/ NORTH-COUNTRY/ SOIL CLASSIFICATION/ SOIL SURVEY/

LRDC BOOK 631.4:633.2(66) 12487

BRAND,B.; BRAMMER,H.

Provisional grassland associations for the interior and coastal savannah zones of the Gold Coast.

Technical Report No.21.

Kumasi: Department of Soil and Land Use Survey 1956

BOTANY-GENERAL
CLASSIFICATION/ GHANA/ GRAMINEAE/ MAP-WITH TEXT/ NORTH-COUNTRY/ PLANT ASSOCIATION/ SAVANNA/ VEGETATION SAMPLING/ VEGETATION SURVEY/

LRDC BOOK 63.001(667) 10718

BORTEI-DOKU,E.; DADSON,J.A; WILLS,J.B.
WORLD COUNCIL OF CHURCHES-ADVISORY COMMITTEE ON TECHNICAL SERVICES

Evaluation of the christian service committee programme in the Northern and Upper Regions of Ghana - also Report of an ecumenical conference held in Tamale, Ghana 21-23 September 1971 - 'The role of the church in rural development'

Tamale, Ghana: Field Committee (North), Christian Service Committee 1971

AGRICULTURE-GENERAL
ADMINISTRATION/ ADVISORY SERVICE/ AGRICULTURAL DEVELOPMENT/ CHRISTIAN/ DEMONSTRATION FARMING/ EDUCATION/ GHANA/ NORTH-COUNTRY/

LRDC BOOK 631:636(667) 21479

GHANA MINISTRY OF FOOD AND AGRICULTURE.UNITED STATES OPERATIONS MISSION TO GHANA.

East Dagomba agricultural and livestock survey, Northern Ghana.

Ghana: Ministry of Food and Agriculture. 1959 iv+87pp

AGRICULTURE-GENERAL,ANIMAL SCIENCE-GENERAL
GHANA/ LAND CAPABILITY/ LAND USE-CURRENT/ LIVESTOCK/ MAP-WITH TEXT/ NORTH-COUNTRY/ SOIL DESCRIPTION-MORPHOLOGY SURVEY AND MAPPING/ SURVEY/

ANNEX I.3

Ghana: Soil reports etc. available at Soil Resources Branch library - A.G.L.S., FAO HQ, Rome.

Ahn, 1959 : Soil/Vegetation in Western Forest Areas

Ahn, 1960 : Mapping, classification of Ghana forest soils

Ahn, 1960 : Soils and Geogr. forest zone, Ghana

Ahn, 1961 : Lower Tano basin, S.W. Ghana

Akenhead, 1948 : Rice Soil Survey, Akuse area

Akenhead, 1948 : Rice Soil Survey, Nugo Ghai area

Asare, 1961 : Tain basin (West Ghana)

Bennema (undated) : Red and yellow soil and groundwater laterite soils of Ghana (33 p.) (reprint)

Brammer, 1954 : Agricultural Potential of Northern Savanne region

Brammer, 1959 : Soils of Ghana

Brammer, 1958 : Ho-Keta plains: Soils

Brammer, 1952 : Detailed soil survey, Kpong area

Brammer, 1967 : Soils: Accra plains

Brammer, 1951/52 : Vegetation studies: Accra plains

Coultas, 1959 : Soil Survey of N.W. Ashanti, Tain basin (West Ghana)

Crosbie, 1957 : Suitability of forest soils of Ghana, for cocoa production

Day, T., 1961 : Soil Survey Lower Volta

Day, T., 1960 : Lower Volta Plains Project

FAO/UNSF, 1963 : Lower Volta Plains Project. Vol I - Vol V (Vol II, Soil Survey and Classification)

FAO, 1967 : Land and Water survey in the Upper and Northern Regions, Ghana. Vol I - Vol VI (Vol III, Soils)

Hagenzieker, F, 1964 : Tropical grey and black earths of the Accra plains

Hotson, 1956 : Some little known aspects of the closed forest zone of the Gold Coast

Mould, A.W.S., 1961 : Detailed prel. survey of Pawmpawn basin

Obeng, H.B., 1970 : Twenty-five years of soil survey and classification in Ghana (1945-1970)(58 p.)

Obeng, H.B., 1960 : Characterization of some latosols and associated soils from the N.W. Savannah zone of Ghana

Obeng, H.B., 1963 : Soils of the Sello-Tuni land planning area, Wata district, near WA (N.W. Ghana)

Obeng, H.B., 1970 : Characterization and classification of some ironpan soils of Ghana (PhD thesis. IOWA University)

Obeng, H.B., 1963 : Soils of Bokwai-Amoafa farm

Radwanski, 1957 : Cocoa soils of Western Ashanti

Gov. Gold Coast, 1951 : Report on the development of the River Volta basin. By Sir William Halcrow and Partners

Riguier, J, 1975 : Ecological zones and landuse (9 p.)
Smith George, K. (undated) : Report on Soil and Agric. Survey of Sene-Obosum River basins (South-Central Ghana)
1970 : List of publications of the Soil Research Institute, Kumasi (29 p.)
U.S.O.M., Ghana, 1959 : Soil and Livestock survey, N.W. Ashanti U.S. Oper. Mission to Ghana
U.S.O.M., Ghana, 1960 : North Gonja Agricultural and Livestock Survey North Ghana (79 p.)
U.S.O.M., Ghana, 1959 : East Dagomba Agricutural and Livestock Survey
Walker, 1957 : Weather and climate of Ghana, Ghana Meteo Dept, Accra (27 p.)

ANNEX II

COMMENTS DR. H. TIESSEN ON SOIL SURVEY INFORMATION AND DRAFT REPORT BY STIBOKA (JUNE 20, 1985)

1. Central to the old classification are drainage classes. In reality many of the "well drained soils" show extensive ponding. In an area mapped as Tingoli (1) water was standing for up to a week during the 1984 rainy season. In other areas mapped as Volta (7) (near the guest house) no water-logging was observed, mainly because of adequate surface drainage.

2. Soil depth is a further important parameter. The 1949/57 soil depth map generally indicates much greater depths than are now present. In several instances, in both Tingoli and Tolon series, present soil depths to gravel or ironstone layers are less than the depth classes indicated in the series description. (See also Appendix C).
   Depth to a concretionary layer - or even the presence of such a layer is extremely variable. At one site mapped as Tolon (2a) depth to solid gravel varied from 23 cm to 65 cm over a distance of less than 40 cm in the field. In the "Nakpok" area (see p. 44 of the report) in one field a concretionary layer was encountered at 40-48 cm, while in an adjacent field a clay layer was encountered instead. This leads to considerable difficulty with classification.

3. An attempt was made in the Stiboka report to adjust unlikely series delineations to the map relief (ref. p. 31). Some such shift appears justified from field observation but the crux of the problem lies with an unsuitable series definition. Soil variability in all areas of moderate relief is to a large extend determined by the local microrelief, so that for instance in the contentious Volta-Kpelesawgu area a patch work of discontinuous areas of the two series exists. A similar patch work is found in the lowland rice growing area were gradual changes of associations from Volta + Changnalili to Kpelesawgu + Nyankpala exist upslope. In terms of Soil Taxonomy the low land areas present close associations of Alfisols (some Volta areas for instance showing clear A_2 horizons), Entisols (rarely sandy but frequently very shallow over ironstone) and Inceptisols (intermediates). A general trend of ustalfs - aqualfs - aquepts is seen down slope with frequent inclusions of Entisols at all levels.

4. The series differentations used in the old classification appears somewhat arbitrary and far to indistinct for a clear differentation of the soils in the field. This results in unsatisfactory map unit delineation, even on the detailed 1 : 10 000 map.
   A more suitable mapping device would be the following grouping.
   A - Tingoli + Tolon as upland soils over sandstone
   B - Nyankpala - upland over shales
   C - Kumayili - upland colluvial or alluvial
   D - Kpelesawgu + Changnalili + Volta series as lowland soils on shales and/or alluvium. This last group could be

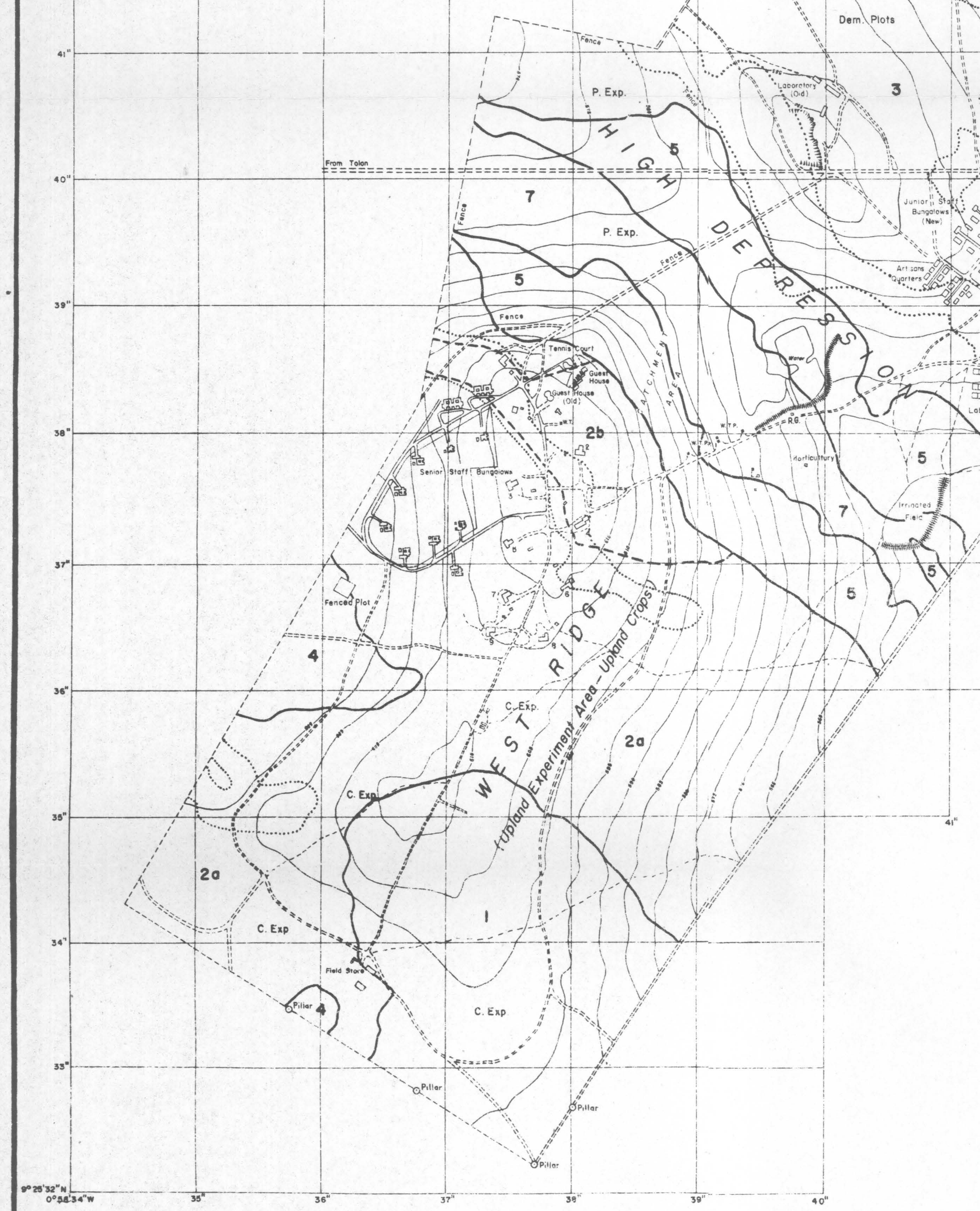
subdivided on the basis of the presence or absence of an A_2 (Ae) and Bt horizon.

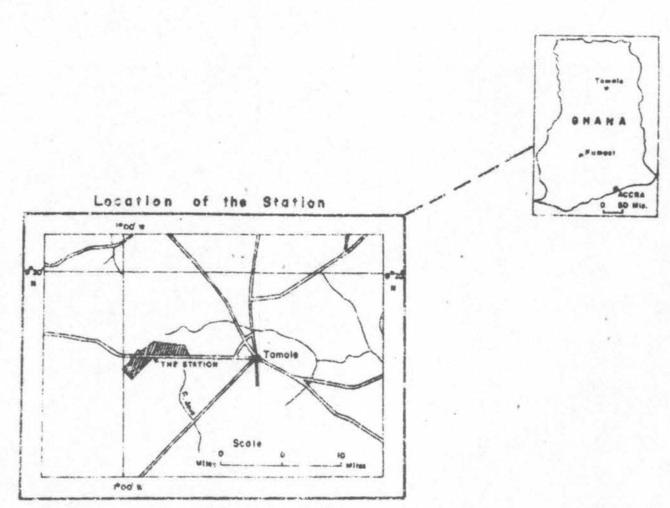
For all these groupings eroded or shallow phases should be mapped, possibly as a percentage of the map unit area. Even in Volta areas clearly erosional (flowing water) exposures of massive hard ironstone are visible.

5. Recommendations for further work: The old classification and mapping system of the station area appears clearly obsolete and in many cases unsatisfactory. Improvements can only be made based on new field observations. New survey work, though, should await the adoption of a suitable system of classification for the Savannah soils of northern Ghana.

Nyankpala Agricultural Experiment Station

GENERAL SOIL INFORMATION



Scale 1:10,000

Feet 500 250 0 500 1000 1500 Feet

Metres 100 0 100 200 300 400 Metres

LEGEND

Soil series

1	**Tingoli series** Well drained, shallow to moderately shallow (approx. 40-60 cm) reddish-brown, sandy clay with ironstone concretions and with a thin, sandy topsoil, overlying tightly packed ironstone concretions in reddish-brown sandy clay, in places with sandstone fragments and plinthite ("soft ironstone").
2a	**Tolon series** Well drained, shallow to moderately shallow (approx. 40-60 cm), orange-brown, sandy clay with ironstone concretions and sandstone fragments and with a slightly humous sandy topsoil, overlying tightly packed ironstone concretions in orange-brown to brown sandy clay, with sandstone fragments and plinthite ("soft ironstone").
2b	**Tolon series, eroded phase** As 2a, but very shallow. (0- 25 cm)
3	**Nyankpala series** Well drained, shallow (approx. 25-30 cm), dark brown to grayish-brown, loamy sand, in places with some ironstone concretions and with a slightly humous topsoil, overlying tightly packed ironstone concretions in orange-brown silty clay, with plinthite ("soft ironstone").
4	**Kumayili series** Well drained, moderately deep to deep (60-120 cm), orange-brown, sandy clay with a slightly humous sandy topsoil, overlying partly indurated plinthite ("fairly soft ironpan").
5	**Kpelesawgu series** Imperfectly drained, shallow to moderately shallow (approx. 25-60 cm), grayish-brown to orange-brown sand to sandy loam, in places with some ironstone concretions and with a slightly humous topsoil, overlying tightly packed ironstone concretions in brownish-gray sandy clay over plinthite ("soft ironpan").
6	**Changnalili series** Poorly drained, shallow to moderately deep (approx. 25- 90 cm), mottled, brownish-gray (loamy) sand to (silt) loam, in places with some ironstone concretions and with a slightly humous topsoil, overlying a massive ironpan with a thickness of 40-150 cm at variable depths.
7	**Volta series** Poorly drained, deep, (90-120 cm) gray and brown mottled (silty) clay loam to silty clay with a slightly humous topsoil, in places with thin concretionary layers at varying depths.
(dotted box)	**Gravel pavement**

Descriptions based on Soil Survey report of the Station carried out by the Soil Research Institute (Adu, 1957).

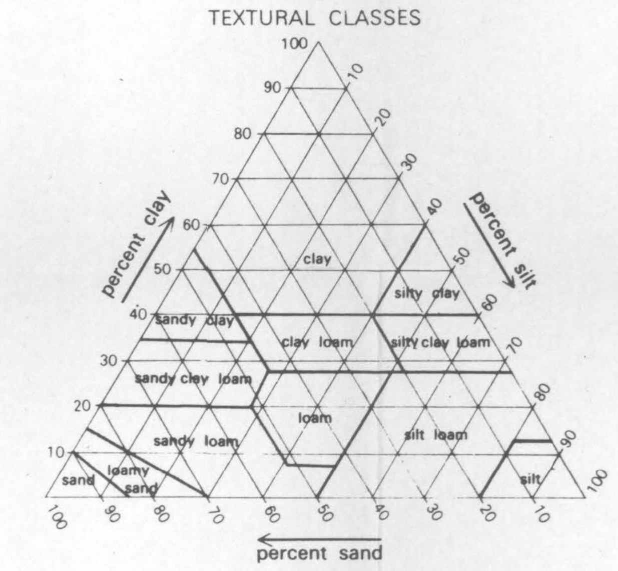
Notes:

- Soil depth refers to effective soil depth to tightly packed ironstone concretions, ironstone pan or rock.
- Soil depth classes (Adu, 1981):

Very shallow	0- 25 cm
Shallow	25- 45 cm
Moderately shallow	45- 60 cm
Moderately deep	60- 90 cm
Deep	>90 cm

- Slightly humous: 0-2% org. matter.
- "Soft ironstone" refers to original description in Adu (1957).
- Soil colour descriptions according to Adu (1957).

TEXTURAL CLASSES



Seed Mult.........Ministry of Agriculture -Seed multiplication demonstration plots

P. Exp...............Pasture Experimental plots under the management of Animal Research Institute (CSIR)

C. Exp...............Crop Experimental plots under the management of Crops Research Institute (CSIR)

Dem. plots..........Students' demonstration plots and other miscellaneous demonstrations

W. T...................Overhead Water Tank

W. T. P...............Water Treatment plant

(symbol)...............Earth dam

R. G....................Rain Gauge

(symbol)...............Cutting

F. G....................Fetish Grove

Sources:
* Base maps photogrammetrically produced from aerial photographs, Survey Department, Accra. Photo date, Feb. 1964
* Air photo interpretation and field information, Feb. 1983
* Ministry of Agriculture – Report on Nyankpala station (I. Will, 1962)
* Site plans of new developments (Nyankpala Agricultural Experiment Station)

Author/Compiler:
E. Amamoo-Otchere, Airphoto interpreter for land resources inventory, Department of Geography, Legon and Research Officer in-Charge Ghana National Atlas Project, CSIR, Accra