World Soil Resources Reports 44

FIRST MEETING OF THE WEST AFRICAN SUB COMMITTEE ON SOIL CORRELATION FOR SOIL EVALUATION AND MANAGEMENT

Accra, Ghana, 12-19 June 1972

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Also issued in this series:

1. Report of the First Meeting of the Advisory Panel on the Soil Map of the World, Rome, 19-23 June 1961.
2. Report of the First Meeting on Soil Survey, Correlation and Interpretation for Latin America, Rio de Janeiro, Brazil, 28-31 May 1962.
3. Report of the First Soil Correlation Seminar for Europe, Moscow, U.S.S.R., 16-28 July 1962.
4. Report of the First Soil Correlation Seminar for South and Central Asia, Tashkent, Uzbekistan, U.S.S.R., 14 September - 2 October 1962.
5. Report of the Fourth Session of the Working Party on Soil Classification and Survey (Subcommission on Land and Water Use of the European Commission on Agriculture), Lisbon, Portugal, 6-10 March 1963.
6. Report of the Second Meeting of the Advisory Panel on the Soil Map of the World, Rome, 9-11 July 1963.
7. Report of the Second Soil Correlation Seminar for Europe, Bucharest, Romania, 29 July - 6 August 1963.
8. Report of the Third Meeting of the Advisory Panel on the Soil Map of the World, Paris, 3 January 1964.
9. Adequacy of Soil Studies in Paraguay, Bolivia and Peru, November-December 1963.
10. Report on the Soils of Bolivia, January 1964.
11. Report on the Soils of Paraguay, January 1964.
12. Preliminary Definitions, Legend and Correlation Table for the Soil Map of the World, Rome, August 1964.
13. Report of the Fourth Meeting of the Advisory Panel on the Soil Map of the World, Rome, 18-21 May 1964.
14. Report of the Meeting on the Classification and Correlation of Soils from Volcanic Ash, Tokyo, Japan, 11-27 June 1964.
15. Report of the First Session of the Working Party on Soil Classification, Survey and Soil Resources (European Commission on Agriculture), Florence, Italy, 1-3 October 1964.
16. Detailed Legend for the Third Draft of the Soil Map of South America, June 1965.
17. Report of the First Meeting on Soil Correlation for North America, Mexico, 1-8 February 1965.
18. The Soil Resources of Latin America, October 1965.
19. Report of the Third Soil Correlation Seminar for Europe: Bulgaria, Greece, Romania, Turkey, Yugoslavia, 29 August - 22 September 1965.
20. Report of the Meeting of Rapporteurs, Soil Map of Europe (Scale 1:1000000) (Working Party on Soil Classification and Survey, European Commission on Agriculture), Bonn, Federal Republic of Germany, 29 November - 3 December 1965.
21. Report of the Second Meeting on Soil Survey, Correlation and Interpretation for Latin America, Rio de Janeiro, Brazil, 13-16 July 1965.
22. Report of the Soil Resources Expedition in Western and Central Brazil, 24 June - 9 July 1965.

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REPORT ON THE FIRST MEETING OF THE WEST AFRICAN SUB-COMMITTEE ON SOIL CORRELATION FOR SOIL EVALUATION AND MANAGEMENT

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Food and Agriculture Organization of the United Nations
Rome, 1974

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INTRODUCTION

For a correct appraisal of soils within a country or inter-countries, it is essential to standardize methodology and classification on the survey and interpretation of soils in order to facilitate exchange of knowledge and experience between countries and avoid duplication of research. This problem is all the more important in Africa where many systems of soil classification and survey procedures are in use and where language barrier is a serious impediment towards standardization of soil resources evaluation procedures between French and English speaking areas.

Aware of the above need for a Regional approach to soil evaluation, the Delegates of ten West African countries who attended the FAO Seminar on the Evaluation of the Soil Resources of West Africa in Kumasi (1970) unanimously recommended that Soil Survey Organizations throughout West Africa should adopt the legend of the FAO/UNESCO Soil Map of the World as a system of reference with a view to unifying the various types of soil classification existing in the sub-region and that FAO should appoint a Soil Correlator to assist Member Countries of West Africa in this endeavour.

FAO implemented the above recommendation as far back as June 1971 by appointing a Regional Soil Resources Officer at its Regional Office for Africa in Accra, Ghana. Since then, consultations and contacts established with the Governments and the leading Soil Institutions in the sub-region led FAO to take the initiative in setting a Soil Correlation Committee for West Africa. At the outset it was thought opportune to constitute and convene a Soil Correlation Sub-Committee made up of four national senior soil scientists nominated by their respective Governments and the FAO Regional Soil Resources Officer. Four countries (two each from French and English speaking countries) where National Soil Institutions exist, nominated one senior soil scientist each to form the membership of this sub-committee. The countries concerned are : Ghana, Nigeria, Togo and Senegal.

The main purpose of this Soil Correlation Sub-Committee was, firstly, to lay the foundation for initiating soil correlation work at national and regional levels. Secondly, to identify and discuss those matters which relate to Soil classification, evaluation, management and conservation which most obviously allow for regional collaboration and, thirdly, to find ways and means for the establishment of regular working relationships on the above subjects. The activities of the Soil Correlation Sub-Committee are meant to lead progressively to the establishment of a fully-fledged Soil Correlation Committee for West Africa, the membership of which will be drawn from all the countries in West Africa.

During the first Soil Correlation Sub-Committee Meeting, with field soil correlation tours organised in Ghana and Togo, in 1972, emphasis was laid not only on the need for but also ways and means of achieving the aims of establishing national and regional soil evaluation through standardised approach. As a positive step the meeting explored the possibility of achieving the above aim through specific programme of work.

The Soil Correlation Sub-Committee for West Africa with its Secretariat at the FAO Regional Office for Africa and whose activities are to be coordinated by the Regional Soil Resources Officer, will continue to function with its delegates from Ghana, Nigeria, Togo and Senegal until a fully fledged Soil Correlation Committee is convened.

PARTICIPATION

Members of the Soil Correlation Sub-Committee for West Africa

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Interpreters

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Dr. F. Mouttapa

Officers of the Session:

Chairman	:	Dr. H.B. Obeng
Vice-Chairman	:	Mr. R. Sant'Anna
Technical Secretary	:	Dr. F. Mouttapa

PROGRAMME AND AGENDA

Sat - Sun June IO-II	:	Arrival of Delegates and Observers
Mon. June I2	:	Opening Session.
9.00 a.m.	:	Submission of Registration papers by participants.
9.I5 a.m.	:	Welcome Address - Dr. M. Dowuona, Chairman, C.S.I.R. Address by FAO Regional Representative for Africa Election of Chairman and Vice-Chairman
IO.I5 a.m.	:	Coffee break
IO.45 a.m.	:	Agenda Item I - Technical Session - papers by delegates of Ghana and Togo : "Soil Correlation in Ghana" - by H.B. Obeng "Soil Resources of Togo and their importance for regional soil correlation" - by R. Sant'Anna
II.30 a.m.	:	Discussions on papers presented by delegates of Ghana and Togo.
I2.00 p.m.	:	Lunch break.
2.30 p.m.	:	Agenda Item I (cont'd) : papers by delegates of Nigeria, Senegal and FAO : "Land classification systems being used in Nigeria and their Correlation problems" - by B.T. Datiri "Definition and Characterisation of some Soils of Senegal which may serve as a system of reference in the French Classification" - by S. Peirera-Barreto. "Opportunities offered by FAO/UNESCO Soil Map of the World for National and Regional Soil Correlation aiming at a better evaluation and management of soil resources in West Africa" - by F. Mouttapa
4.00 p.m.	:	Discussions on papers presented by the delegates of Nigeria, Senegal and FAO.
Tuesday June I3	:	Agenda Item 2 - Visit to Soil Research Institute, Kumasi
7.00 a.m.	:	Arrival at Kotoka International Airport
7.30 a.m.	:	Travel by air to Kumasi
8.15 a.m.	:	Arrival at Kumasi
9.30 a.m.	:	Tour of the various Divisions of the Soil Research Institute, CSIR, Kwadaso - Kumasi. Inspection of profile pits showing representative semi-deciduous rainforest soils, Kwadaso Central Agricultural Station.

Tue. June I3 (cont'd)

2.30 p.m.	:	Lunch break
4.00 p.m.	:	Visit to the National Cultural Centre.
6.30 p.m.	:	Cocktail party at the Central Agricultural Station, Kwadaso (courtesy of the Ag. Director, Soil Research Institute).
Wed. June I4	:	Agenda Item 3 : Full day field tour in Ghana
7.00 a.m. to 6.30 p.m.	:	Trip to Atebubu with stopovers at Ejura and **Atebubu.** Inspection of profile pits enroute (packed **lunch break at** Atebubu).
Thurs. June I5 7.30 a.m. to 6.30 p.m.	:	Agenda Item 3 (cont'd) : Full day Field trip to Accra via Bonsu and Nsawam with inspection of profile pits enroute. (Packed lunch at Nkawkaw). Night halt at Accra
Fri. June I6	:	Agenda Item 4 : Visit to the Soil Institute of Togo
7.00 a.m.	:	Travel by road to Lomé (Togo). Inspection of profile pits enroute from Accra to Lomé.
I2.30 p.m.	:	Arrival at Lomé and lunch break.
4.00 p.m.	:	Visit to the Division des Etudes Pédologiques et de l'Ecologie Générale de l'Institut Polyvalent de Recherches".
	:	Welcome to Togo address by Mr. Nahm-Tchougli, "Directeur de Cabinet" Ministry of Rural Development and Mr. **Bloch,** United Nations Resident Representative in Togo
	:	Cocktail party at the "Division des Etudes Pédologiques et de l'Ecologie Générale" (Courtesy of the Director of the Soil Research Institute of Togo).
Sat. June I7	:	Agenda Item 5 : Field Tour in Togo
6.30 a.m.	:	Field trip to Davie, Nuatja, Chra, Atakpame, Anie
I2.30 p.m.	:	Packed lunch break at Anie.
2.30 p.m.	:	Departure for Palime, inspection of profile pits enroute.
6.30 p.m.	:	Arrival and night halt at Palime.
Sun. June I8	:	Agenda Item 5 (cont'd)
8.00 a.m.	:	Departure from Palime. Examination of soil profiles between Palime and Lomé.
I2.00 p.m.	:	Working session at the Division des Etudes Pédologiques et de l'Ecologie Général - Lomé.
5.00 p.m.	:	Departure from Lomé by road to Accra.
8.00 p.m.	:	Arrival and halt at Accra.

Mon. June I9	:	Agenda Item 6
9.00 a.m.	:	Review and discussions in the light of the soil correlation field tours in Ghana and Togo.
I0.00 a.m.	:	Coffee break.
I0.30 a.m.	:	Agenda Item 7 : Meeting of the drafting team constituted by Members of the Sub-Committee.
I3.00 p.m.	:	Break for lunch
I4.00 p.m.	:	Agenda Item 7 (cont'd)
I6.00 p.m.	:	Agenda Item 7: Adoption of recommendations. Closing session of the First Soil Correlation Committee Meeting.
I8.30 p.m.	:	Cocktail party at the Residence of the Assistant Director-General of FAO and Regional Representative for Africa jointly offered by the FAO Regional Representative for Africa and FAO Country Representative in Ghana.

OPENING SESSION IN GHANA

AND

WELCOME ADDRESSES IN TOGO

I. The First Sub-Committee Meeting on Soil Correlation for West Africa was opened on 12 June 1972 at Accra by Dr. M. Dowuona, Chairman of the Council for Scientific and Industrial Research (CSIR) on behalf of the Government of Ghana. Mr. Mensah, Assistant Director-General for African Affairs and Regional Representative for Africa delivered the opening address on behalf of the Director-General of FAO.

At a brief ceremony arranged at Lome by the "Division de la Pédologie et de l'Ecologie Générale" for inaugurating the field correlation tour in Togo, welcome addresses were delivered by Mr. Pierre Nahm Tchougli, "Directeur du Cabinet du Ministère de l'Agriculture et de l'Economie Rurale" on behalf of the Government of Togo and by Mr. Bloch, UNDP Resident Representative for Togo.

2. Mr. Dowuona welcomed the West African Delegates and the participants of the meeting- he reiterated his views expressed during the FAO Regional Seminar on the Evaluation of the Soil Resources in West Africa held in Kumasi in December 1970 when he had stressed the importance of modern soil survey methods and techniques for the evaluation of soils in developing countries in terms of their suitability for sound agricultural development.

It was most gratifying to note, he remarked, that the important recommendation passed at the Kumasi Seminar relating to the assignment of a Soil Correlator, had been speedily implemented by the Director-General of FAO.

He considered that this First Soil Correlation Sub-Committee Meeting would constitute an important step towards achieving standardization in the description, classification and evaluation of the soils in West Africa.

The value of standardization in the use of common terminology and techniques could not be denied in a region such as West Africa, where with respect to soils, the lack of coincidence of state boundaries with those of "natural regions" is quite noticeable.

It was therefore, important that the sub-committee should succeed in its task in order that in future, a basis could be laid for a common system of classification and correlation of the soils of the Region.

He called attention to the fact that the work of the Sub-Committee as well as of the main Committee was part of the FAO/UNESCO Soil Map of the World Scheme, which provided a basis for widening the knowledge on soils and for transfer of experience in soil technology.

Dr. Dowuona stated further that soil study which is basic to all development, should be vigorously pursued, in order to be better equipped to tackle the problems of living on this Earth and those of economic development generally. He, therefore, wished to link the importance of finding a common vocabulary for the soils of the area to the all important objective of establishing wider economic groupings in West Africa as well as on the entire continent. The same need for an enlargement of the horizon beyond national boundaries would hold true for all associations in science and indeed all spheres of knowledge.

3. Mr. Moise C. Mensah, Assistant Director-General for African Affairs and Regional Representative for Africa, then remarked that the presence of Senior Soil Scientists at this first Sub-Committee Meeting bore witness to the most encouraging interest shown in this undertaking by FAO's Member Nations and its sister technical assistance organizations alike and thanked the Chairman of the CSIR and the Directors of the respective Soil Research Institute of Ghana and Togo for the excellent preparation made.

He said that the importance given by FAO to the recommendations made during the Soil Seminar held at Kumasi in December 1970 was a testimony to the speedy appointment of the Regional Soil Resources Officer to work in cooperation with National Soil Scientists with a view to initiating and pursuing regional soil correlation for better soil evaluation and management. However, he reminded the meeting that meaningful results in soil correlation in the broadest sense could only be achieved through a concerted approach by all soil specialists working in the Region. Similar recommendations had recently been made at various meetings sponsored by FAO and bilateral programmes. Time had now come to translate these recommendations into practical action "on the ground".

A Soil Correlation Committee for West Africa could stimulate this much-needed cooperation, and by inaugurating the present sub-committee, an important first step had been made. The main purpose of this meeting was to lay the foundation for a more fully fledged committee.

A first priority, he stressed, would be to make optimal use of the considerable information on West African soils already in existence, to correlate these results at the national and regional levels, in order to enable transfer of knowledge relative to soil evaluation and management. Emphasis should be laid on the use which is to be made of these soil data by those who are concerned with agricultural development in the field.

Wishing the Meeting a complete success, he expressed the hope that an example may be set for similar meetings to be undertaken in the East and Central African Regions.

4. Welcoming the Delegates of the Sub-Committee Meeting on behalf of the Government of Togo at the "Division de la Pédologie et de l'Ecologie Générale" at Lome, Mr. Nahm-Tchougli, "Directeur de Cabinet" in the Ministry of Rural Development expressed the priority given by his Government for : international cooperation and collaboration, the betterment of the rural population, and the war against famine, malnutrition, diseases and rural exodus. He remarked that in the present context of socio-economic changes taking place in Togo, soil science has to play a key role in the agricultural development programme. Unfortunately, soil science in Africa, and more particularly in Togo is at an early stage of development. Problems related to soil management and productivity are many and they have to be solved as rapidly as possible to satisfy the pressing need of the Nation. This can be achieved rapidly only through effective and constructive collaboration and cooperation of neighbouring nations within the Sub-Region. He particularly thanked the United Nations and specifically FAO and more particularly its Regional Office for Africa for having brought together National Soil Scientists of West Africa for building up such inter-regional collaboration and cooperation through the establishment of the Soil Correlation Committee for West Africa.

He expressed also his gratitude to the Soil Research Institutes of Ghana and Togo and to all other Delegates who are contributing to the success of this Seminar. He called the Soil Scientists to keep always in mind during their deliberations the urgent needs of the farmers who have to make a decent living from the soils.

5. Then Mr. Bloch, United Nations Resident Representative for Togo welcoming the Delegates thanked the Government of Togo for hosting the Delegates and for the good arrangements made by its National Soil Institute for making this technical meeting a success as well as for the confidence put by the Government "vis-à-vis" of the United Nations. (*)

(*) The full text of the main addresses made in Ghana and Togo are given in Appendix A of this report.

ELECTION OF CHAIRMAN AND VICE-CHAIRMAN

Dr. H. Obeng, Delegate from Ghana was elected Chairman of the First Soil Correlation Sub-Committee Meeting for West Africa.

Mr. R. Sant'Anna, Delegate from Togo was elected Vice-Chairman of the Meeting.

SUMMARY OF TECHNICAL DISCUSSIONS

I. PRESENTATION OF TECHNICAL PAPERS

I.I. Discussions have been initiated by the presentation of the following five papers summarized in Appendix D.

I. Soil Correlation in Ghana - H. Obeng

2. The Soil Resources of Togo - by R. Sant'Anna

3. Soil Survey and Land Classification in Nigeria and its Correlation Problems - by B.T. Datiri

4. Definition and Characterisation of some soils of Senegal which may serve as a system of reference in the French classification - by S. Peirera-Barreto

5. Opportunities offered by FAO/UNESCO Soil Map of the World for National and Regional Soil Correlation aiming at a better evaluation and management of Soil Resources in West Africa - by F. Mouttapa

I.2. Characterisation of "ferrallitique" and "ferrugineux" soils

It was remarked that the Soil Map of Togo at the scale of I:I 000 000 prepared by Mr. Lamouroux shows more than half of the country under "sols ferrugineux"; on the contrary most of the soils in Ivory Coast are known as "sols ferrallitiques". Questions were raised whether the soil scientists who have worked in Ivory Coast if asked to map soil in Togo may find more "ferralitic soils" than Lamouroux.

It was agreed that it is often difficult to differentiate a "sol ferrugineux" from a "sol ferrallitique" by using any of the following criteria :-

a) Climate : Both of the soils are found in high or lower rainfall areas. The rainfall limit of I200 mm distinguished in Madagascar for differentiating these soils is not valid for Senegal, Ivory Coast, Ghana or Togo.

b) Soil colours are not diagnostic.

c) Cation exchange capacity presents a broad overlapping range.

d) If base saturation is taken in consideration 80% of the soils will go under "Sols ferrugineux".

e) The sexquioxide ratio, as evidenced by the recent work of Dr. Segalen, is more related to the drainage condition in the soils than to the pedogenetic processes.

f) Clay skins and textural B horizon are not often the characteristics of "Sols ferrugineux" alone.

However, it was agreed that soil structure and the compactness of the A and B horizons are often consistent criteria used in the field for differentiating "sol ferrugineux" from "sol ferrallitique".

Dr. Perraud reported that sandy soil formations overlying an older ferrallitic material are found in the North Eastern zone of Ivory Coast, which is characterised by one rainy season followed by a long dry spell. These soils characterised by a deep surface horizon rich in organic matter and a massive B horizon have been classified as ferruginous soils. Such soils have been classified by earlier French soil scientists as "sol ferralitique". As a result of this, the soil map of Ivory Coast prepared by Dr. Perraud indicates more "Sol ferrallitique" than maps prepared by earlier French soil scientists.

However, it was agreed that soil structure and the compactness of the A and B horizons are often the consistent criteria used in the field for differentiating a "sol ferrugineux" from a "sol ferrallitique". Thus a "sol ferrugineux" is often characterised by a massive, compact and well differentiated soil horizons; while the profile of a "sol ferrallitique" shows a deep and homogeneous soil with well developed soil structure.

.3 Need for standardization of soil description and classification at national and regional level

It was remarked that soil studies and surveys, within a country, are carried out in the sub-region either by one national research organization like in Ghana and Togo or by various Universities or bilateral or multilateral agencies like in Nigeria. In this latter case, each institution follows its methodology and approach and no meeting ground exists to evolve a common procedure for evaluating soil resources at national level and undertake experiments on their management.

In Nigeria, soil studies have been carried out by using various systems of classification: d'Hoore classification is used for Northern Nigeria, whereas the systems of Vine and Charter are frequently adopted in the North-Western part. The Eastern zone is mainly mapped by using the Dutch soil classification. Presently, the Land Resources Division of the British Overseas Development Adminstration is mapping soil in Nigeria by using the FAO system. Therefore, it was generally agreed that there is an urgent need for countries like Nigeria to take immediate steps to standardize terminology and methods of soil characterisation and classification on national level with a view to correlating soils so far distinguished in the country.

In the French speaking areas of West Africa soils are described and classified as per the French Soil classification evolved by Prof. Aubert. Since the French classification has been improved and standardized over the past few years, it was remarked that it would be necessary to review the earlier work for bringing uniformity and improving soil correlation at national and regional level.

In the English speaking areas the systems of classification used are derived mainly from Charter, Brammer, Vine, d'Hoore and more recently USDA 7th approximation and FAO systems.

It was observed that the basic soil unit used in most of the soil classification systems prevailing in the sub-region for characterizing and describing soil is "soil series". The definition of soil series in the French system is very close to the one defined in the USDA Soil Survey Manual.

I.4 Objectives of the Soil Correlation tours in Ghana and Togo

It was accepted that most of the technical discussions of practical value can be advantageously held during the field correlation tours in Ghana and Togo which have been organized by the Soil Research Institute of the Council for Scientific and Industrial Research at Kumasi and the "Division des Etudes Pédologiques et de l'Ecologie Générale de l'Institute Polyvalent de la Recherches" at Lomé. The main purposes of these tours were to :-

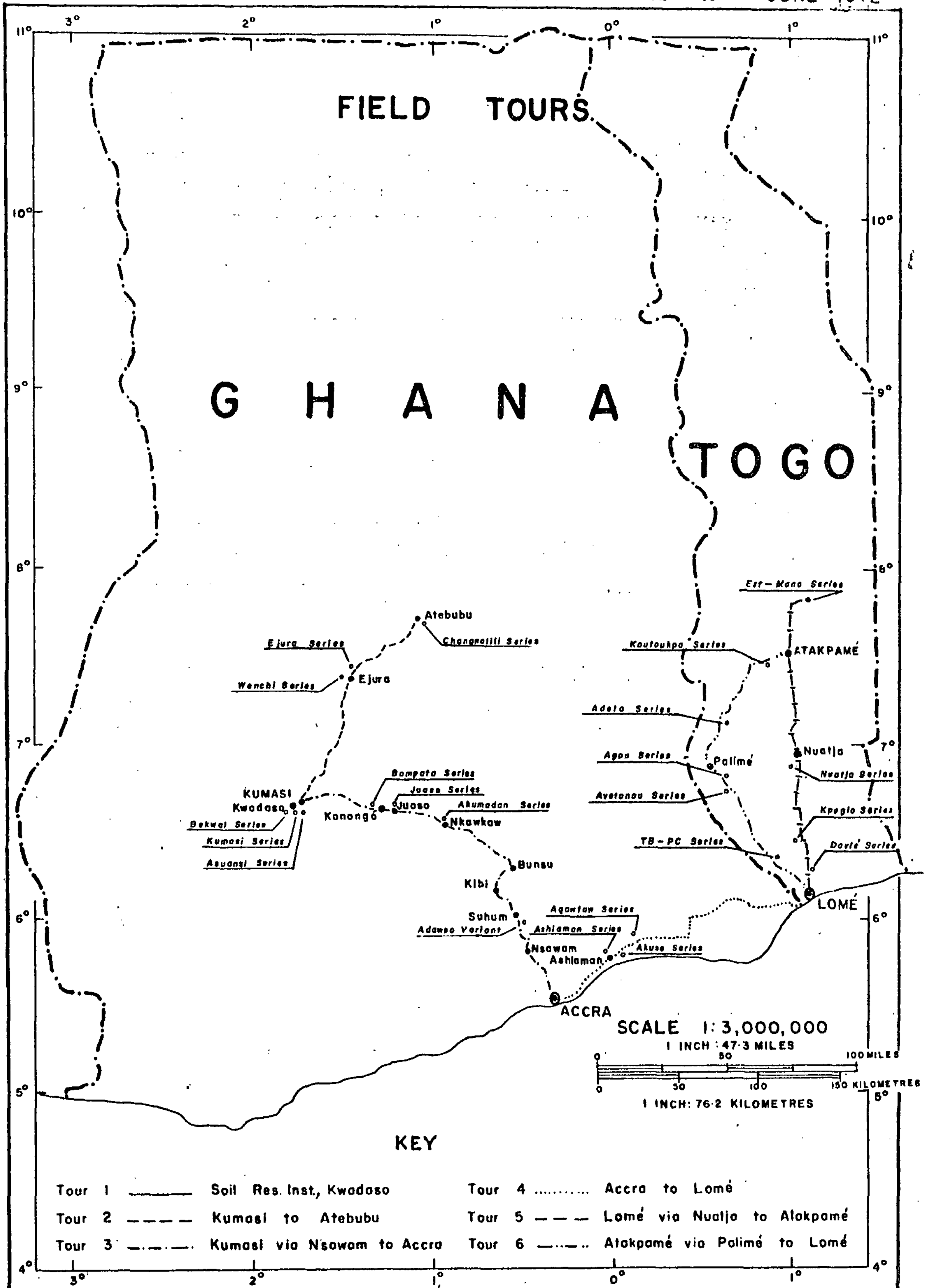
a) observe some of the major soil formations occuring in Ghana and Togo.

b) characterise and classify them in the system of classification in use in Ghana and Togo and give their equivalent in FAO/UNESÇO system of soil groupings.

c) relate the soil profiles to **their environment.**

d) discuss problems of their utilization and determine their limitations to cultivation.

SOIL CORRELATION IN WEST AFRICA SUB-COMMITTEE MEETING 12TH–19TH JUNE 1972



Prepared by the Cartographic Staff, SOIL RESEARCH INSTITUTE, (C. S. I. R.) Kumasi. June, 1972

2. SOIL CORRELATION TOUR IN GHANA

The major representative soil formations occurring in the following main ecological zones of Ghana as described below, have been studied by following three transects : a) Kumasi - Atebubu; b) Kumasi - Accra; c) Accra - Aflao (see Index Map).

Ecological zones	Names of Soil Series
- Semi-deciduous rain-forest zone	Bekwai - Kumasi - Asuansi Juaso - Bompata - Akumadan
- Forest Savannah-transitional zone	Ejura - Wenchi - Changnalili
- Coastal savannah zone	Ashaiman - Akuse - Agawtaw

2.I Moist semi-deciduous rain-forest zone

2.I.I. The environment

A. Climate

The semi-deciduous rain forest zone is characterised by two rainy seasons with monthly totals reaching their maxima in May-June and October. The totals in each of these months are similar and the period December to February and mid-July, August and early September are much drier than the rest of the year. Yearly total rainfall varies from I270 to I778 mm. Temperatures are high with little variation from year to year. Absolute minima and maxima temperatures range between I0°C and 33°C. Relative humidities are generally over 90% during the night and early morning. Humidities are below 89% in January where there is a considerable fall in humidity.

B. Geology and Geomorphology

The area traversed is mainly on ancient crystalline rocks constituted by Birrimian schists and phyllites, granites, grandorites and diorites. Tarkwaian and Togo sediments comprising of sandstones, quartzites, phyllites, conglomerates and shales have also been encountered. Over the schists, phyllites and granite the topography ranges from gently undulating to gently rolling; slopes usually range from 3 to 80%. Broad flat-floored or rounded valleys are separated by gently rounded hills (60 to 90 m above the valley bottoms); however, steeper relief reaching approximately 240m are often seen where Upper Birrimian rocks occur.

The Birrimian and granitic topography is diversified by inselbergs some of which are ancient peneplain residuals. The lower ones (45 to 300 m above sea level) are capped with ironpan or with deep, red, uniform, relict, piedmont drift soils. The higher ones I000 - 2400 m to 300 - 720 m are capped with bauxite crust.

Over the Tarkwaian and Togo rocks, slopes are very steep and the topography more markedly rugged than in the phyllites and granite areas. The Tarkwaian sediments constitute the major gold bearing rocks of Ghana.

C. Vegetation and Land Use

The zone is dominated by moist semi-deciduous rainforest of the Celtis-Triplochiton Association of Taylor (I952). Many of the species are deciduous for various periods between October and April. It is within this area that most food and cocoa farming takes place in Ghana. The major food crops grown include plantains, bananas, cassava and cocoyams; coffee and cola are also important in this area.

2 .I.2. Soil formations occurring over phyllite and granite

The various soil series occurring in the recurring toposequence observed over phyllite and granite are indicated in diagram No. I; this diagram illustrates the occurrence of the various soil series in the landscape and is by itself self-explanatory.

Three soil series in the above associations have been examined during the field visits; they are : Kumasi, Bekwai and Akumadan. The full descriptions of these series along with analytical data are given in Appendix B.

2.I.2.I. Kumasi Soil Series is characterized by :-

a) An A horizon relatively rich in organic matter (8% in the first IO cm) free from iron stone concretions; with fine granular and friable structure. Soil texture is sandy clay loam to loam.

b) An Argillic B horizon containing 25 to 35% by volume of quartz gravel and ironstone concretions up to a depth of I50 cm. Soil texture is gravelly clay. The base saturation is less than 50.

Limitation

- The fertility status of these soils decreases very rapidly after clearing and cultivation. Deficiency of phosphorus is shown after 2 to 3 years of continuous cropping.
- There is no response to nitrogen during the first year of cultivation.
- These soils are susceptible to erosion particularly when brought under sustained food crop cultivation.
- Gravel may become a serious limiting factor if it exceeds 60% by volume.

Classification

- Forest Ochrosol, gravelly phase (Ghana)
- Dystric Nitosols, petric phase (FAO)
- Typic paleudult (USDA)
- "Sol ferrallitique fortement désaturé, remanié, modal" (French)

2.I.2.2. Bekwai Series is characterized by :-

a) An A horizon with organic matter content of 5.2% on the first 5 cm and 2.7% below; the texture is clay loam; the structure is moderately granular and is friable.

b) An argillic B horizon, dark red (7.5 YR 3/6) to red (7.5 YR 6) in colour with massive and firm structure; the texture is clay, ironstone concretions and quartz (25 to 30% by volume) are found up to an average depth of I50 cm; base saturation is less than 50%.

Limitations

- This soil has almost the same characteristics and limitations of the Kumasi series.

Classification

-	Forest ochrosol, concretionary phase	(Ghana)
-	Humic Nitosols, petric phase	(FAO)
-	Rhodic paleudult	(USDA)
-	"Sol ferrallitique fortement désaturé remanié, modal"	(French)

2.I.2.3 Akumadan Series

Akumadan series is a very deep red soil, free from gravel and occurring usually in relatively flat to slight undulating summit. It is developed in drift material covering the old erosion surface and is characterized by :-

a) A thin A horizon relatively rich in organic matter (5.45%) of dark reddish brown colour (2.5 YR 3/6); the soil texture is clay-loam.

b) An homogeneous deep argillic B horizon of dark red colour (IO YR 3/6) with medium sub-angular blocky and firm structure; the soil texture is clay.

Limitation

Akumadan series has very good physical characteristics; however, its fertility status decreases very rapidly after deforestation; deficiency in phosphorus appears very quickly after I to 2 years of cultivation. The soil is susceptible to erosion when brought under sustained single cropping system of cultivation.

Classification

-	Forest ochrosol, non concretionary phase	(Ghana)
-	Humic Acrisols	(FAO)
-	Rhodic Paleudult	(USDA)
-	"Sol ferrallitique fortement désaturé typique, modal sur matériel remanié (au niveau de la famille)".	(French)

2.I.3 Soil formation occurring over Tarkwaian sediments

Juaso and Bompata series have been observed under the Tarkwaian schists and quartzites. The detailed profile descriptions and the analytical data for the above two soil series are given in Appendix B.

2.I.3.I. Juaso series is characterized by :

a) A thin A horizon relatively rich in organic matter (5%) of dark brown colour (7.5 YR 4/2) with medium crumb structure; the texture is sandy loam; frequent ironstone concretions and quartz gravel are found in this A horizon.

b) A deep argillic B horizon of red colour (2.5 YR 4/8) with massive structure; ironstone concretions and quartz gravel are abundant in the first I00 cm and decreases below (30 to 35% by volume); the texture is clay.

c) Mottles are noticed in the horizon free from gravels at I20 cm depth.

Limitation : The fertility status of this soil which is mainly localised in the A horizon decreases rapidly after clearing of the forest and under sustained cultivation.

A high percentage of gravel (60% by volume) may be a limiting factor for certain food or cash crops.

Classification

- Forest ochrosol, concretionary phase	(Ghana)
- Humic Acrisols, petric phase	(FAO)
- Rhodic Paleudult	(USDA)
- "Sol Ferrallitique fortement désaturé remanié, rajeuni".	(French)

2.1.3.2 Bompata Series is characterized by :-

a) A horizon of dark reddish brown colour (5 YR 4/4) with crumby to fine subangular blocky structure; the soil texture is sandy loam.

b) A very deep (600 cm) homogeneous argillic B horizon; dark red in colour (10 YR 4/6) and free from gravel; the structure is medium subangular and firm; the soil texture is clay.

Limitation

- No limitation on physical properties.
- The fertility status decreases rapidly after clearing of forest and under sustained cultivation.

Classification

- Forest Orchosol, non-gravelly phase	(Ghana)
- Dystric Nitosols	(FAO)
- Rhodic Paleudult	(USDA)
- "Sol ferrallitique fortement remanié au niveau de la famille".	(French)

2.1.4 Summary of field discussions

The presence of a thick ironstone concretion and/or quartz gravel layer, within 1 m of the surface (Kumasi, Bekwai, Juaso series) or very deep in the profile (Akumadan or Bompata), indicates that most of the soils observed are not originating from the rock formation underlying, immediately below. Hence, the evolution of the soils materials above and below the gravel layers may be different. Often the evolution of the soil above and below the gravel layers may be influenced by the water movement in the soil profile (lateral and vertical) which could be very different.

It was noticed that the character "remanié" is introduced in the French classification at a higher level. While this character is considered at phase, series or the family level in the USDA and FAO systems.

DIAGRAMS ILLUSTRATING SOME TYPICAL GHANA SOILS IN THE FOREST ZONE

Typical Forest Ochrosol Soil Associations Over Phyllite and Granite

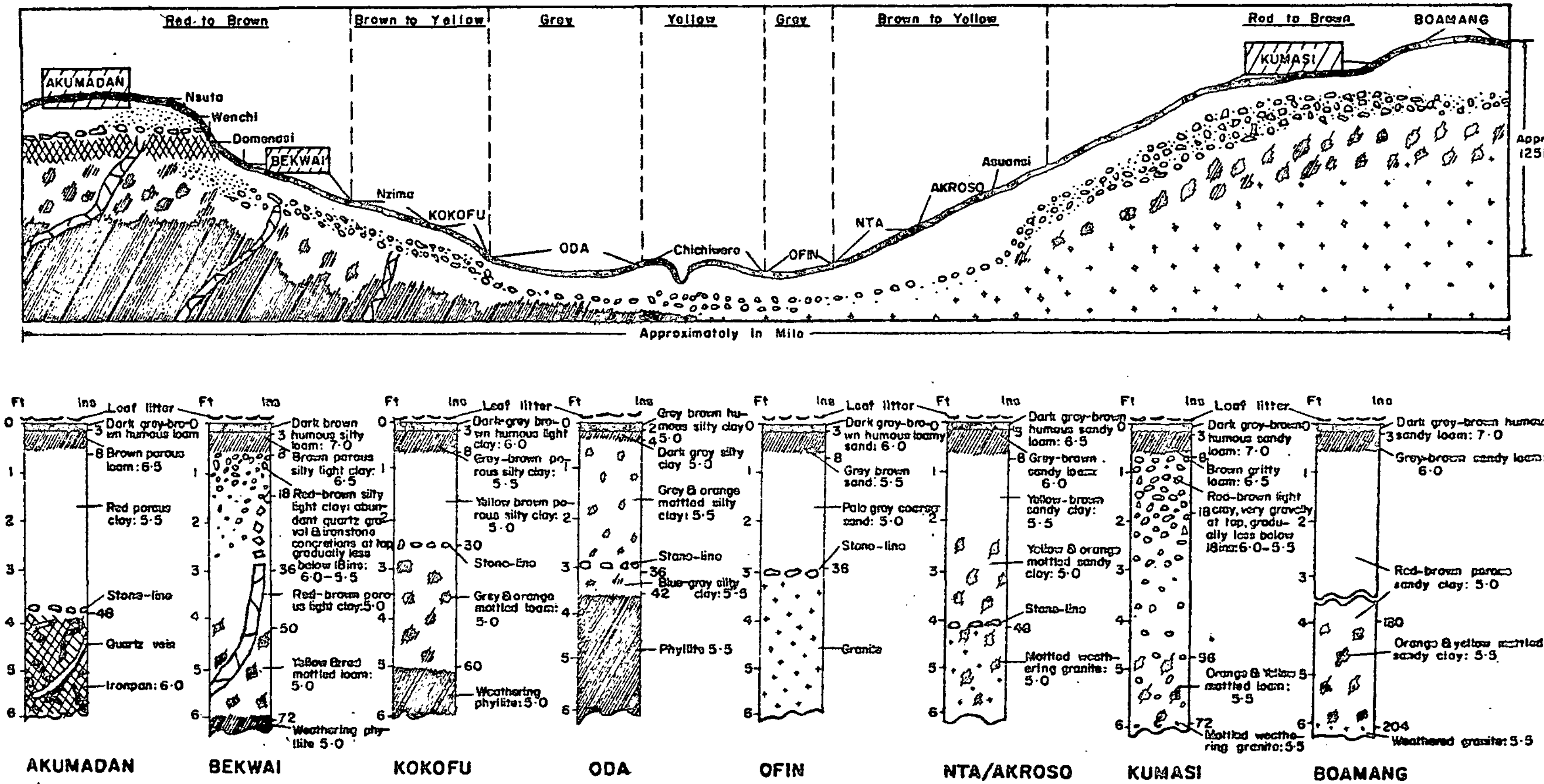


Diagram No. I

DIAGRAM ILLUSTRATING THE PROFILE OF THE LANDFORM ENCOUNTERED DURING FIELD TRAVERSE FROM KUMASI TO ATEBUBU

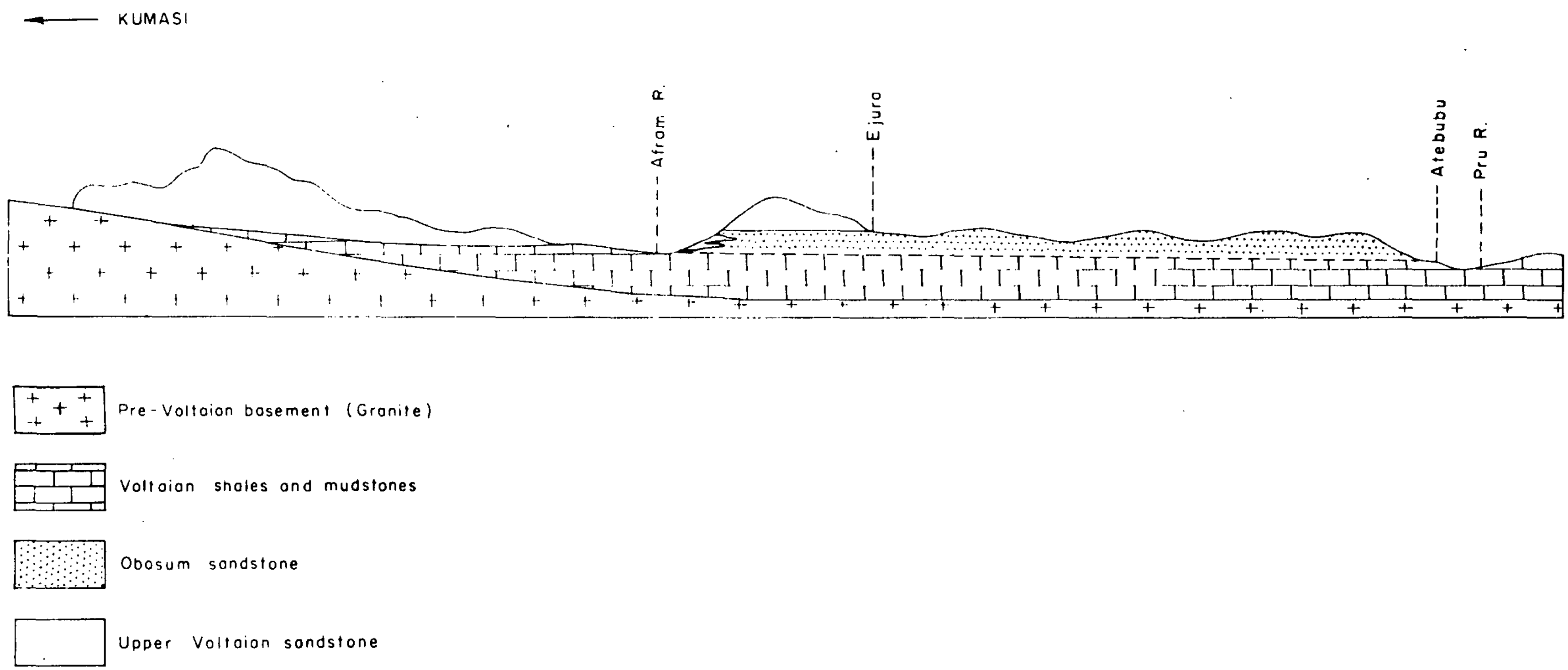


Diagram No. 2

2.2 Forest savannah - transitional zone

2.2.I Environment

A. Climate

The area has two rainy seasons just as the rest of Southern Ghana. The main season occurs from April to June followed by a short dry spell from mid-July to end of August. The minor rainy season occurs in September and October followed by the main dry season from November to mid-March. Rainfall is about 54 inches (I372 mm) per annum. Morning and mid-day relative humidities are at their highest during the wet season of July, August and September. Mean monthly figures range between 85-88% during the mornings, decreasing to 70-74% during mid-day. The lowest relative humidity usually occurs in March where it is around 73% in the morning and 45% at mid-day. Absolute mean temperatures are similarly highest in March (above I00°F or 38°C) and absolute mean temperatures are lowest (55°F or I3°C) during the months of January and February.

B. Geology and Geomorphology

The geology of the area consists entirely of Voltaian sediments. The sediments are the most extensive formation in Ghana, extending over approximately 45% of the country. Around Ejura the formation consists of sandstones that are thick-bedded, fine-grained, flaggy, micaceous, ferruginous or feldspathic.

The area lies along the rim of the Voltaian basin formed by a ring of high scarplands rising to over 600 m above sea level. The topography is uniform. Slopes are gentle everywhere, steepening only where resistant bands of rock outcrop or where peneplain residuals occur. The general level is between I20-I50m above sea level. The predominant slope reflects the gentle gradient of the Volta river itself to which all slopes are graded.

Most of the major tributaries of the Volta (within Ghana) have their sources outside the Voltaian Basin and, therefore, reach the surrounding scarp usually in broad valleys. A number of shorter tributaries rise within the basin. Many of them dry up during the dry season; this seasonal shortage of water may be one of the chief causes of the low population densities over extensive areas within the basin.

C. Vegetation and Land Use

The vegetation consists of transitional forest. Essentially, this is composed of islands of forest species encircled by a band of vigorous savannah tree species which in turn merges into open tall grass savannah. Swamp savannah type of vegetation occurs along the broad, water-logged bottom lands, and riverain forest along the major streams and rivers.

Yams, cassava and maize are the major crops grown, and the deep soil constituted by Ejura series, is well suited to the production of these crops. The soil is also suitable for the extensive cultivation of millet, groundnuts, kenaf, Urena lobata and tobacco. Yields, although generally low owing to poor natural fertility, can be significantly increased through mulching and application of fertilizers especially nitrogen and phosphorus. Traditional cultivation is generally practised, but large-scale permanent mechanised farming tracts can also be seen like Ejura Farms Ltd., Ejura, Commercial Farms Ltd., Atebubu and Abua Farms Ltd., Prang.

2.2.2 Soil formations in sandstone and clay shale areas

Two soil profiles belonging to Ejura and Changnalili series have been observed in the recurring toposequence met over sandstone and shale. The diagram No. 2 schematises the landform observed during the field trip. Detailed description of these series along with analytical data are given in Appendix B.

2.2.2.I. Soils of the sandstone areas : Ejura series

Ejura series occupies nearly level to level uplands; it is free of gravel and is a yellowish red colour (5 YR 4/8). Other soil series found in association with Ejura series in the toposequence (see diagram No.3) are : Amatin series (moderately well drained), Dentenso series (imperfectly drained) on the lower slopes and Sene series (poorly drained) valley bottom soil.

Ejura series is characterized by :-

a) A sandy A horizon generally dry and leached with low organic matter content (0.7%).

b) A sandy clay loam, argillic, B horizon followed at about I60 to I90 cm by a mottled horizon overlying solid ironspan. The cation exchange capacity is very low in the B horizon (5 meq %).

Limitation

- Low fertility status and very low cation exchange capacity
- Sandy nature of the top soil which dries up quickly during the main dry season.

Classification

- Savannah ochrosol, non gravelly phase	(Ghana)
- Dystric Nitosols	(FAO)
- "Sol ferrallitique typique appauvri"	(French)
- Paleustult	(USDA)

2.2.2.2. Soil of clay shale areas : Changnalili series

During the tour only one soil profile was observed in the clay shale area belonging to Changnalili series which is classified under Ghana system of classification as ground water laterite. This soil series is characterized by :-

a) A soil profile influenced by hydromorphism.

b) A sandy loam A horizon with fine mottles - the general colour of the soil is dark grey (5 YR 4/) to dark reddish grey (5 YR 4/2).

c) A massive gravelly loamy argillic B horizon with iron gravel followed by a hard ironpan.

DIAGRAM ILLUSTRATING THE REPARTITION IN THE LANDSCAPE OF SOILS ASSOCIATED WITH EJURA SERIES IN THE SANDSTONE AREA

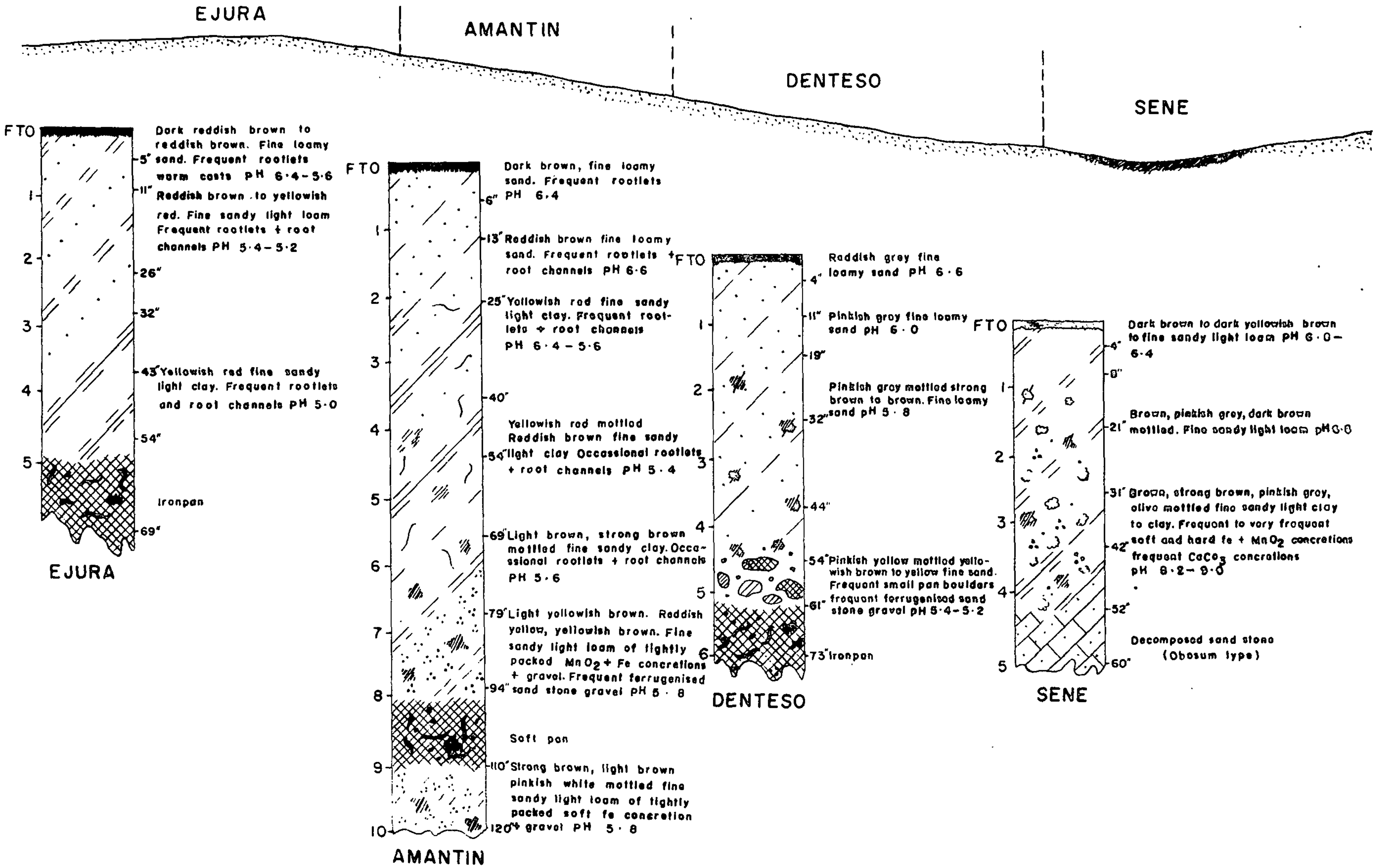


Diagram No. 3

Limitation

- Sandy nature of the top soil which dries up rapidly during the dry season.
- The thickness of the top soil; ironpan may in certain cases appear within 25 cm of the surface.
- The fluctuating water table. These soils are saturated with water throughout the profile during the rainy season and the top soil is very dry during the dry season.

Classification

- Ground water laterite (Ferromangustetros)	(Ghana)
- Luvic Arenosols, petroferric phase	(FAO)
- "Sols hydromorphes mineraux à pseudo-gley" avec cuirasse de profondeur"	(French)
- Tropaqualf	(USDA)

2.2.3 Summary of field discussions

Discussions on soils of the shale areas centred mainly on the actual pedogenetic factors influencing Changnalili series.

2.2.3.I "Sols à pseudo-gley"

During the rainy season the water table in the Changnalili series rises from the iron pan layer to the surface; during the dry season the whole profile and particularly the top sandy soil is dried up. Such soils evoluting under the influence of a fluctuating water regime have been defined at the Stuttgart Seminar on hydromorphic soils as "Sols hydromorphes à pseudo-gley". It was noted that the terminology of "pseudo-gley" does not exist in the FAO or the USDA classification systems. The consensus was that the term of "pseudo-gley" as defined by the Stuttgart Seminar needs to be considered, if possible, in the FAO classification.

2.2.3.2 Genesis of the iron pan formation in Changalili series

The relation between the top soil and the underlying iron pan is not apparent, and its formation difficult to explain. The concensus was that there is a clearcut discontinuity between the soil and the thick iron pan layer. Accumulation of clay immediately above the iron pan layer clearly indicates a movement of clay material down the profile.

2.2.3.3 Soil management problems of Changnalili series

Depending upon the depth at which the impermeable ironpan layer is found, this soil needs to be drained during the rainy season and irrigated during the dry season. The need to find ways and means of conserving moisture in the soil during the dry season was stressed and close contour bunding like in Asia was suggested for preserving enough moisture in the soil with a view to producing a successful crop during the dry season.

2.3 Coastal Savannah Zone

2.3.I Environment

Climate - The mean annual rainfall of this area is around 889mm. There are two rainy seasons, approximately from April to June and from September to November. These rains, especially the second, are unreliable and make farming hazardous. At the same time periodic heavy rains present erosion and drainage problems.

Temperatures are highest during the main dry season (December to March) and lowest during the short dry season **(July to August).** Absolute maxima and minima range between 40°C and I2°C.

Humidities are relatively high throughout most of the year. Afternoon humidities are generally from 55-65%, falling to around 40% during the main dry season. On the coast, values may be I0-20% higher. Humidities rise to almost I00 per cent at night for the most part of the year over the Accra plains.

Geology and Geomorphology

The major part of the Accra plains is underlain by ancient igneous rocks (Dahomeyan or Archean gneisses and schists) and relatively young, unconsolidated sediments of Tertiary age. The gneisses and schists are either basic or acidic. The basic rocks consist almost entirely of garnetiferous hornblende gneiss while the acidic rocks are mainly fine-grained muscovite biotite schists and gneisses. Recent alluvium occupies the Volta flood plains and the major streams on the plains.

The plains form an area of low relief rarely rising above 250 feet (77 m) except where the surface is broken by steep-sided inselbergs. A low watershed, running east-west, divides the streams flowing north into the Volta (which lies some 88 km east from Accra) from those flowing south into the sea. The streams have broad valleys and flow intermittently. Owing to the imperviousness of the majority of the soils in this area, the rain water does not penetrate the ground easily but generally runs off as a broad sheet flood.

The well defined southward flowing streams receive their main supplies of water from the Akwapim range lying to the north. Near the coast these rivers broaden into long narrow lagoons. Within the plains the Volta has an alluvial area varying from nil to several miles broad and is annually flooded in parts. The river reaches the sea through a broad area of channels and salt lagoons.

Vegetation and Land Use

Thicket vegetation generally occurs on the Red Earths (e.g. Toje series); but on Vertisols (e.g. Akuse and Ashaiman series) short and medium grassland with widely scattered small clumps of thicket confined to old termite-mounds are encountered. Low riverain woodland occurs along stream channels. Forest and thicket occur on some inselbergs, but most carry savannah vegetation. The Volta flood-plain is mainly under tall swamp-grassland with frequent small swamp trees but patches of thicket occur locally and there is riverain forest along the river bank. Along the coastal lagoons bare or sparsely-covered succulent herbs and low mangrove thicket occur.

Agriculture is practically confined to the better-drained soils (e.g. Toje series). Shifting cultivation is practised so that at any one time much of the land is under fallow vegetation. Fallow periods are generally short and because of low fertility and frequent drought conditions crop yields are poor. The major crops grown are cassava, tobacco and tomatoes.

The heavy soils (e.g. Akuse and Agawtaw series) are at present very little cultivated but they constitute the major grazing areas of the plains. The heavy nature, difficult moisture relationships, the erratic nature of the rainfall and alkalinity in the case of Agawtaw series, have up to now inhibited their development. Investigatory work on their use is in progress by the University of Ghana, Agricultural Research Stations, located on the plains at Nungua and Kpong.

The rocky inselbergs classified as unproductive land should be used as game reserves. The fresh-water swamps and saline marshes are also unproductive at present.

2.3.2. Soil formation

Three soil profiles have been examined within the Accra plains. They belong to : Ashaiman, Akuse and Agawtaw series (see Appendix B for detailed description of soil profiles and analytical data).

2.3.2.1 Ashaiman series is a deep, dark, greyish brown, heavy clay (2.5 Y 4/2), developed on basic gneiss; vertical cracks can be seen during the dry season up to the C horizon at a depth of 100 cm, these cracks may have a width of . cm. The soil peds show evidence of slickensides. Flooding occurs only in very few places.

Classification

-	Tropical brown earth	(Ghana)
-	Chromic Vertisols	(F.A.O)
-	"Vertisol à drainage exterieur possible, structure anguleuse de surface, sous-groupe vertique"	(French)
-	Typic Chromustert	(U.S.D.A.)

2.3.2.2 Akuse Series is a very dark grey (10 YR 3/1), deep soil showing more pronounced characteristic of vertisol than the Ashaiman series, it has A and C horizons. During the dry season cracks are wider than cm and they extend down to the C horizon (00 cm).

Akuse series is found in more level topography than the Ashaiman series.

Limitations of Ashaiman and Akuse series

Both the soils, Ashaiman and Akuse series have the well known limitations of deep vertisols; they are very hard and difficult to work during dry seasons and reversely very soft and plastic during wet seasons.

Classification

- Tropical black earth (Ghana)
- Pellic Vertisols (F.A.O)
- "Vertisol à drainage extérieur possible à structure anguleuse de surface; sous groupe vertique grumosolique" (French)
- Typic Pellustert (U.S.D.A)

2.3.2.3 Agawtaw Series is a hydromorphic saline soil showing an abrupt transition between a sandy A horizon and a compact clay loam B horizon with a columnar structure. The profile seen showed a water seepage at the transition zone between the A and B and B and C horizons.

Sodium content is high in the B horizon (8 meq %).

Classification

- Tropical grey earth (Ghana)
  Gleyic Solonetz (F.A.O)
- "Vertisol à drainage extérieur réduit sous groupe modal". (French)
- Natrustalf (U.S.D.A.)

3. SOIL CORRELATION TOUR IN TOGO

3.I Description of the environment

Two main routes were followed during the field correlation tours in Togo as indicated in the Index Map :

I) traverse from North to South from Lomé to Kolokope via Tsevié, Nuatja;

2) traverse from North West to South West from Kolokope via Atakpame, Amlame, Palime to Lomé.

During the course of the tours soils in the following geomorphic units were examined :-

I) coastal zone
2) continental terminal zone.
3) Precambrian plateau zone
4) foot hills zones of the South Western hills.

Diagram No. 4 shows a S-NW cross-section of the area traversed. A brief description of the environment of the area visited in Togo is given below.

3.I.I. Geology

The geologic formations over the area traversed during the field tours are :-

3.I.I.I. Quaternary formations constituted by recent marine and alluvial deposits.

3.I.I.2 Tertiary formations of Cretacian Eocene periods called: "Continental Terminal". Marine deposits of Cretacian and Eocene periods have been deposited in the sedimentary basins which can be observed on the slopes leading to the Lama depression. These formations named "Continental Terminal" constitute two series of plateaux separated by a large valley called the depression of Lama. The soils developed from these materials are clayey and are called "terre de barre" ("terre barre" in Portuguese meaning clay soils).

3.I.I.3 The Precambrian formation: With the exception of the sedimentary formation found in the Southern part of Togo, most of the country is under Precambrian formation. This formation starts from few kilometres north to Tsevié. One can distinguish the following sub-divisions :-

a) The Dahomean series constituted by gneiss and micaschists of various origin (sedimentary and volcanic).

b) Atakorian series formed by interstratified layers of quartzites and micaschists overlying the Dahomean formation.

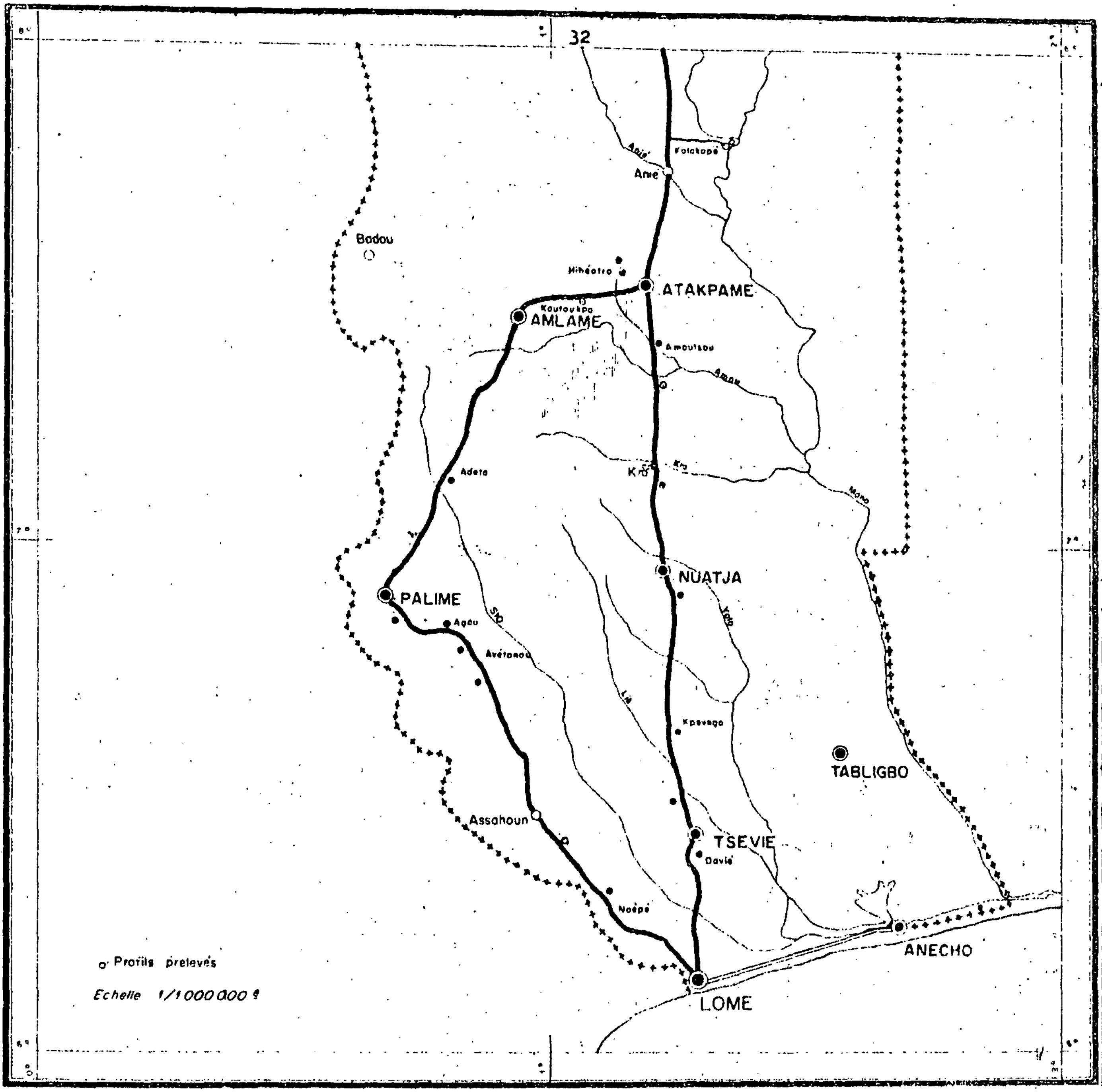
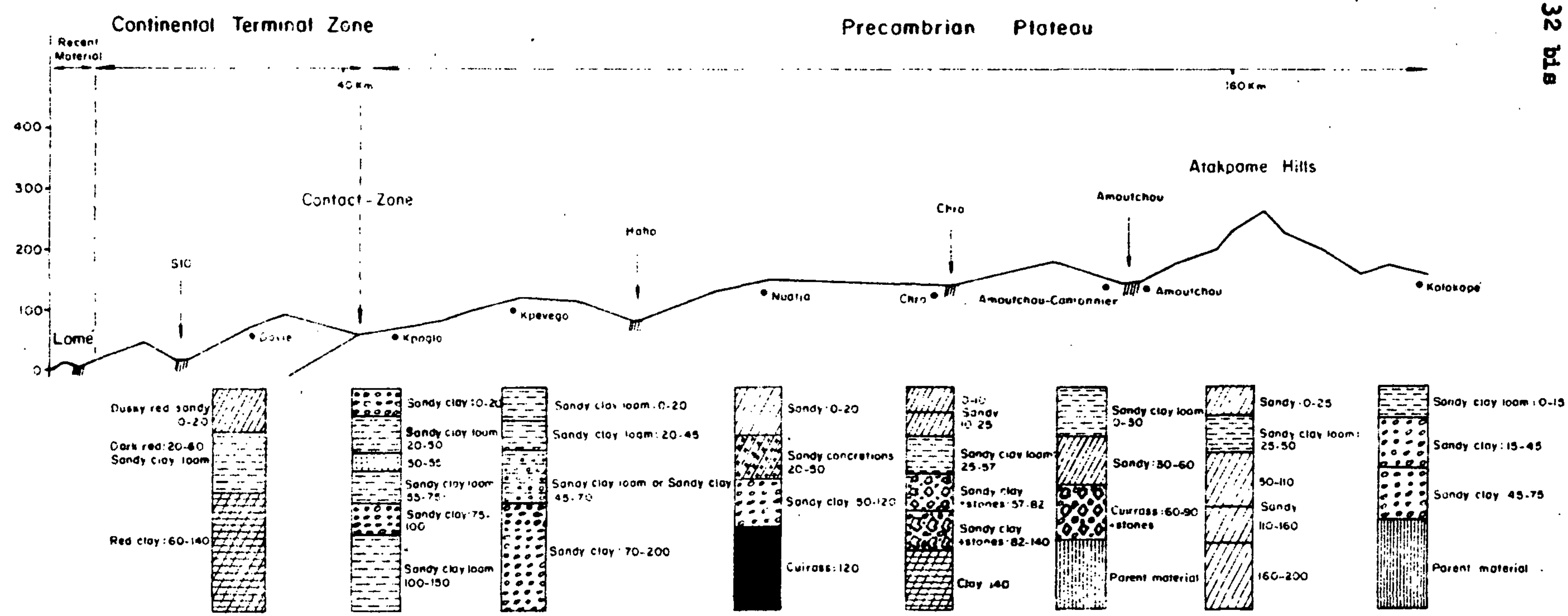

Kolokopé
Anié
Badou
Hihéatro
ATAKPAME
Koutoukpa
AMLAME
Amoutsou
Amou
Kra
Adeta
Mono
NUATJA
PALIME
Agou
Avétonou
Kpavago
TABLIGBO
Assahoun
TSEVIE
Davié
Noépé
ANECHO
LOME
o Profils prelevés
Echelle 1/1000000

Diagramme nº 4

Schematic S-NW Cross section of the land seen during the field tour in TOGO



3.I.I.4 Volcanic formation: Granitic or Granito-Biotite formations are observed between Atakpame and Palime. They form a narrow band of 5 km length between the Atakorian and Dahomean formations.

The above geologic formations have given rise to six main landform units :-

I) the coastal area forming a narrow band of 2 km width.
2) alluvial plains.
3) the plateau of the Continental Terminal constitutes a band of land of 30 to 50 km width running E to W; it is formed by a series of plateaux separated by valleys. The broad valley formed by depression of Lama seperates this area into two zones (northern and southern). The plateaux are under deep red soil formation, while the soils of the foot slopes are of sandy colluvial nature. Ironpan, rocky formations are often exposed on the border of the plateaux. The soils in the depression of Lama are hydromorphic black clays often calcareous.
4) Peneplain of the Precambrian rock basement, north to the plateaux of the "Continental Terminal" is a vast peneplain shaped in the Precambrian formation. It presents an undulating topography with a few inselbergs here and there.
5) Hilly areas with high level plateaux.

3.I.2 Climate and hydrography

The climate in the coastal and the plateau regions is of equatorial type characterised by two rainy and two dry seasons of unequal length.

3.I.2.I Rainfall

The major rainy season is between March and July with a maximum of rainfall in June; it is followed by a short dry season of two months duration. As one goes north the duration of this short dry season is shortened and disappears. The minor rainy season is from end of September to beginning of November with a maximum in October. The major dry season begins in November and ends in March.

The two diagrams Nos. 5 and 6, show the monthly mean rainfall distribution for six stations: two for the plateaux region (Atakpame, Palime) and four others for the "Région Maritime".

The annual rainfall between Tsevié and Nuatja in the south is I.IOO mm whereas it is .450 mm in the north at Atakpame.

The temperature is high and its variation not important. The mean annual temperatures are between 25 and 28°C. The difference between maxima and minima temperatures is around 6 to 9°C.

The following table gives the mean maxima and minima temperatures in three locations in the south, central and north of the areas visited :-

Temperature

Stations :	Lomé	Nuatja	Anié
Mean Max	30°4	33°[illegible]	33°2
Mean Min	27°8	21°8	18°6
Variation	7°6	11°7	14°6

The highest temperatures occur at the beginning of the first rainfall.

3.I.2.2 Hygrometry and Wind

Few data exist on hygrometry; the following are figures for Atakpame station.

Hygrometry in % at Atakpame

Months	J	F	M	A	M	J	J	A	S	O	N	D
Maximal	96	95	94	95	97	97	97	97	97	97	97	96
Minimal	33	30	4I	51	55	62	67	65	64	58	47	37

The region of the "Plateaux" are under the influence of the "harmattan" which blows from the Sahara to the Atlantic Ocean. Its influence is felt for three months, from December to February; its velocity is around [illegible]m/s.

The coastal region is under the influence of the S.W. monsoon.

The evaporation is often higher than the rainfall around Lomé.

3.I.2.3 Hydrography

The major important Rivers are Mono, Sio and Haho; the main tributaries of Mono are Ogon, Anié, Amon, Kra.

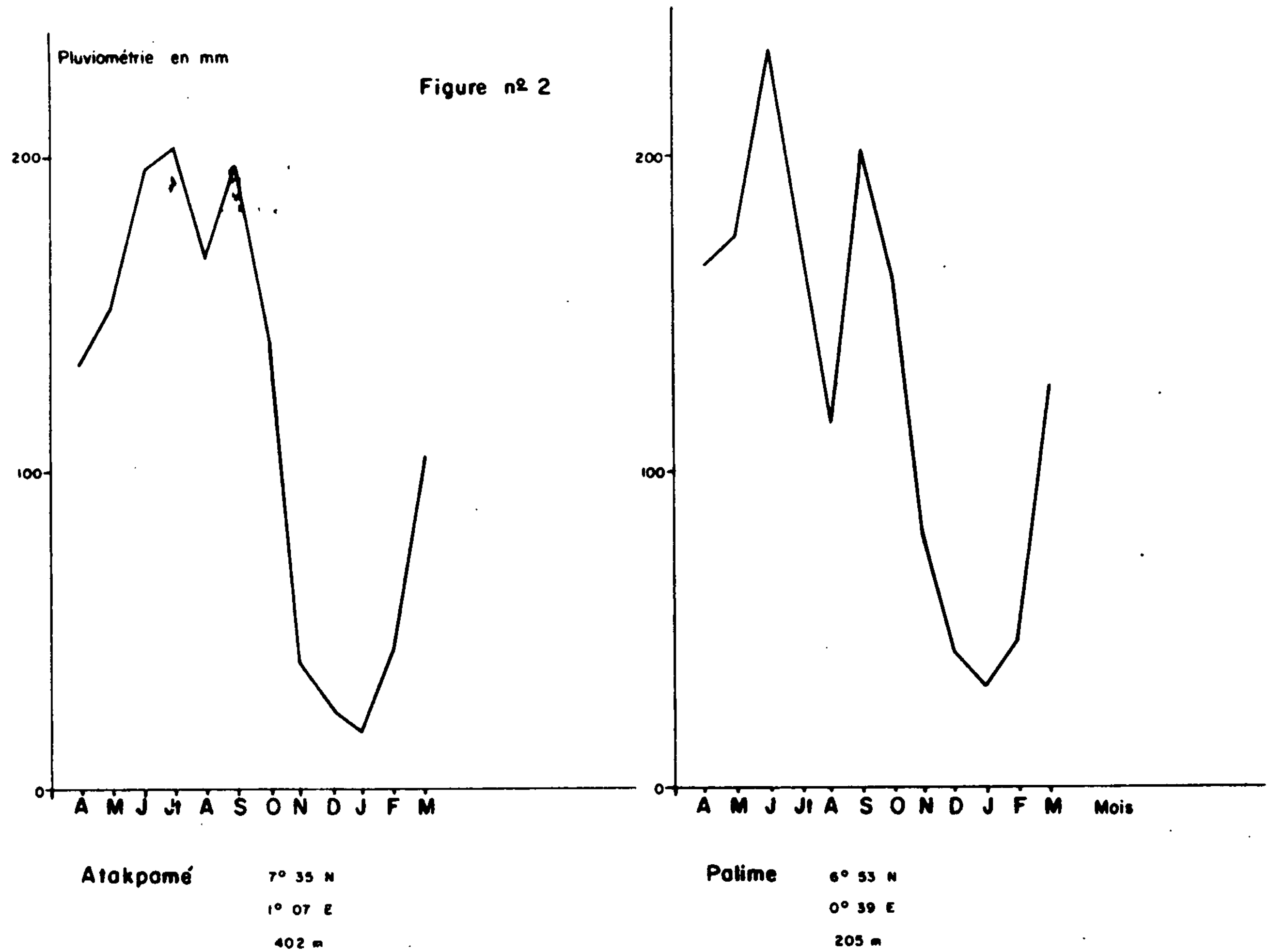
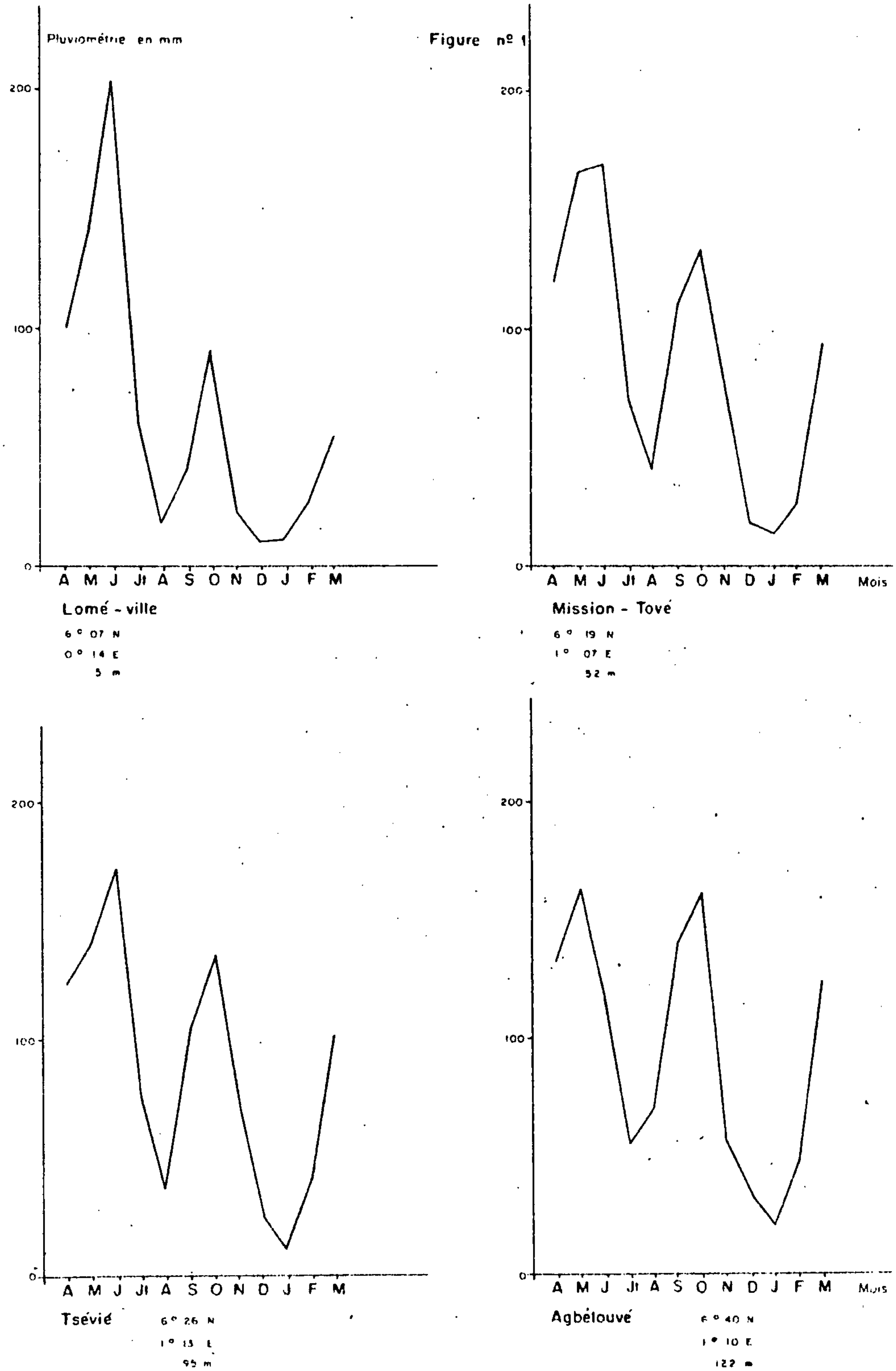


Diagramme Nº 5. Rainfall pattern in the "Région of plateaux" (TOGO)

Diagramme Nº 6. Rainfall pattern in the "Région Maritime (TOGO)



3.I.3 Vegetation

The predominant vegetation within the areas visited is as follows

3.I.3.I. Coastal area

The main vegetation is coconut with underwood constituted by:- Cynodon Dactylon, Opuntia, Passiflora.

3.I.3.2 The Plateaux areas of "Terre de Barre"

The secondary bushy growth of trees is constituted by :- Sterculia tragachanta, Milletia Thoningii, Fagara Xanthoxy-Ioides, Uvaria chamce, Dichrostachys glomerata.

The dominant trees are Elaeis Guinensis, Adansanita Digitata.

The alluvial plain of Sio is mainly under sugarcane and rice crops.

3.I.3.3 The Precambrian Plateau

The prevailing vegetation is a savannah woodland constituted by the following species:- Afzélia africana, Pterocarpus crinacens, Butyrospermum parkii, Adansonia digitata, Parkia Biglobosa, Burkea africana, Lophira alata, Daniellia oliveri, Isoberlinia doka.

The tree strata is mainly formed by : Hymenocardia acida, Terminalia avicenoides, Vitex cienkowskyi, Combretum micrathum.

The grass vegetation is composed of : Andropogon Sp., Pennisetum polystachyton, Loudetia togoensis, Imperata cylindrica.

The density of trees varies with the rainfall. Near Anié the following new species can be seen: Terminalia macroptera, Tephrosia sp. pseudocedrola Sp., Sarcocephalus esulentus.

3.I.3.4 Togo Hills

The main species of the Guinean Forest zone are found in the Togo hills; they are: Antiaris africana, Chlorophora excelsa, Triplo-cordifolia, Khaya Senegalensis.

3.2 **Soil formation**

3.2.I Soil formation within the Continental Terminal

The soil developed in the old Tertiary sediment of "the Continental Terminal" is constituted by deep, red, clayey soils referred to locally as "Terre de Barre". The detailed soil description as well as analytical data are given in Appendix B. These soils are characterised by :-

a) A deep homogenous soil profile.
b) The texture of the top soil is loamy sand to sandy loam, with no clay skins.
c) The texture of the lower horizon is clay; clay skins are present.
d) A well drained profile with good permeability to air and water with high infiltration rate.
e) The base saturation is low in the B horizon (33-43%).
f) The organic matter content of the profile examined which was kept fallow

for a period of I5 years is 4% within the first 20cm and decreases up to I.2% at 60 cm depth.

Remarks: Two major soil formations are distinguished in the "Terre de Barre" :-

Degraded "Terre de Barre" are soils brought under continuous cultivation by shortening considerably the fallow period. The crop yields in these soils are low. Deficiency of nitrogen is common. No response was observed for phosphorus and potassium.

Non-degraded "Terre de Barre": These soils are found in areas where fallow period is longer. The productivity of these soils is high and the deficiency in N.P.K. is usually not observed in the farmers' field. Response to fertilizer is not significant. No response to nitrogen and phosphate was experienced by IRAT for maize. Under normal soil management the yield per ha obtained without fertilizer is 50 t/ha for maize and 30 t/ha for manioc.

Limitation

The annual rainfall in the area being only 800 mm, the main limiting factor is high infiltration rate in the top soil.

Classification - French classification is in use in Togo at national level

- "Sol ferrallitique moyennement désaturé typique appauvri" (Togo and French)
- Humic Nitosols (FAO)
- Savannah Ochrosol - concretionary phase (Ghana)
- Rhodic Paleustalf (USDA)

3.2.2 Soils formed over the Precambrian Plateaux

3.2.2.I Kpoglo series

This soil series is found under magmatites issued from gneiss. They cover extensive areas in the transitional zone separating the Tertiary sediment from the Precambrian formations. Detailed description and analytical data of the soil profile is given in Appendix B.

The main characteristics of these soils are :-

a) Presence of a stone-line at about 55 to 60 cm depth in the profile.
b) The texture of the soil above the stone-line is silty clay to clay; presence of weatherable materials.
c) The soil below the stone-line shows evidence of clay skin, the texture is clay. Deeply weathered rocks are found from 80 to I00 cm.
d) The organic matter content is around 3 to 2% up to a depth of 50 cm.

These soils are presently used for food crops (maize, cassava). In general the yield obtained by the farmers is better than in the "Terre de Barre".

Limitation

The main limitation is the heavy texture due to the vertic characteristic of the soils.

Classification

- "Sols bruns à tendance vertique" (Togo and French)
- Humic Cambisols, petric phase (FAO)
- Tropical brown earth (Ghana)
- Vertic Ustropept (USDA)

3.2.2.2 Nuatja series

The detailed description of this series and the analytical data is given in Appendix B. The soil is characterised by an iron pan found at a depth of I00 to I20 cm overlying a rock formation developed from the Chra embroschistes group.

The following are the characteristics of the soils found usually on a flat topography :-

a) The top soil is sandy to sandy loam; the organic matter content is around 4% on the topmost layer and I.8% below;
b) The argillic B horizon is silty clay;
c) Plinthite is found from a depth of 50 cm;
d) A compact and hard ironpan layer is found at I20 cm;
e) Evidence of hydromorphism is found from 50 cm; its influence is observed up to the top horizon.

This soil series covers extensive area around Nuatja; it is used mainly for food crops (maize, cassava, yam) and also for cotton and banana cultivation.

Limitation

The main limitation is the depth of the soil and hydromorphy. Water control may be necessary under sustained and rational use of the land for crop production.

Classification

- "Sols ferrugineux tropicaux hydromorphes lessivés à cuirasse" (Togo and French)
- Ferric Acrisols, petroferric phase (FAO)
- Regosolic ground water laterite (Ghana)
- Plinthustalf (USDA)

3.2.2.3 East Mono series

East Mono series is developed from orthogneissic formation constituted by biotitite and amphiboles. It is a moderately deep vertisol. The main characteristics of these soils are :-

a) the top soil (up to a depth of I5 to 20 cm) is loam;
b) the texture of the sub-soil is silty clay;
c) deeply weathered rock formations are observed from 75 to 90 cm depth.

These soils are mainly cultivated to cotton, maize and rice. Under traditional cultivation such soils are cultivated by raising small conical heaps which facilitate their management during dry and wet season. The yield of cotton mono (Barbadense) is 400 kg/ha, while Allen variety (g. hirsutum) yield 850 kg/ha in farmers fields. Under proper management yield of I000 kg/ha has been obtained at the Cotton Research Station (IRCT) at Kolokope.

Limitation

Common physical limitations known for vertisols* are applicable for these soils.
Depth may be a limiting factor in certain cases particularly for tree plantation.

Classification

- "Vertisol à drainage externe réduit - modal" (Togo and French)
- Pellic Vertisols (F.A.O)
- Tropical black clay (Ghana)
- Pellustert (USDA)

3.2.3. Foot hill soil formation between Atakpame and Palime

3.2.3.I Hiheatro series

Hiheatro series is a colluvial soil derived from quartzite. The main characteristics of this soil are :-

a) An A horizon of 20 to 30 cm depth with sandy loam to sandy clay loam texture.
b) An argillic B horizon.
c) A thick stony layer with many angular boulders.
d) Plinthite is observed at the contact of B horizon and the stony layers at a depth of I00 to I20 cm.

These soils are found mostly in piedmont position between 250 to 350 cm contours sometimes very deep, they are mostly used for food crops, occasionally for coffee and cocoa.

Limitation

- The main limitation may be the depth of the soil.
- The percentage of gravel and pebbles on the surface soil
- Erodibility.

Classification

- "Sols ferrallitiques moyennement désaturés, remaniés,- modaux" (Togo and French)
- Humic Acrisols (FAO)
- Forest Ochrosol (Ghana)
- Rhodustult (USDA)

3.2.3.2 Koutoukpa series

Koutoukpa series is a colluvium derived from quartzite and schites; it has almost the same main characteristics as the previous soil, Hiheatro series. However, this soil is more evoluted than Hiheatro series and hence has a lower fertility status.

The limitations are the same as mentioned for Hiheatro series.

3.2.3.3 Adeta series

Adeta series is a colluvial soil overlying a deep weathered micaschist formation. Its main characteristics are :-

a) A sandy loam top-soil with few quartz gravel and containing about 2 to 3% of organic matter.
b) Sub-soil horizon with a sandy-clay loam texture but with numerous gravel and pebbles (50 to 70% by volume) and an argillic B horizon.
c) C horizon deeply weathered.

Limitation

The main limitation of these soils is the high percentage of gravel.

Classification

"Sol Ferrallitique faiblement désaturé, appauvri"	(Togo and French)
Orthic Luvisols, petric phase	(F.A.O)
Forest Ochrosol, concretionary phase	(Ghana)

3.2.3.4 Tove series

Tove series is a colluvial soil formation with concretionary horizons at 50 cm depth. Its main characteristics are :-

a) An A horizon rich in organic matter (10%) with many quartz gravels.
b) A sub-soil horizon containing numerous gravels and pebbles (50 to 70% by volume)
c) A compact concretionary layer found at 50 to 60 cm depth.

The soil is mainly developed under forest. Cocoa is sometimes grown in this area.

Limitation

The main limitation for crop production may be the gravel content.

Classification

"Sol ferrallitique moyennement désaturé, humifère, remanié, induré"	(Togo and French)
Humic Lithosols, petric and petroferric phases	(F.A.O)
Forest Ochrosol, concretionary phase	(Ghana)
Paleudult	(USDA)

3.2.3.5 Agou series

Agou series is developed over gneissic formation in the transitional zone between biotite gneiss and heterogeneous basic rocks varying from feldspathic amphibolites to pyroxene. Agou series is deep, uniform and well drained red soil. It is characterized by :-

a) A sandy clay loam A horizon relatively rich in organic matter (4.5%) with much quartz gravel.
b) An argillic B horizon with a very good structure and shiny peds. The texture of the B horizon is generally clay. The gravel content decreases with depth.

The soil is mainly cultivated for food crops and coffee.

Limitation

- The main limitating factor to cultivation is a high percentage of quartz pebbles within the top soil.
- Susceptibility to erosion when not covered by vegetation.

Classification

- "Sol ferrallitique moyennement désaturé, remanié"	(Togo and French)
- Dystric Nitosols	(F.A.O)
- Forest Ochrosol	(Ghana)
- Paleudult	(USDA)

3.2.3.6 Gadjawoukpe series

Gadjawoukpe series is formed within the biotite gneiss area. It is a humic soil,moderately deep, overlying a compact ironpan. It is characterized by :

a) A thick clay loam mollic A horizon, with high base saturation (70 meq %) and base exchange capacity (30 to 25 meq %).
b) A textural B horizon with few iron concretions on the top which decrease with depth; iron concretions are found from 50 cm depth downwards.
c) The layer immediately above the iron pan is concretionary with plinthite.
d) A compact concretionary iron pan.

This soil is fertile and is mainly under cocoa trees.

Limitation

In spite of the relatively high inherent fertility status of Gadjawoukpe series, the main limitation would be the depth at which the ironpan layer occurs.

Classification

- "Sol brunifié, intergrade vers les sols ferrallitiques"	(Togo and French)
- Humic Nitosols	(F.A.O)
- Forest brunosol-ochrosol intergrade	(Ghana)
- Tropidalf	(USDA)

3.2.3.7 Avetonou series

Avetonou series is found in biotite gneiss area. It is constituted by a sandy deposit overlying a hard iron pan underlain by deeply weathered quartzitic micaschists. It is characterized by :

a) A sandy A horizon relatively rich in organic matter (4.2%)
b) A homogeneous sandy B horizon up to a depth of 80 to 100 cm.
c) A thick (60 to 80 cm) iron pan concretionary layer.
d) Deeply weathered rock (quartzitic micaschists).

The origin and the genetic formation of the pan layer is not known.

Remnants of old pieces of earthen pots have been found in the B horizon.

These soils are saturated with water for 3 to 4 months of a year.

Limitation

- Water-logging for 3 to 4 months in a year and lacking moisture during the dry season.
- Low fertility
- Depth of the soil

Classification

- "Sol ferrugineux tropical très lessivé à cuirasse"	(Togo and French)
- Cambic Arenosols, petroferric phase	(F.A.O)
- Savanah ochrosol/ground water laterite intergrade	(Ghana)
- Eutropept	(USDA)

3.2.4 Soils formed at the contact between the Tertiary deposit (Terre de barre) and the Precambrian plateau

These soils are characterised by the following succession of heterogeneous horizons of variable thickness :-

a) Sandy loam to sandy soil layer varying from 10 cm to 60 cm in thickness.
b) A concretionary layer of variable thickness, friable to compact and hard.
c) Ferruginous sandstone boulders embeded in a clayey matrix of variable colours
d) Deeply weathered rock formation, compact, impermeable.

Limitation

The main limiting factor is the depth of the soil.

Classification

- "Sol ferrallitique moyennement désaturé, remanié sur continental terminal"	(Togo and French)
- Savanah ochrosol (concretionary and iron pan phases)	(Ghana)
- Ferric Luvisols, petric phase	(F.A.O)
- Paleustalf	(USDA)

3.3 Summary of Field Discussions in Togo

3.3.I Difficulty to classify polyphased soils

Many of the soils encountered in the Precambrian area were not necessarily derived from the underlying parent material. This is often evidenced in the profile by the presence of a thick stone-line or layer of iron pan separating the upper soil formation from the lower rock formation. The problem of soil classification arises often, when the upper soil layer horizon is thin (IO or 30 cm at the most). In the French classification provision is made at the sub-group level under the denomination of "sol remanié". Such provision does not exist either in the FAO or USDA systems. In case of the FAO classification if one considers the upper soil formation one may classify it as an Acrisol or Luvisol, for example, whereas the horizon below the stone layer can be a Cambisol.

3.3.2 Iron pan: It was often not possible to explain the origin and genetic formation of the iron pan under the prevailing ecological condition.

3.3.3. Transition zone between "Terre de barre" and the Precambrian Plateau

It was observed that the transition zone between the "terre de barre" and the Precambrian Plateau is very similar in Togo and the Ivory Coast, i.e. same distribution of horizons and particularly the same type of sandstone boulders. However, in the Ivory Coast the upper soil layer is thick and constitutes the Tertiary Sand formation.

3.3.4 Soil series as defined in Togo

Soil series is a group of soils derived from the same parent material under the same pedogenetic process and having a similar soil horizon in the first upper 60 cm.

3.3.5 Relation between landform and soils in Togo

During the field tour in Togo different soil formations were observed in two major land form areas :

I) on "terre de barre"

2) on the Precambrian basement.

The land form in "terre de barre" is slightly dissected. The valleys are not deep; the shapes of the slopes are almost straight or very slightly convex. These features indicate that the landform has reached a certain equilibrium. However, if one considers the dynamics of the surface soils, one can notice an intensive process of run-off which favours soil erosion and in the degradation of the top soil layer. This has been observed on the "terre de barre" of Togo and Dahomey.

The geomorphic unit coming under the "terre de barre" is an extensive erosion surface sloping towards the sea.

The processes of dissection of the landform in the granite-gneiss formation are similar to the ones prevailing in the **"terre de barre". However,** valleys here are deep and the slopes strongly convex.

Two important soil forming processes are prevailing in this zone :

1) the process of "remaniement"

2) the internal lateral water movement in the soil profile designated by the French geographers as a "hypodermic run-off". This run off has a great genetic influence on the "sol ferrugineux".

4. SUMMARY OF THE FINAL DISCUSSIONS HELD AT ACCRA AT THE END OF THE FIELD CORRELATION TOURS

4.I Need for a standardized approach for characterizing and classifying soils in the region

Technical discussions during the first day meeting at Accra and soil correlation tours in Ghana and Togo brought out the following facts.

4.I.I Definitions and terminology used for characterising and classifying soils in the field and in the laboratory vary not only from country to country but also within a country. Therefore, the need was recognised by all members to adopt common terminology and definitions for characterizing and classifying soils in the sub-region.

4.1.2 For implementing the recommendation No.5 (see Appendix C) made at the Kumasi Soil Seminar the following working procedure which was to be adopted by the various Soil Institutions in the sub-region was agreed upon by the Delegates for initiating work on soil correlation at national and regional level :-

a) Describe soil as per the FAO Guidelines.
b) Classify soil by giving side by side the national system and its equivalent within the FAO/UNESCO system of classification.
c) Characterize soil by using internationally recognised procedure of soil analysis, or describe fully the methodology followed for soil analysis. It was agreed that the FAO Soil Bulletin No. IO entitled "Physical and Chemical methods of Soil and Water Analysis" could be advantageously used as a reference Book.

In this connection, the Representative of IRAT recalled that the standardized terminology as used by the French Soil Scientists has been described in the publication entitled "Glossaire Pédologique pour la Description des Profils"; this publication was introduced by Prof. Aubert at the Kumasi Soil Seminar. He also informed the meeting that correlation between the terminology used in the above publication and the FAO Guidelines for Soil Description was being established by the French Scientists at IRAT.

4.I.3 The need to assess the various methods of soil analysis used in the different soil institutions working in the region was stressed. It was suggested that the sub-committee through its secretariat should collect such information and make an estimate of the best method. In this connection, it was also suggested that the same soil sample could be sent to various institutions in the region, and the analytical results obtained compared.

The ORSTOM Representative informed the meeting that work on standardization of analytical methods has been carried out by its Organization in the region and documents on these subjects could be made available to FAO.

4.2 Need for national and regional soil correlation

It was agreed that essentially, soil correlation should be undertaken or re-inforced at national level before initiating it on regional level. This is particularly the case in Nigeria where soil survey and studies are carried out by a number of organizations and universities each using its own system. As accepted at the Soil Seminar at Kumasi (1970), soil correlation at national and regional level is to be undertaken using a common terminology based on the FAO system of soil description and classification.

4.3 Need and scope for developing and improving FAO/UNESCO legend of the World Soil Map for classifying soils in the sub-region

The FAO soil legend for the World Map has been prepared so as to accommodate the world soil formations on a map of the scale 1:5 000 000. It is, therefore, to be expected that modifications will be made when one desires to work with a larger scale. An excellent example is set by the international group of experts working for the compilation of the Soil Map of Europe at the scale of 1:1 000 000 by using the FAO/UNESCO soil legend; this exercise has led them to introduce and define in the above legend new sub-units.

As an outcome of various observations made during the field soil correlation tours in Ghana and Togo, the following suggestions were recommended for consideration with a view to improving the FAO classification so as to accommodate, in an adequate manner, all the soils occuring in the region.

4.3.1. Most of the French "ferrallitique" soils are differentiated under FAO system as Ferralsols or Acrisols or Luvisols in the sub-region. The following remarks were made by the Representative of ORSTOM.

The separation of Ferralsol, Acrisol and Luvisol under tropical conditions is based on the degree of alteration of clay minerals. The main pedogenetic process is the same for these soil groups i.e. ferralitisation; however, the main difference remains in the degree of ferralitisation, which decreases from Ferralsol to Luvisol. Therefore, there is a need in case of tropical soils to introduce the oxic characters of B horizon in the Acrisol and Luvisol. Otherwise by using the present definitions of the FAO soil classification one runs the risk of grouping the Acrisol and Luvisols distinguished in the temperate zone with those of the tropical areas.

4.3.2 Soil scientists using French classification stressed the need to introduce the terminology of pseudo-gley in the FAO system.

4.3.3 It was stressed that definitions of gleyic horizon need to be improved and made more concise. It was also suggested that while characterising hydromorphic soils the water regime in the soil needs to be taken into consideration along with the morphologic aspect of the soil profile. This suggestion falls in line with the decisions reached at the seminar on hydromorphic soils held at Stuttgart in 1971.

4.3.4 It was also felt that there was a need to define how to classify polyphase soils often encountered in the region, particularly when the top soil is not deep. It might be necessary to define to what extent the characteristics of the lower horizon could be taken into consideration for classification together with the top soil layers. A depth limit of 60 cm was tentatively suggested for food crop production; this depth limit should, however, depend upon three main classes of land use; crop, pasture, forest.

4.3.5 It was also stressed that the definition of Nitosols should include the characteristic of soil structure which was one of the diagnostic elements in the field.

4.3.6 Finally, it was agreed that there was the need for more precise definitions for stony and petric phases, as well as the importance of relating the texture of the soils with the percentage by volume of coarse elements (stones, gravels, pebbles).

4.4. Compilation of a regional soil map of West Africa at the scale of 1:1 000 000

It was unanimously agreed that a soil map of West Africa should be compiled by the Committee at the scale of 1:1 000 000 by using the FAO/UNESCO soil legend to test and improve upon the FAO classification system in the Region and assist regional soil correlation.

In order to more effectively achieve the objective of compiling a soil map of West Africa using the FAO legend, it was decided as a start for each national delegate to compile a soil map of his particular country based on the FAO units.

The Representative of ORSTOM has offered to compile a Soil Map of Ivory Coast at the scale of 1:2 000 000 using the FAO/UNESCO soil legend. The result of his work would be communicated to the Sub-Committee as soon as completed.

4.5 Need to integrate soil characteristics with the environment for improving soil correlation

Soil correlation should aim at characterising a soil in an adequate manner so as to know its possibilities and limitations for agricultural use. This could be achieved only through a better understanding of the environment as a whole. Therefore, for achieving the above objectives, a multidisciplinary approach is needed for integrating the morphological aspect of the soil to the pedogenetic process influenced by the environment as a whole ("Bilan morphogenèse-pédogenèse").

4.6 Need to correlate soil characteristics with results of agronomic experiments

The main objectives of soil correlation are :-

a) To improve knowledge on soils so as to understand and predict their limitations and potentialities;

b) To be able to transfer information and results on soil management from one place to another with similar soils and ecological conditions.

It was generally agreed that most of the agronomic experiments carried out on soil fertility or management did not take full account of the soil characteristics. Hence, correlation between soil characteristics and agronomic experiments are inadequate or lacking at present in the sub-region. The need was felt that such work has to be undertaken urgently at national level so as to try to quantify the problems associated with soil management.

The following line of action was adopted by the meeting with a view to initiating work at national level in Ghana, Togo, Nigeria and Senegal:-

1) locate on a map all the agricultural research stations existing in the country and collect information on research projects carried out on soil management in the above stations;

2) review work on soil management and soil fertility at all the Agricultural Research Stations where detailed soil maps exist;

3) correlate soil information with the results of agronomic data.

Progress report in this respect was to be sent by the Members of the Sub-Committee to the Secretariat of the Sub-Committee at the FAO Regional Office and communicate the same to the other Members of the Sub-Committee.

It was observed that a large amount of agronomic data on soil management were available in the other member countries. Therefore, the Secretary of the Sub-Committee was asked to try to obtain such data from the other member countries of the West African sub-region with a view to forwarding copies to the rest of the other countries.

It was decided and agreed upon by the members of the Sub-Committee that the first progress report should be sent to the Secretariat at the FAO Regional Office for Africa by the 1 October 1972.

4.7 Suggestions for improving the field correlation tour in future

Following suggestions were made for improving future field correlation tours:-

I) more time should be given for examination of soil profiles by selecting only few typical and representative soil profiles to be inspected;

2) soil description should contain essential elements referring to diagnostic horizons (clay skins etc.) so that one could be able to make soil correlation from a distance;

3) if possible, representative sites should be selected, based on landforms and ecological units so as to observe soil profile along a topo-sequence; because better soil correlation could be achieved if the soil profile was precisely described and adequately located in its environment;

4) ample provision should be allowed in the time-table for discussing in a meeting or in the field or through other means to be determined, problems related to land management;

5) documents should be forwarded to members well in advance before the meeting.

4.8 Documents to be made available by FAO to the Delegates

In order to assist the National Delegates of the Sub-Committee to classify and describe soils as per the FAO system, the Secretary of the Sub-Committee at the Regional Office for Africa was requested to keep members of the Committee informed of all new developments in the FAO classification; he was also to forward to them the following documents :-

I) Definitions of Soil Units for the Soil Map of the World - i.e. World Soil Resources Report No.33

2) Key to Soil Units for the Soil Map of the World - Dec. AGL/SM/70/2 Sept. 1970

3) Guidelines for Soil Description

4) Physical and Chemical Methods of Soil and Water Analysis, Soils Bulletin No.IO - 1970

5) World Soil Maps of Africa with the legend.

6) Any other FAO documents which may be relevant for soil correlation work at national and regional level.

4.9 Documents introduced by the Representative of IRAT

The following documents were introduced by the IRAT Representative at the meeting :-

I) "Glossaire de Pédologie - Description de l'environnement en vue du traitement informatique". Published in I97I by the Association of Informatic and Biosphere - Paris.

2) Soil Surveys and Assessment of Land Use Capabilities - IRAT.

TERMS OF REFERENCE OF THE SUB-COMMITTEE ON SOIL CORRELATION FOR WEST AFRICA

1. Background information

In the light of recommendation No.5 made at the FAO Seminar on the Evaluation of the Soil Resources in West Africa (see Appendix D) at Kumasi, FAO through its Regional Office for Africa has set up in close consultation and collaboration with Member Countries in the Sub-Region, a Soil Correlation Committee for West Africa. As the first step, it was thought necessary for FAO to constitute a Sub-Committee, which will through its work lead to the establishment of a fully fledged Soil Correlation Committee for West Africa with the full participation of all Member Countries in the Sub-Region. This Sub-Committee comprises:- a) Senior Soil Scientists nominated by the Governments of four countries in the Sub-Region where national soil institutions exist and b) the FAO Regional Soil Resources Officer for Africa. Member governments of the selected four countries (two French and two from English speaking areas) which nominated their representativeSenior Soil Scientists for this Sub-Committee are the Governments of Ghana, Nigeria, Senegal and Togo.

2. Summary of discussions on the orientation and attribution to be given to the Committee

2.1 Delegates and Observers unanimously recognised and stressed the necessity and usefulness of a permanent Soil Correlation Committee for West Africa, fully supported by Member Governments, which can provide a sub-regional forum for :-

a) exchange of information and experiences;

b) developing standardized methods for soil resources evaluation, management and conservation;

c) making optimal use in the immediate future of the considerable amount of dispersed and uncoordinated information on soils of West Africa, their use and management;

d) pooling expertise and existing knowledge on soils for establishing correlation at national and regional levels with a view to improving on existing knowledge on soils, their characteristics, the interelation with with the environment, and for transferring knowledge on soil management from one region to another having similar ecological condition;

e) promote regional approach for solving, through coordinated research programme, problems on soil evaluation and management.

2.2 The meeting recognised that FAO, through its Regional Office for Africa in Accra should continue to accommodate the Secretariat of the Soil Correlation Sub-Committee for West Africa. The FAO Regional Soil Resources Officer for Africa will continue to act as the Technical Secretary of the Committee.

2.3 The present Sub-Committee through its Secretariat at the FAO Regional Office for Africa should work for the need and benefit of the West African Region until the fully-fledged Soil Correlation Committee for West Africa is convened.

2.4 Delegates and Observers were of the common opinion that this Sub-Committee needs to meet again and function for some time before broadening its scope into a fully-fledged Committee.

2.5 With a view to securing the continuity in its work and particularly for maintaining a certain consistency in the approach of work elaborated in common during the present deliberations, it was strongly suggested by the Delegates that the bilateral and multilateral organizations in the area should be represented as far as possible by the same representatives who attended the first meeting of this Sub-Committee.

3. Terms of reference of the Sub-Committee

The present Soil Correlation Sub-Committee for West Africa with its Secretariat at the FAO Regional Office for Africa and with the Regional Soil Resources Officer as its Technical Secretary will function until a fully fledged Soil Correlation Committee for West Africa is convened under the following terms of reference :-

3.I Encourage collaboration between West African National Soil Scientists and those of multinational and bilateral research organizations for exchange of information and experience.

3.2 To promote the mutual acceptance of standardized soil evaluation methods by using a)FAO Guidelines for soil description and b) the legend of the FAO/UNESCO Soil Map of the World as a system of reference by correlating existing national soil classification with the units of this legend; to translate this aim into positive action, by compiling a soil map of West Africa at the scale of I:I 000 000 with the present knowledge of soils in the region.

3.3 To promote soil correlation at national and regional levels with a view to aiming at a better evaluation and management of soil resources in West Africa.

3.4 To review research work already completed or underway on the evaluation, management and conservation of soils in the West African region with a view to : a) facilitating transfer of information from one region to similar environment and b) determining the extent of additional research that needs to be undertaken in future in this respect.

3.5 To determine and recommend a programme of applied research which is of immediate use to agricultural development programmes at national and regional level on specific problems of soil evaluation, management and conservation.

3.6 Propose possible "bench mark" sites so as to lay the basis for a regional cooperative research programme on soil management with a view to obtaining maximum information on soil technology for improving agricultural production.

3.7 The final aim of the Soil Correlation Sub-Committee for West Africa would be the establishment of a fully fledged Soil Correlation Committee for West Africa which may lead to the constitution of a Soil Evaluation and Management Centre for West Africa, the status and functions of which would be defined by the interested Member Governments.

The above-mentioned objectives can be achieved through :-

a) organisation and coordination of work at national level by each of the National Members of the Sub-Committee.

b) regular periodic reports and correspondence to be submitted by each National Delegate Member of the Sub-Committee to the Technical Secretary of the Sub-Committee at the FAO Regional Office for Africa, Accra, Ghana.

c) the Secretariat of the FAO Regional Office for Africa will keep in close touch with the Member Governments which are not presently represented on the Sub-Committee for: collecting and disseminating information and reporting the work undertaken by the Sub-Committee in the Sub-Region. The Secretariat will also keep the Members of the Sub-Committee informed of the "desirata" of the various Member Countries in the Sub-Region.

d) organization of national soil correlation work by each of the National Delegate Members of the Sub-Committee. With FAO financial assistance for travel, one or two National Members of the Sub-Committee along with the Technical Secretary of the Committee can participate to such correlation work.

e) regular annual regional soil correlation meetings to be planned well in advance.

f) exchange of technical information.

RECOMMENDATIONS

Recommendation No.I: Expression of thanks

The participants of the Sub-Committee Meeting on the Correlation of the Soils of West African Sub-Region :

Convinced that the meeting has provided an opportunity for discussing problems directly related to the Correlation of the Soils of West Africa and their evaluation in terms of their practical utilisation for increased and sustained crop and livestock production;

Record their warm appreciation of the initiative taken by FAO in organizing this important meeting and in providing the means of achieving its objectives;

Request the Director-General of FAO to convey an expression of their deep sense of gratitude: to the Governments of Ghana and Togo for their generosity in acting as hosts to the meeting, to the Governments of Nigeria and Senegal for the keen interest they have shown in the establishment of the Sub-Committee by nominating their respective Delegates along with the above-mentioned Governments; to the Chairman of CSIR of Ghana for the excellent facilities and services provided for the meeting; and to the Directors and staff of the Soil Research Institute of Ghana and Togo for the painstaking preparation made for the follow-up field soil correlation trips in their respective countries; and finally to all those who contributed in diverse ways to the success of the Meeting.

Recommendation No.2

The Meeting

With a view to implementing Recommendation No.5 on international standardisation of soil evaluation methods passed at the FAO Seminar on the Evaluation of the Soil Resources of West Africa - Kumasi (1970)

Being aware of the necessity of correlating soils of the various countries of West Africa, by using the legend of the FAO/UNESCO Soil Map of the World as a system of reference to unify the various systems of soil classification in the sub-region, with a view to drawing from experience within the sub-region and elsewhere in the practical utilisation of existing soils in terms of increased agricultural production;

Noting that in order to achieve this mutual cooperation there should be standardization of existing methods in soil description, analysis and cartography;

Taking into consideration problems encountered during field soil correlation trips within Ghana and Togo which brought into the forefront the apparent lack of standardization in soil classification and evaluation methods

Recommends

A) that the various National Soil Institutions within the West African sub-region and more specifically those belonging to the Member countries represented on the sub-committee should endeavour to :-

I) standardize soil description by using the FAO guidelines.

2) correlate soils at national and regional level and compile national soil maps on a scale of I:I 000 000 utilising the FAO/UNESCO legend of the Soil Map of the World and thereby finding a common basis for the improvement of that system.

3) produce reports on correlation of pedological and agronomic data from existing agricultural stations and indigenous farmers where detailed soil maps or soil data exist, and that, a first progress report should be submitted to the FAO Secretariat by 1 October I972. Such progress reports are to be followed up by three monthly reports which are to be immediately communicated to Member Governments in the Sub-Region by the Secretariat at the FAO Regional Office for Africa.

B) that FAO should

I) continue to maintain the Secretariat of the Sub-Committee at its Regional Office for Africa through the services of the Regional Soil Resources Officer.

2) collect soil on agronomic data from the existing agricultural stations of Member countries in the Sub-Region not represented on the Sub-Committee for the purpose of correlation studies by the Sub-Committee.

3) take necessary steps to extend the activities of the Sub-Committee to include other Member countries of West Africa.

Suggests that the Director-General of FAO consider exploring the possibility of assisting the Sub-Committee or any subsequent Committee on Soil Correlation for West Africa to be set up in executing this important undertaking by at least convening yearly meetings.

CLOSING SESSION

I. In his closing remarks, the Chairman of the First Soil Correlation Sub-Committee Meeting for West Africa summarized the final days' discussions as follows :-

It has been made quite evident that such benefit could be derived from a Regional cooperation and collaboration among Soil Scientists of the Sub-Region, exchange of visits by the Senior Staff of the various National Soil Institutes with a view to reach standardization of methods and terminology; to study each others working methods and to exchange working documents. Such cooperation and collaboration would assist to improve considerably and fastly the knowledge on soils of the sub-region and particularly on their management. In this connection, the language barrier between English and French speaking nationals was stressed and FAO was urged to assist in translating documents.

Recommendations had been made to use the FAO guidelines for soil description in soil surveys undertaken in the Region, as well as the FAO document on the physical and chemical methods for soil and water analysis; to prepare at national level a soil map at the scale of I:I 000 000; to make an effort to correlate soil characteristics with the agronomic field research which has so far been carried out at agricultural research stations and experimental farms, as far as they can be made available; finally that regular three monthly progress reports on the above work should be prepared by the National Delegates starting from 3 October 1972; and that FAO should collect as soon as possible information from countries of the Sub-Region, not represented on the Sub-Committee so far. The results thus collected should be made available to all other Member States in West Africa.

The next meeting of the Sub-Committee on Soil Correlation for West Africa was to be convened by the Secretariat of the Sub-Committee about in a year's time.

2. The Representative of IITA stated that the translation facilities which were about to be arranged at his Institute would be put at the disposal of the Sub-Committee if the appropriate request would be made by the FAO Regional Representative for Africa.

3. At the closing session, Mr. Mensah, Regional Representative for Africa expressed satisfaction on the FAO Director-General's behalf with the results reached at the Sub-Committee's meeting, which was to a large extent due to the collaboration of the Governments of Ghana, Nigeria, Togo and Senegal, the assistance provided by the Governments of Ghana and Togo, for hosting the Meeting to the very efficient organization made by the National Delegates of Ghana and Togo, and the excellent team spirit which had animated this Working Group. Considering this and the fact that constructive contributions had been made by other Soil Scientists from technical aid agencies like Overseas Development Adminstration, I.I.T.A., I.R.A.T. and ORSTOM, he felt that the experience here obtained, might serve as a model for similar such meetings in their disciplines, since ample opportunity was thus provided for technical in-depth discussions by thoroughly knowledgeable participants as a contrast to what could usually be accomplished at large conferences endeavouring to cover the entire continent. He assured the meeting that FAO would make every effort to give the Sub-Committee all possible support to enable it to function effectively and serve the needs of the sub-region as a whole and congratulated the meeting on its substantial achievement, making room for future sub-regional specific activities through its recommendations.

4. Dr. H. Obeng, the Chairman of the First Sub-Committee Meeting on Soil Correlation for West Africa in his closing speech thanked the Director-General of FAO and the Regional Representative for Africa for convening the meeting and wished that the Programme of Work set up by the Sub-Committee would be successfully continued to the benefit of the entire West African Region. He also thanked all the Members of the Sub-Committee and the Observers for their collaboration and participation and particularly for the excellent team spirit which prevailed from the beginning until the end of the Meeting and which enabled a considerable amount of constructive work within a short period of time to be achieved.

APPENDIX A

ADDRESSES PRESENTED AT THE OPENING SESSION IN ACCRA AND WELCOME ADDRESS IN TOGO

1. Welcome address by Dr. M. Dowuona, Chairman, CSIR (Ghana)

It was with great pleasure that I accepted the invitation to welcome, on behalf of the C.S.I.R. and the Government of Ghana, the delegates to this meeting sponsored by FAO. Ghana is honoured and happy to be given the opportunity of playing host in less than two years to a second meeting concerned with soil problems, and the C.S.I.R. is delighted to be able to provide a suitable meeting place.

I had the honour to be Chairman at the opening ceremony of the FAO Regional Seminar on the Evaluation of Soil Resources in West Africa held in Kumasi in December 1970. On that occasion, in my introductory remarks, I described very briefly the development of soil survey work in Ghana and stressed the importance of modern soil survey methods and techniques for evaluating soils in developing countries, particularly for the purposes of agricultural development. I also stated as a warning to other countries that in Ghana many agricultural projects in the past had come to grief, owing to the failure or reluctance on the part of the Government at that time to make proper use of the available knowledge in the field of soil science, in determining what the nature and scope of the projects should be.

This meeting, I understand, is one of the direct results of the Kumasi Seminar, because it was at that Seminar that it was recommended "that soil survey organizations throughout West Africa should actively encourage mutual acceptance of standardized techniques and, in particular, should adopt the legend of the FAO/UNESCO Soil Map of the World, as a system of reference to unify the cartography of soils in West Africa, correlating soils classified in existing national systems of soil classification with the units of this legend! ".

It is most gratifying that this recommendation has been given speedy consideration by the Director-General of the FAO, and that in fact, a correlator, in the person of Dr. Mouttapa, has already been appointed and is at post and present at this meeting. I take this opportunity to congratulate the Director-General of FAO for the speed with which he has implemented this very important recommendation.

The present meeting is really a Sub-Committee, comprising representatives of four West African countries - two English-speaking and two French-speaking - which has been charged with the responsibility of discussing certain important technical matters relating to the problem of soil correlation in West Africa. The successful completion of this assignment will constitute an important step in the programme of achieving some standardization in the description, classification and evaluation of the soils of West Africa.

The universality of Science rests on the fact that science does not only deal by means of an established methodology with nature and natural phenomenon, which are universal, but it also uses to a large extent a common vocabulary. The more precise the vocabulary of a particular scientific discipline is, the easier it is for scientists of different nationalities to understand each other and work together. In this connection, perhaps the vocabulary of mathematics is par excellence the most precise.

We all - scientists and others alike - are forced by political realities to work within our countries and states, whose boundaries do not coincide with those of the 'natural regions' of the Earth. Although this problem appears more acute in Africa, it is in fact a universal problem. Very rarely do political boundaries coincide with natural physical boundaries of 'natural regions' in every respect. This is so because the forces which have created the political states existing today, are different from those which gave birth to the 'natural regions' of the Earth.

In regard to the soil - the natural resource in which this meeting is particularly interested - this lack of coincidence of state boundaries and those of 'natural regions', is very noticeable. The composition of the original rock formations, the weather and other climatic elements, the rivers and other forces, which have all contributed to the composition and distribution of the soils of West Africa, operated and continue to operate over areas which **do not correspond to** the existing boundaries of the political states of the area. So in the interest of the proper development of scientific knowledge of the area, scientists working in one country must know and work with scientists working in similar fields in, at least, the adjoining territories. In this context, the value of standardization of terminology and techniques could not be denied. It is most important, therefore, that the work of this Sub-Committee should be successful as it will clear the way for the real exercise in determining common criteria for differentiating one type of soil from another, thus providing the basis for common classification and ultimate correlation of the soils of the area. Without some agreement in this respect, scientists from different but contiguous countries might find themselves at cross purposes when dealing with identical soil specimens, while this need not be the case.

The work of the Sub-Committee and in fact of the main Committee is also meant to be related to a world-wide scheme - that is, units of the FAO/UNESCO legend. The wider the scope of standardization, the more the scientists from areas outside West Africa will have a better idea of the relationship of the types of soils which exist in other regions. Clearly within the broad descriptions which may be arrived at, as our knowledge increases more and more groups and sub-groups will be identified. To use an analogy from language itself there will be the main language itself first, to be followed by as many dialects as can be identified later.

All will agree that the soil is basic to all development. Underneath it are the natural minerals, it is the medium for growing the food which mankind needs to feed itself, and it is the firm base on which shelter is provided. Therefore, the more comprehensive and detailed our knowledge of the soil, the better we will be equipped to deal with the problems of living on the Earth and of our economic development generally. I am not here to tell you the importance of soil science which must begin with reliable and valid soil survey and classification in each State. Indeed I should think you the experts in this field are eager to tell everybody else that your field of study is the most important of all the sciences. That may be so. I grant, however, that soil science is very important and should be vigorously pursued and no more.

I have already emphasised the need for scientists working the discipline of soil science in West Africa to develop a common vocabulary in the interests of science itself. There is another reason for them to do this; it is to further the much publicised objective of wider economic groupings **not** only in West Africa but in the whole continent. In this connection I venture to say that no wider groupings can be soundly based without proper knowledge and understanding of the types of soils - these being perhaps the most important composite resource available. There should be, therefore, general agreement on what is meant by designating a specimen of soil as of this or that type.

In the scientific and indeed in all spheres of knowledge, national associations must enlarge their horizon by co-operating effectively with other national associations in corresponding fields in the West African Region. This, in my view, is the only way of laying a sure and sound foundation for the wider community which most progressive people hanker after.

As I said at the beginning I came here to welcome you both on behalf of the CSIR and the Ghana Government; so I must resist the temptation of talking along about some of the matters which your meeting has caused me to reflect upon. I would end, therefore, by reiterating the welcome extended to you at the beginning, and by wishing you a successful and rewarding meeting, and a happy stay in Ghana.

2. Address by Mr. Moïse C. Mensah, Assistant Director-General and FAO Regional Representative for Africa

Distinguished delegates,

It is both an honour and a pleasure to me on behalf of FAO to welcome you to this first meeting of the Soil Correlation Sub-Committee for West Africa. Your presence in force here today bears in no small measure witness to the most encouraging interest shown in this undertaking by our member Governments and sister technical assistance organizations alike.

2. In particular, I would like to thank the Chairman of the Council for Scientific and Industrial Research of Ghana who has been so kind to open this meeting and has placed the excellent facilities of the Council at our disposal. Many thanks are also due to the directors and scientists of the Soil Research Institute at Kwadaso and the "Institut Polyvalent de Recherche, Division des études pédologiques" in Lomé for arranging this most essential part of your programme : the work to be undertaken in the field.

3. I would now like to say a few words on the subject which is of much concern to all of us here today : soil correlation at both national and regional level in West Africa, for planning agricultural research and development programmes as well as for the best utilization and conservation of our soils. But permit me first to call to mind an earlier gathering of soil scientists: the FAO Seminar on the Evaluation of Soil Resources in West Africa held at Kumasi in December 1970. Those of you who, at the time, attended as delegates will recall that one of the seminar's main recommendations stressed the importance of international standardization in soil classification and survey methods. More in particular, it was stressed that soil survey organizations throughout West Africa, should actively encourage mutual acceptance of standardized methodology, techniques

and terminology to be used in their soil evaluation programmes. The legend of the FAO/UNESCO Soil Map of the World, furthermore, was recommended for use as a system of reference to unify the cartography of soils in West Africa and to correlate soils classified in existing national systems of soil classification with units of this legend. To further this aim, it was suggested that the Director-General of the Food and Agriculture Organization appoint a soil correlator to the FAO Regional Office in Africa to work in collaboration with national correlators. Dr. Mouttapa has now been assigned among others to that task since June 1971 as Regional Soil Resources Officer. However, meaningful results in that sense can only be obtained through a concerted approach by all soil specialists working in the region.

4. Similar views and calls for closer national and regional cooperation have recently been heard at the FAO Seminar on Cooperative Agricultural Research in the Guinean Zone as well as at the Seminar on Tropical Soil Research held under the auspices of the Ford Foundation, I.R.A.T. and I.I.T.A. Time has now come to translate these recommendations and resolutions into practical action "on the ground".

5. A Soil Correlation Committee for West AFrica, we at FAO feel, could stimulate this much needed cooperation. It being understood, works to be undertaken at regional or sub-regional levels should, at all times ensure full support at the national level. In an initial stage, therefore, we have thought it opportune to first constitute and convene the present sub-committee which unites Soil Scientists with long time experience at the national soil institutes of their home countries.

6. It will not be imprudent to say that today we have made that important first step and we are most grateful for the confidence given by our Member Governments and the interest accorded to these efforts by you, soil scientists, who are delegates and guest here today. We highly appreciate the presence of specialists from IRAT, ORSTOM, of the British Overseas Development Agency and the IITA. Their wide experience on this continent and beyond will certainly prove of great value in your deliberations.

7. Returning now to the order of the day, I believe we should keep the following foremost in mind. The main purpose of this first sub-committee meeting is meant to lay the foundation for the fully-fledged West African Soil Correlation Committee. In the first instance, therefore, I would suggest your discussions centre around identifying those aspects of your work which most obviously allow for such collaboration and to find practical ways and means for the establishment of regular working relationships, to tackle them.

8. You will agree with me, I am sure, that one first priority would be to concentrate on making optimal use of the considerable amount of information on the West African soils, their evaluation and management, already collected by scientists in the Region during past decades. Expertise now should be pooled to correlate soil at national and regional levels so as to enable transfer of knowledge on their management fron one site to another.

9. Provision, however, should also be made at this stage to broaden the scope of the Committee by introducing in its programme of work matters relating to soil evaluation and management, for, without the inclusion of these two aspects work on soil correlation may become a theorotical exercise. Soil correlation in the region should aim for a better understanding, planning, management and

conservation of our potential soil resources. Emphasis should, therefore, be laid on the use which can be made of the soil data by those who are concerned with agricultural development in the field. Numerous questions as to how these soils should best be managed and what conservation measures will prove most effective remain to be answered. I have found it most appropriate that your programme of work provides considerable technical discussions in the field both in Ghana and Togo in order that the attention can be paid to finding solutions which are relevant to the specific African environment.

10. The success of your efforts at the start will decisively provide the basis for a viable West African Soil Correlation Committee in the future. A thoroughly critical look at its possible functions, structure and organization at this very early stage cannot be stressed too much. It is hoped that other steps will follow soon, which if judiciously planned, can contribute substantially to solve problems of great importance to the agricultural and economic development of Africa and which may set an example for similar undertakings in the East and Central African Region.

11. In the final analysis the outcome will depend on collegate and professional understanding and fruitful working relations. I am confident that the coming week will provide you with an excellent opportunity to further strengthen these ties. Distinguished delegates and guests, I wish this first meeting of the Soil Correlation Sub-Committee for West Africa as well as your excursions in the field a complete success.

3. Welcome address by Mr. P. Nahm Tchougli, Chief of Cabinet of the Ministry of Rural Economy - Togo

Distinguished delegates, ladies and gentlemen,

It is a great pleasure to me, on behalf of the Ministry of Rural Economy and, on my personal behalf, to welcome you all to Togo.

Since few years, Togo has become the cross road of many international and regional conferences due to realistic policy of our Government, the economic stability of our country, and more particularly due to the leadership of our dynamic Head of State, General Etienne Eyadema.

Today, we are deeply honoured and really very proud to receive you among us in Togo. The Government of Togo, by accepting to host the First Meeting of the Soil Correlation Committee for West Africa organized by FAO, wanted to emphasise its main preoccupation to promote: the cooperation between Nations, the development of rural population, the war against under-development aiming at putting an end to malnutrition, famine, rural exodus, diseases.

In fact, in the present days of social and political changes, an agricultural revolution is a must. It is all the more necessary since it gives to mankind the possibility to seek solutions to satisfy the demands of increasing growth of population. Soil Science, in this revolution, occupies an important place, since it is the key factor for crop production. In Africa and more particularly in Togo, soil science is just at its initial stage; it has to face many difficulties; therefore, it has to be strongly supported from every corner. That is why, we highly appreciate the continuous services rendered by the FAO of the United Nations in this field through moral support, technical assistance of Experts and supply of equipment.

The study of soils is still relatively a young, but complex science, its development can be achieved only through a concerted effort of many nations. Particularly, our agricultural development problems are similar to those of many other developing countries; solutions for solving these problems would be much easier if we are pooling together our resources in scientific and technical know-hows. Exchange of knowledge among us can greatly assist in finding rapidly solutions to our many common problems. International and intra-regional collaboration are fundamental for young States like ours. This being, one can now understand the usefulness of this Regional Meeting on Soil Correlation for West Africa; we can only commend the initiative in this respect taken by FAO, which in fact strengthens the fraternal ties as well as the collaboration already existing between Togo and its immediate or far off neighbours. However, there is always a large gap between what one wishes to do and what is practically achieved; and we are aware that inspite of our strong desire, there is a long way to go towards the road of Unity. Every stone put up in building the edifice of our Unity would be highly appreciated and this Committee meeting has contributed to add one more stone to this building.

We are fully aware of the amount of work necessitated in the preparation of this meeting. And that is the reason why I would like with your kind permission, to pay tribute to all who have come from near or far contributed to the preparation and the success of this first Committee Meeting; my gratitude goes more specifically to the FAO Regional Office for Africa and its Experts, to the Soil Research Institute of Ghana and to our National Soil Science Institute.

Before wishing you a happy stay in Togo, I would like to call upon you to keep always in mind during your deliberations, the urgent needs of the farmers who have to make a decent living from the soils.

APPENDIX B

DESCRIPTION OF SOIL PROFILES EXAMINED DURING THE SOIL CORRELATION FIELD TOURS IN GHANA AND TOGO

1. Descriptions and analytical data of soil profiles examined in Ghana

1.1 Kumasi Series

Classification:
- Forest Ochrosol (Ghana)
- Dystric Nitosols, petric phase (FAO)
- "Sol Ferrallitique fortement désaturé, remanié, modal" (French)
- Typic Paleudult (USDA)

Parent material: Residual loam derived from decomposed granite.

Topo site : Upper slope
Slope : 3%
Drainage : Well drained
Altitude : 249 m (830 ft.)
Vegetation: Moist deciduous forest
Rainfall : 1473 mm (58 inches)

Horizon	Depth (cm)	Description
A11	0 - 7	Dark reddish brown (5YR 3/2) sandy clay loam coarse and fine granular;friable; many fine and medium rocks; pH 4.4; abrupt wavy boundary.
A12	7-11	Dark reddish brown (5YR 3/3) sandy loam; weak fine granular friable; many fine roots; pH 4.6; clear wavy boundary.
A13	11-18	Yellowish red (5YR 4/6) sandy loam; massive; firm; few fine ironstone gravel and concretions (about 5% by volume); common fine roots; pH 4.5; clear wavy boundary.
B21	18-23	Yellowish red (5 YR 4/6) gravelly clay loam; massive; firm common ironstone gravel and Fe concretions (about 25% by volume); pH 4.5; clear wavy boundary.
B22	23-46	Red (2.5YR 4/8) gravelly clay; massive; firm; few fine roots; common ironstone gravel and concretions (about 25% by volume); pH 4.9; clear wavy boundary.
B23	46-70	Red (2.5YR 4/8) gravelly clay; massive; firm; few fine roots; many ironstone gravel and concretions (about 35% by volume); pH 4.9; clear wavy boundary.
B24	70-87	Red (2.5YR 4/8) gravelly clay; massive; firm; common ironstone gravel and Fe concretions (about 25% by volume); pH 5.0; clear smooth boundary.
B25	87-114	Red (2.5YR 5/6) gravelly clay; massive; firm; common ironstone gravel and concretions (about 30% by volume); pH 5.1; clear smooth boundary.
B26	114-151	Red (10 R 4/6) gravelly clay with common fine faint yellowish red (5YR 5/6) mottles; massive; friable; common ironstone gravel (about 25% by volume) white mica specks; pH 5.2; clear wavy boundary.
B27	151-201	Red (2.5YR 4/8) gritty clay with common fine distinct yellowish red (5YR 5/8) mottles; massive; firm; few ironstone gravel (less than 5% by volume); pH 5.2; clear irregular boundary.
C1	201-238	Red (10R 4/6) sandy clay; massive; friable; many specks of white mica; pH 5.0; gradual smooth boundary.
C2	238-320	Red (7.5R 4/8) sandy loam with few fine faint reddish yellow (7.5YR 6/6) mottles; massive; friable; many specks of white mica; pH 5.1

KUMASI SERIES (DYSTRIC NITOSOLS)

Horizon	Depth (cm)	Particle Size Analysis % Sand (2-0.06)	Silt (0.06-.002)	Clay	pH	Organic Matter (oven dry) C	N	C/N	O.M. %
A11	0-17	59.5	13.1	27.4	4.4	4.65	.291	15.97	8.00
A12	17-27	75.8	8.8	15.4	4.6	1.10	.074	14.86	1.89
A13	27-45	65.6	11.4	25.0	4.5	.63	.051	12.85	1.08
B21	45-57	52.6	13.2	54.2	4.5	.64	.046	13.91	1.10
B22	57-115	43.4	11.5	45.1	4.7	.55	.058	9.50	.95
B23	115-175	38.6	11.4	50.0	4.9	.38	.029	13.1	.65
B24	175-217	38.5	13.5	48.0	4.0	.44	.036	12.2	.76
B25	217-285	36.4	19.2	44.4	5.1	.40	.023	17.4	.69
B26	285-377	38.6	21.4	40.0	5.2	.35	.019	18.42	.60
B27	377-502	24.0	24.0	52.0	5.2	.35	.021	16.66	.60
C1	502-595	53.0	27.0	20.0	5.0	.21	.008	26.2	.36
C2	595-800	55.5	29.8	14.7	5.1	.18	.004	45.0	.34

Horizon	Depth (cm)	Cation Exchange meq % T(CEC)	Ca	Mg	Mn	K	Na	S(TEB)	Base Sat. (S/Tx100)
A11	0-17	12.25	4.29	1.52	.01	.21	.25	6.28	51.3
A12	17-27	3.97	.84	.29	.01	.06	.19	1.39	35.0
A13	27-45	4.07	.51	.14	.001	.84	.20	.90	21.0
B21	45-57	4.56	.35	.31	.001	.65	.31	1.02	22.4
B22	47-115	5.14	.44	.26	.001	.05	.28	1.03	20.0
B23	115-175	4.17	.38	.31	.001	.02	.31	1.02	24.5
B24	175-217	4.83	.56	.21	.001	.01	.25	1.03	21.3
B25	217-285	4.96	.59	.21	.001	.01	.24	1.05	21.2
B26	285-377	4.51	.43	.32	.001	.02	.35	1.12	24.8
B27	377-502	5.25	.45	.37	.001	.01	.35	1.18	22.5
C1	502-595	3.29	.20	.15	.001	.01	.25	.61	18.5
C2	595-800	4.74	.23	.20	.001	.02	.24	.69	18.4

1.2 Bekwai Series

Locality: Kwadaso, C.A.S.

Classification:
- Forest Ochrosol (Ghana)
- Humic Nitosols, Petric phase (FAO)
- "Sol **ferrallitique fortement désaturé**, remanié modal" (French)
- Rhodic paleudult (U.S.D.A.)

Parent material : Residual silt loam derived from decomposed phyllite.

Topo site : Upper
Slope : 2.1/2 to West
Drainage : Well drained
Altitude : 255m (850 ft)
Vegetation : Moist deciduous Forest
Rainfall : 1473mm (58 inches)

Horizon	Depth (cm)	Description
A11	0 - 7	Dusky red (10 R 3/2) clay loam; weak fine and medium granular; very friable; many fine roots; pH 5.2; abrupt wavy boundary.
A12	12 - 27	Dusky red (10 R 3/4) clay loam; moderately medium granular; **friable; many fine and medium roots; pH 5.0; abrupt wavy boundary.**
A13	27 - 45	Dusky red (10 R 3/4) gravelly clay loam; moderate medium granular; friable; common fine gravels and ironstone concretions (about 30% by volume), common fine and few medium roots; pH 4.7; clear smooth boundary.
B21	45 - 60	Dark red (10 R 3/6) very gravelly clay loam; massive; firm; many gravel and ironstone concretions (about 65% by volume); few fine roots; pH 5.5; clear smooth boundary.
B22	60 - 91	Dark red (7.5R 3/6) very gravelly clay; massive; firm; many ironstone concretions and quartz gravel (about 50% by volume), few fine roots; pH 4.8; clear smooth boundary.
B23	91 - 125	Red (7.5R 4/6) gravelly clay; massive; firm; common ironstone concretions and quartz gravel (about 30% by volume), few roots; pH 4.9;clear smooth boundary.
B24	125 - 175	Red (7.5R 4/6) gravelly clay; massive; firm; many fine roots, many gravels(about 35% by volume), quartz vein; pH 5.0; clear smooth boundary.
B25	175 - 220	Red (7.5R 4/6) gravelly clay; massive; firm; few fine roots; common gravel and quartz vein, few ironstones concretions (about 20% by volume); pH 4.9; clear smooth boundary.
B26	220 - 295	Red (10R 4/6) gravelly clay; massive; firm; common gravel and few ironstone concretions (about 20% by volume); pH 5.3; clear smooth boundary.
B27	295 - 397	Red (10R 4/6) clay; weak fine subangular blocky; firm; few gravels(less than 10% by volume); pH 4.9; clear smooth boundary.
B28	397 - 467	Red (10R 4/6) clay; very weak fine subangular blocky; firm, few gravels; pH 5.1; clear smooth boundary.
B29	467 - 490	Red (10R 4/6) clay with common medium distinct brownish yellow (10YR6/6) mottles; very weak fine subangular blocky; firm; pH 4.9; clear smooth boundary.
C1	490 - 674	Red (10R 4/6) silty clay with many coarse distinct light brown (7.5YR 6/4) mottles; massive; firm; pH 5.2; abrupt smooth boundary.
C2	674 - 725	Brown (7.5YR 5/4) silt loam of decomposed phyllite with common medium distinct red (2.5YR 5/6) mottles; massive; friable; pH 5.1.

BEKWAI SERIES (HUMIC NITOSOLS)

Horizon	Depth (cm)	Particle Size Analysis %			pH	Organic Matter (oven dry)			
		Sand (2-0.06)	Silt (0.06-.002)	Clay	1:1	C	N	C/N	O.M.%
A11	0-12	43.3	28.9	27.8	5.2	5.17	.413	12.5	8.89
A12	12-27	43.8	27.6	28.6	5.0	2.76	.238	11.6	4.75
A13	27-45	39.6	27.7	32.7	4.7	1.46	.145	10.1	2.51
B21	45-60	42.0	23.0	35.0	5.5	.69	.065	10.6	1.19
B22	60-91	38.0	18.6	43.4	4.8	.67	.061	10.9	1.15
B23	91-125	27.5	14.7	57.8	4.9	.51	.040	12.8	.88
B24	125-175	25.3	17.5	57.2	5.0	.48	.043	11.2	.83
B25	175-220	24.3	19.5	56.2	4.9	.53	.047	11.3	.91
B26	220-295	26.5	25.0	48.5	5.3	.32	.032	10.1	.55
B27	295-397	16.5	33.0	50.5	4.90	.24	.021	11.4	.41
B28	397-467	11.0	38.5	50.5	5.10	.20	.010	11.1	.34
B29	467-490	12.2	40.0	47.8	4.85	.18	.018	10.0	.31
C1	490-674	10.[illegible]	57.5	42.5	5.20	.11	.011	10.0	.19
C2	674-725	9.0	64.8	26.2	5.10	.03	.006	15.0	.15

Horizon	Depth (cm)	Cation Exchange meq %							
		T(CEC)	Ca	Mg	Mn	K	Na	S(TEB)	Base Sat (S/Tx100)
A11	0-12	20.37	11.85	3.41	.16	.33	.39	16.14	79.2
A12	12-27	13.22	5.34	1.03	.17	.14	.31	6.99	52.9
A13	27-45	9.42	2.56	.54	.13	.09	.28	3.60	38.2
B21	45-60	5.59	3.24	.48	.03	.08	.27	4.10	73.3
B22	60-91	6.17	2.07	.70	.01	.07	.25	3.10	50.2
B23	91-125	7.04	1.52	.41	.001	.06	.27	2.26	32.0
B24	125-175	6.69	.76	.55	.001	.03	.03	1.60	22.9
B25	175-220	6.41	.37	.47	.001	.03	.38	1.25	19.5
B26	220-295	6.09	.31	.41	.001	.03	.28	1.03	16.9
B27	295-397	6.28	.35	.36	.001	.05	.28	1.04	16.6
B28	397-467	5.51			.001	.05	.28	.88	14.7
B29	467-490	6.31	.29	.31	.001		.25	.91	14.4
C1	490-674	4.73	.21	.26	.001	.04	.28	.82	17.3
C2	674-725	3.31	.21	.26	.001	.03	.31	.78	23.6

1.3 Akumadan Series

Locality: Mile 62 Kumasi-Nkwawkaw road
Classification:
- Forest Ochrosol (Ghana)
- Humic Acrisols (FAO)
- "Sol ferrallitique fortement déeaturé typique, modal sur matériel remanié" (French)
- Rhodic Paleudult (U.S.D.A.)

Topo site	: Upper Slope
Slope	: 3%
Drainage	: Well drained
Altitude	: 240m (800 ft)
Vegetation	: Thicket
Rainfall	: 1727 mm (68 inches)

Parent Material : Upland non-concretionary clay drift associated with Birrimian schists and phyllites.

Horizon	Depth (cm)	Description
Ap	0 - 7.6	Dark reddish brown (2.5YR 3/4) humus clay loam; moderate, medium granular structure; friable; abundant medium roots; abrupt, smooth boundary; pH 6.0.
B21	7.6 - 20.3	Dark red (2.5YR 3/6) silty clay; moderately weak, medium subangular blocky structure; slightly firm; frequent fine roots; diffuse, smooth boundary; pH 5.4
B22	20.3 - 48.3	Dark red (10 R 3/6) silty clay; moderate, fine and medium subangular blocky structure; firm; occasional fine roots; diffuse, smooth boundary; pH 4.6.
B23	48.3 -152.4	Dark red (10 R 3/6) silty clay loam; moderate, medium subangular blocky structure; firm; rare fine roots; abrupt, smooth boundary; pH 5.0.
B24	152.4 -198.1	Dark red (10 R 3/6) silty loam; moderately weak, fine subangular blocky structure; firm; very frequent hard and soft ironstone concretions, rare,small angular quartz stones; very rare fine roots; clear, smooth boundary; pH 5.2.
B25	198.1-236.1	Dark red (10 R 3/6) brownish yellow (10YR 6/6) mottled clay loam; extremely firm massive; gradual, smooth boundary; pH 5.4.
B26m	236.1-256.5	Dark red (10 R 3/6) and brownish yellow (10YR 6/6) mottled; ironpan; extremely firm; massive; pH 5.4.

AKUMADAN SERIES (HUMIC ACRISOLS)

HORIZON	DEPTH (cm)	CS 2 - .06	PARTICLE SIZE DISTRIBUTION %						ORGANIC MATTER		pH 1:1	CATION EXCHANGE meq %						
			M.Sand .6 - .2	F.Sand .2 - .06	C.Silt .06 - .02	M.Silt .02-.006	F.Silt .006-.002	Clay	C%	O.M %		T(CEC) NH4	Ca	Mg	Mn	K	Na	S(TEB)
Ap	0-8	3.2	12.7	18.6	12.1	14.4	10.5	28.5	3.17	5.45	4.90	16.77	3.08	1.26	.28	.25	.17	5.07
B21	8-20	2.4	9.0	18.8	9.0	13.8	7.4	39.6	1.18	2.03	4.70	12.43	.81	.33	.23	.10	.13	1.60
B22	20-48	3.1	7.0	14.	8.9	11.8	6.5	48.5	.68	1.17	4.80	9.52	.52	.19	.07	.04	.15	.97
B23	48-152	3.5	8.7	18.0	11.5	14.3	10.2	33.8	.58	1.00	5.10	11.15	.55	.19	.06	.08	.14	1.03
B24	152-198	6.6	9.6	14.0	14.5	13.3	10.5	31.5	.35	.60	5.30	11.20	.42	.11	.04	.06	.12	.75
B25	198-236	13.0	12.3	15.5	13.0	11.6	8.6	26.0	.23	.39	5.40	10.19	.36	.14	.01	.04	.13	.68
B26m	236-265								.19	.33	5.40	8.62	.51	.10	.01	.05	.16	.8

1.4 Juaso Series

Locality : Oil palm plantation
Juaso State Farm.

Classification:
- Forest Ochrosol (Ghana)
- Humic Acrisols, petric phase (FAO)
- "Sol ferrallitique fortement désaturé remanié rajeuni" (French)
- Rhodic paleudult (U.S.D.A.)

Parent material: Secondary over weathered Tarkwaian Schist.

Profile No. B2205

Topo site : Upper slope
Slope : 2.1/2%
Drainage : Well drained
Altitude : 231m (770 ft)
Vegetation : Oil palm plantation
Rainfall : 1651mm (65 inches)

Horizon	Depth (cm)	Description
Ap	0 - 10.2	Dark brown (7.5YR 4/2) sandy loam; weak fine and medium crumb; friable; abundant fine and medium roots; occasional ironstone concretions and quartz gravel; abrupt smooth boundary; pH 5.2.
B1cn	10.2-27.9	Reddish brown (5YR 5/4) sandy loam; massive; slightly firm; plentiful fine roots; frequent ironstone concretions; occasional quartz gravel; clear smooth boundary; pH 5.0.
B21cn	27.9-55.9	Red (2.5YR 4/6) clay; massive; slightly firm; plentiful fine roots; abundant ironstone concretions; frequent quartz gravel, occasional small subangular quartz stones; diffuse smooth boundary; pH 4.8.
B22tcn	55.9-86.4	Red (2.5YR 4/8) clay; massive; slightly firm; abundant ironstone concretions, occasional quartz gravel; clear smooth boundary; pH 4.8.
B23	86.4-114.3	Red (2.5YR 4/8) clay loam with common fine distinct, strong brown (7.5YR 5/6) mottles; very weak fine subangular blocky; firm; rare ironstone concretions and quartz gravel, frequent patches of decomposed rock; clear wavy boundary; pH 4.8.
B3	114.3-162.6	Red (2.5YR 4/8) clay loam with common fine and medium, distinct strong brown (7.5YR 5/6) mottles; very weak fine subangular blocky; firm; rare ironstone concretions and quartz gravel, frequent patches of decomposed rock; clear wavy boundary; pH 5.0.
C1	162.6-213.4	Red (2.5YR 4/6), strong brown (7.5YR 5/6) and yellowish brown (10YR 5/4) mottles sandy clay loam; massive; friable; very frequent patches of decomposed rock; pH 5.0.
C2	213.4-269.2	Decomposed Tarkwaian schists.

JUASO SERIES (HUMIC ACRISOLS)

HORIZON	Depth (cm)	C. Sand 2 - .06	Particle Size Analysis % M.Sand .6-.2	F.Sand .2-.06	C.Silt .06-.02	M.Silt .02-.002	F.Silt .006-.002	CLAY .002	Organic Matter C%	C/N	O.M %		MOISTURE EQUIV.	Cation exchange meq % T(CEC) NH_4	Ca	Mg	Mn	K	Na	S (TEB)	Base Sat. S/T x 100
Ap	0-10	3.9	21.7	35.8	16.2	5.4	3.2	13.8	2.96	11.13	5.09	5.7	16.0	2.13	6.49	2.05	.14	.53	.18	9.39	77.4
B1cn	10-28	8.0	14.8	33.8	15.2	6.2	3.0	19.2	.70	10.29	1.20	5.1	14.3	5.37	1.01	.46	.005	.10	.15	1.72	32.0
B21 cn	28-56	7.3	11.5	19.6	8.6	3.5	3.0	46.5	.66	9.17	1.14	4.9	22.7	9.91	1.22	.62	.005	.15	.15	2.14	21.6
B22 tcn	56-86	9.5	9.7	16.8	6.5	2.8	1.9	52.8	.42	8.24	.72	4.9	24.6	8.84	.88	.41	.005	.14	.16	1.59	18.0
B23	86-114	5.2	10.1	16.4	15.3	8.8	3.4	40.8	.31	7.95	.53	4.9	23.7	8.20	.67	.36	.005	.05	.14	1.22	14.9
B3	114-162	7.1	14.7	19.7	13.0	11.0	6.0	28.5	.14	5.83	.24	5.0	20.4	5.76	.49	.26	.005	.04	.19	.98	17.0
C1	162-213	7.8	21.1	21.1	13.8	10.0	4.2	22.0	.12	6.0	.21	5.2	16.8	4.05	.36	.20	.005	.03	.14	.73	18.0
C2	213-269	2.2	52.5	24.3	11.0	10.0	5.1	6.9	.03	5.0	.05	5.4	11.4	1.13	.24	.10	.005	.02	.09	.45	34.4

1.5 Bompata Series

Locality: 2.1/2 miles along Konongo - Agogo road.

Classification:
- Forest Ochrosol (Ghana)
- Dystric Nitosols (FAO)
-"Sol ferrallitique fortement remanié au niveau de la famille"(French)
- Rhodic Paleudult (U.S.D.A.)

Topo site : Upper slope
Slope : 1%
Drainage : Well drained
Altitude : 270m (900 ft)
Vegetation : Cocoa
Rainfall : 1524mm (60 inches)

Horizon	Depth (cm)	Description
A11	0 - 7.6	Dark reddish brown (5YR 3/4) sandy loam; moderate, fine and medium crumb structure; friable; abundant fine roots; abrupt smooth boundary; pH 5.8.
A12	7.6-20.3	Reddish brown (2.5YR 4/4) sandy loam; very weak fine subangular blocky; slightly firm; plentiful fine and medium roots; gradual smooth boundary; pH 5.7.
B21	20.3-45.7	Dark red (10 R 3/6) clay; weak fine subangular blocky; slighly firm; few fine root; diffuse smooth boundary; pH 5.0.
B22	45.7-147.3	Red (10 R 4/6) clay; weak fine and medium subangular blocky; firm; few fine roots; diffuse smooth boundary; pH 5.0.
B23	147.3-330.2	Red (2.5YR 4/6) clay; weak fine and medium subangular blocky; firm; very few fine roots; diffuse smooth boundary; pH 5.1;
B24	330.2-635.0	Red (10 R 4/6) clay; weak fine and medium subangular blocky; firm; very few fine roots; abrupt smooth boundary; pH 5.0.
C1	635.0-716.3	Dark red (10 R 3/6) clay loam; very weak fine subangular blocky; firm occasional soft and hard ironstone concretions, frequent quartz gravel and medium, subangular ferruginised quartz stones, occasional traces of decomposed rock. Clear smooth boundary; pH 5.3.
C2	716.3-767.1	Weak red (10 R 4/4) clay loam; very weak fine subangular blocky; firm; occasional quartz gravel; rare quartz stones, frequent pieces of decomposing Tarkwaian quartzite; pH 5.0.

BOMPATA SERIES (DYSTRIC NITOSOLS)

HORIZON	DEPTH cm	C. Sand	PARTICLE SIZE DISTRIBUTION %						Fe		TOTAL (P)PPM	ORGANIC MATTER			pH 1:1	MOISTURE EQUIV.	EXCHANGE CAPACITY
			M.Sand .6-.2	F. Sand .2-.06	C. Silt .06-.02	M. Silt .02-.002	F. Silt .006-.002	CLAY .002	Free Fe	Free Mn		C%	O.M %	C/N			
A11	0 - 8	2.3	21.2	44.3	10.2	6.8	3.3	11.9	1.48	0.07	203	1.14	1.96	9.58	5.8	1.9	6.38
A12	8 - 20	2.3	17.0	41.6	12.2	5.2	4.7	17.5	2.00	0.04	168	.41	.71	8.37	5.7	1.15	4.20
B21	20- 46	1.9	11.5	20.4	8.9	4.4	2.9	50.0	4.13	0.03	260	.43	.74	7.96	5.0	2.57	7.65
B22	46-147	2.0	9.2	16.3	11.1	7.4	6.2	47.8	4.73	0.03	241	.27	.46	6.75	5.0	2.85	7.42
B23	147-330	3.1	6.1	13.2	10.5	8.3	6.2	52.0	4.85	0.02	228	.16	.28	6.15	5.1	3.87	7.80
B24	330-635	1.8	7.4	16.0	14.0	11.1	6.2	43.5	5.00	0.02	181	.07	.12	4.11	5.2	2.58	7.14
C1	635-716	5.1	10.9	20.5	11.3	8.8	8.0	35.4	6.38	0.01	181	.04	.07	2.86	5.3	2.04	5.72
C2	716-767	1.0	19.4	34.5	11.7	11.1	4.3	18.0	7.38	0.01	225	.03	.05	3.00	5.6	1.57	4.27

HORIZON	DEPTH cm	C. Sand	CATION EXCHANGE meq %						Base Sat. S/T x 100
			Ca	Mg	Mn	K	Na	S (TEB)	
A11	0 - 8	2.3	2.68	1.32	.35	.17	.10	4.62	72.4
A12	8 - 20	2.3	1.57	.84	.07	.07	.10	2.64	62.9
B21	20- 46	1.9	1.76	.65	.07	.07	.15	2.70	35.3
B22	46-147	2.0	1.02	.47	.04	.09	.16	1.78	24.0
B23	147-330	3.1	.74	.51	.01	.03	.18	1.47	18.8
B24	330-635	1.8	.49	.20	.01	.03	.11	.84	11.8
C1	635-716	5.1	.45	.09	.01	.02	.15	.72	12.6
C2	716-767	1.0	.52	.10	.005	.02	.12	.76	17.8

1.6 Ejura Series

Locality : Mile 67 Ejura-Amantin Road.

Classification:
- Dystric Nitosols (Ghana)
- Savannah Ochrosol (FAO)
-"Sol ferrallitique typique appauvri"(French)
- Paleustult (U.S.D.A.)

Parent material: Sandy loam derived from weathered sandstones.

Profile No. : 2603

Topo site	: Summit
Slope	: 1% to South
Drainage	: Well drained
Altitude	: 210m (700 ft.)
Vegetation	: Tall grass savanna
Rainfall	: 1397 mm (55 inches)

Profile Description

Horizon	Depth (cm)	Description
A11	0 - 42	Dark reddish brown (5YR 3/2) loamy sand; very weak fine and medium granular; very friable; many fine roots; common worm holes and casts; pH 6.0; clear smooth boundary.
A12	42 - 87	Dark reddish brown (5YR 3/2) loamy sand; very weak fine granular; friable; common fine roots; ant holes; pH 6.0; abrupt smooth boundary.
A13	87 - 125	Yellowish red (5YR 4/6) loamy sand; massive; friable; few fine roots; pH 6.1; clear smooth boundary.
B1	125 - 177	Yellowish red (5YR 4/8) loamy sand; massive; friable; few fine roots; pieces of broken pots; pH 6.1; abrupt smooth boundary.
B21	177 - 285	Red (2.5YR 4/8) sandy clay loam; massive; firm; few fine roots; pieces of charcoal; pH 5.5; clear smooth boundary.
B22	285 - 375	Red (2.5YR 4/8) sandy clay; massive; firm; few fine roots; pH 5.5; clear smooth boundary.
B23	375 - 442	Red (2.5YR 4/8) sandy clay; massive; firm; few fine roots; pH 5.4; clear smooth boundary.
B24	442 - 577	Yellowish red (5YR 4/8) sandy clay; massive; firm; few fine roots; pH 5.6; clear smooth boundary.
B25	577 - 640	Yellowish red (5YR 5/8) sandy clay loam with few fine faint strong brown (7.5YR 5/8) mottles; massive; firm; few fine roots; pH 5.4; clear smooth boundary.
B26	640 - 705	Reddish yellow (7.5YR 6/6) sandy clay loam with many medium distinct red (10 R 4/6) mottles; massive; firm; few fine roots, partially indurated; pH 5.5; gradual smooth boundary.
B27	705 - 770	Reddish yellow (7.5YR 6/6) sandy clay loam with many medium distinct red (10 R 4/6) mottles; massive; firm; few fine roots, partially indurated; pH 5.5; gradual smooth boundary.
C1	770 - 877	Brownish yellow (10YR 6/6) sandy clay loam, many coarse prominent very pale brown (10YR 7/3) + yellowish red (5YR 4/6) mottles; massive; firm; partially indurated; pH 5.4; clear smooth boundary.
C2	877 - 930	Brownish yellow (10YR 6/6) sandy clay loam, many coarse prominent light grey (10YR 7/2) and yellowish red (5YR 4/6) mottles; massive; firm; partially indurated; pH 5.5; clear smooth boundary.
C3	930 - 970	Brownish yellow (10YR 6/6) reddish brown (5YR 5/4), light grey (10YR 7/2) white (10YR 8/2) pinkish grey (7.5YR 7/2) and red 2.5YR 4/6) prominently mottled sandy clay loam; massive; firm; mottled zone; pH 5.5; abrupt smooth boundary.
11Cm or 11Bm	970 +	Ironpan.

<u>EJURA SERIES (DYSTRIC NITOSOLS)</u>

HORIZON	DEPTH (cm)	Particle Size Analysis			pH 1:1	Organic Matter %				Cation exchange meq %							Base Sat. S/T x 100
		Sand 2.0-.06	Silt .06-.002	Clay .002		C	N	C/N	O.M %	T (CEC)	Ca	Mg	Mn	K	Na	S(TEB)	
A11	0-42	81.1	13.2	5.0	6.0	.42	.022	19.09	.72	2.69	1.24	.29	.01	.10	.26	1.90	70.6
A12	42-87	80.1	13.7	6.2	6.0	.48	.021	22.86	.83	2.89	1.47	.45	.001	.04	.26	2.22	76.8
A13	87-125	79.0	14.0	7.0	6.1	.23	.015	15.33	.40	3.12	1.01	.40	.001	.06	.26	1.73	55.4
B1	125-177	81.0	13.0	8.0	6.1	.13	.011	11.81	.22	1.63	.69	.40	.001	.04	.27	1.40	89.9
B21	177-285	57.1	11.3	31.6	5.7	.26	.023	11.30	.45	5.04	1.71	.92	.001	.06	.28	2.97	58.9
B22	285-375	46.6	15.4	38.0	5.5	.19	.023	8.26	.33	5.46	1.20	.67	.001	.80	.24	2.19	40.1
B23	375-442	48.6	14.9	36.5	5.4	.17	.018	9.44	.29	5.40	1.12	.52	.001	.05	.27	1.96	36.3
B24	442-577	49.4	14.6	38.0	5.6	.11	.015	7.33	.19	4.77	1.02	.42	.001	.05	.26	1.75	36.7
B25	577-640	49.5	16.0	34.5	5.4	.09	.012	7.50	.15	4.66	1.00	.42	.001	.05	.29	1.76	37.8
B26	640-705	45.8	20.0	34.2	5.4	.09	.008	11.25	.15	4.53	1.01	.20	.001	.06	.26	1.53	33.8
B27	705-770	45.8	21.2	35.0	5.5	.07	.011	6.38	.12	4.60	1.22	.21	.001	.06	.25	1.75	37.8
C1	770-877	49.5	23.5	27.0	5.4	.06	.007	8.57	.10	4.06	1.28	.31	.001	.05	.28	1.92	47.3
C2	877-930	45.6	21.4	33.0	5.5	.05	.008	6.25	.09	3.74	1.20	.36	.001	.03	.25	1.84	49.2
C3	930-970	45.6	21.4	33.0	5.5	.06	.008	7.50	.10	3.21	.93	.26	.001	.05	.25	1.49	46.4

1.7 Changnalili Series

Locality: Atebubu Commercial Farm

Classification: Groundwater Laterite (Ferromangustetros) (Obeng, 1970)
- Luvic Arenosols, petroferic phase (FAO)
-"Sols hydromorphes mineraux à pseudogley avec cuirasse de profondeur" (French)
- Tropaqualf (USDA)

Topo site : Lower slope
Slope : 1%
Drainage : Imperfectly to poorly drained.
Altitude : 114m (380 ft)
Vegetation : Savannah
Rainfall : 1245mm (49 inches)

Parent Material : Clay loam derived from weathered clay shale.

Horizon	Depth (cm)	Description
A11	0 - 7.6 cm	Dark greyish brown (10YR 4/2) sandy loam; weak, medium and fine crumb structure, friable; frequent fine and medium roots; pH 5.7; clear smooth boundary.
A12	7.6-22.9	Dark brown (10YR 4/3) sandy loam with few, fine strong brown (7.5YR 5/6) mottles; weak medium and fine granular structure; friable; occasional fine and medium roots; pH 5.5; clear smooth boundary.
B21	22.9-43.2	Brown (7.5YR 5/4) sandy loam with few, fine faint strong brown (7.5YR 5/6) mottles; massive, breaking to weak fine and medium subangular blocks; firm, rare, small soft brown ironstone concretions, occasional fine roots; pH 5.2; clear smooth boundary.
B22	43.2-58.4	Brown (7.5YR 5/4) clay loam with common, fine faint strong brown (7.5YR 5/6) mottles; massive, breaking into weak fine subangular blocks; firm; occasional small soft, irregular ironstone concretions; rare fine roots; pH 5.4; abrupt, smooth boundary.
B23m	58.4-94.0	Seepage iron pan; massive; indurated; occasional large pieces of iron pan; rare fine roots; pH 5.9; clear smooth boundary.
B24m	94.0-121.9	Indurated, seepage iron pan; massive.

CHANGNALILI SERIES (LUVIC ARENOSOLS)

HORIZON	DEPTH (cm)	C. Sand 2 - .6	PARTICLE SIZE DISTRIBUTION % M. Sand .6-.2	F. Sand .2-.06	C. Silt .06-.02	M. Silt .02-.006	F. Silt .006-.002	CLAY .002	TOTAL P (PPM)	ORGANIC MATTER % C%	O.M %	C/N	pH 1:1	Cation exchange meq. % T(CEC) NH4	Ca	Mg	Mn	K	Na	S(TEB)
A11	0 - 8	0.2	7.7	38.6	20.5	16.0	4.6	12.4	143	.75	1.29	13.16	5.7	5.19	2.90	1.06	.01	.15	.15	4.26
A12	8 - 23	0.3	7.0	38.2	21.0	14.1	5.4	14.0	146	.57	.98	13.25	5.5	4.54	1.94	.75	.01	.07	.17	2.93
B21	23- 43	0.3	6.1	38.6	16.8	16.0	6.4	15.8	71	.37	.64	8.60	5.2	4.04	1.31	.55	.01	.07	.13	2.06
B22	43- 58	0.6	6.0	38.4	18.8	14.8	5.6	15.8	82	.20	.34	6.89	5.4	4.67	1.54	.70	.001	.08	.12	2.44
B23m	58- 94	20.8	11.7	25.5	13.0	12.0	5.8	11.2	70	.21	.36	7.24	5.9	6.68	2.13	1.01	.001	.15	.17	3.46
B24m	94-122	32.1	13.8	15.7	17.4	8.6	4.7	7.7	199	.19	.33	16.57	5.9	6.69	1.50	.80	.001	.10	.12	2.52

1.8 Ashaiman Series

Locality : Accra Plains

Classification:
- Tropical Brown Earth (Ghana)
- "Vertisol à drainage extérieur possible, à structure anguleuse de surface, sous groupe vertique" (French)
- Typic Chromustert (U.S.D.A.)
- Chromic Vertisols (FAO)

Parent Material : Residium from basic gneiss.

Topo site : Middle slope
Slope : 2%
Drainage : Imperfectly drained.
Altitude :
Rainfall : 35 inches.

Profile Description

Horizon	Depth (cm)	Description
A11	0 - 10	Very dark greyish brown (2.5Y 3/2) silty clay, moderate fine to medium granular and weak fine subangular blocky; vertical cracks, many fine and medium roots, few fine lime concretions, pH 7.6; clear smooth boundary.
A12	10 - 22	Dark greyish brown (2.5Y 4/2) silty clay; moderate fine to medium granular and weak fine subangular blocky, firm, very little quartz gravel, few CaCO3 concretions; many fine and medium roots; vertical cracks, pH 7.8; clear smooth boundary.
A13	22 - 32	Dark greyish brown (2.5Y 4/2) silty clay, irregular angular peds breaking to medium angular block, firm, common fine and medium roots, frequent CaCo3 concretions, little fine quartz gravel; pH 7.7; gradual smooth boundary.
A14	32 - 70	Dark greyish brown (2.5Y 4/2) silty clay with very dark grey (2.5Y 3/1) slickensides, irregular angular peds breaking to moderate, medium angular blocky, firm; horizontal and vertical cracks; few MnO2 concretions; frequent CaCo3 concretions, little fine quartz gravel; few fine roots: pH 7.8: clear smooth boundary.
A15	70 - 100	Very dark greyish brown (2.5Y 3/2) silty clay very dark grey (5Y 3/1) slickensides, irregular angular peds breaking to moderate medium angular blocky, firm; few roots; frequent CaCo3 concretions, horizontal cracks; pH 7.7; clear smooth boundary.
AC	100 - 125	Very dark greyish brown (10YR 3/2) silty clay with very dark grey (5Y 3/1) slickensides mottled dark brown (10YR 3/3) irregular angular peds breaking to moderate medium angular blocky; firm; few patches of decomposed rock; occasional CaCo3 concretions; very few fine roots; pH 7.5; abrupt smooth boundary.
C	125 - 165	Dark brown (10YR 3/3) silty loam with very frequent patches of decomposed rock; pH 7.1; clear smooth boundary
R	165 - 190	Weathered hornblende gneiss. pH 7.3.

ASHAIMAN SERIES (CHROMIC VERTISOLS)

HORIZON	DEPTH (cm)	MOISTURE AIR - DRY SOIL PER CLAY	Particle Size Analysis %				Organic Matter %				Cation exchange meq. %							Base Sat. S/T x 100
			% Sand 2-0.06	% Silt .06-.002	Clay .002	pH 1:1	C	N	C/N	O.M %	T (CEC)	Ca	Mg	Mn	K	Na	S(TEB)	
A11	0-10	13.93	17.8	20.5	62.5	7.60	1.53	.179	8.5	2.63	57.78	54.67	12.14	.001	.66	.95	68.42	118.4
A12	10-22	14.11	15.0	20.0	65.0	7.80	1.21	.114	10.6	2.08	59.25	58.14	12.87	.001	.19	.84	72.04	121.6
A13	22-32	14.37	9.0	23.8	67.2	7.70	1.32	.098	13.5	2.27	81.71	54.19	12.20	.001	.19	1.02	67.60	82.7
A14	32-70	14.47	12.0	21.0	[illegible]	7.80	.63	.082	7.7	1.08	83.63	46.84	14.30	.001	.19	2.06	63.37	75.8
A15	70-100	14.52	10.0	22.8	67.2	7.70	.50	.065	7.7	.86	83.46	48.82	15.00	.001	.14	3.05	67.01	80.3
AC	100-125	14.03	19.2	30.0	50.8	7.50	.68	.033	20.6	1.17	57.90	69.44	16.80	.001	.09	5.10	91.43	157.9
C	125-165	12.44	34.8	29.7	35.5	7.10	.19	.014	13.6	.33	58.33	86.20	18.80	.001	.08	6.49	111.57	201.6
R	165-190	11.00	41.8	34.2	24.0	7.30	.15	.031	4.8	.26	50.72	44.87	12.40	.001	.04	3.33	60.64	119.6

1.9 Akuse Series

Locality: Accra Plains

Classification:
- Tropical Black earth (Ghana)
- Pellic Vertisols (FAO)
- "Vertisol à drainage extérieur possible à structure anguleuse de surface sous groupe vertique grumosolique" (French)
- Typic Pellustert (USDA)

Parent material : Residium from weathered basic gneiss.

Topo site : Lower slope
Slope : 2% to South
Drainage : Imperfectly drained
Altitude : 27m (90 ft)
Vegetation : Short-grass Savannah
Rainfall : 889mm (35 inches)

Profile Description:

Horizon	Depth (cm)	Description
A11	0 - 20	Very dark grey (10YR 3/1) clay; moderate fine to medium granular and weak fine subangular blocky; firm; many fine roots; vertical cracks; pH 6.6; clear smooth boundary.
A12	20 - 67	Very dark grey (10YR 3/1) clay; irregular angular peds breaking to medium and fine subangular blocky; firm; very fine ironstone concretions and CaCo3 concretions, parallel vertical cracks, many fine and medium roots, pH 7.5; clear smooth boundary.
A13	67 - 120	Very dark grey (10YR 3/1) clay; irregular angular peds breaking to medium subangular blocky; firm, common fine Fe concretions and gravel, few CaCo3 concretions, common fine roots; pH 7.7; gradual smooth boundary.
A14	120 - 191	Very dark grey (10YR 3/1) clay with black (10YR 2/1) slickensides, irregular angular peds breaking to moderate medium angular blocky; firm; network of horizontal and vertical cracks; common fine roots; slickensides at 50°-60° to the surface; pH 7.8; clear smooth boundary.
A15	191 - 285	Very dark grey (10YR 3/1) clay with black (10YR 2/1) slickensides; irregular angular peds breaking to moderate medium subangular blocky; firm; few medium and common fine roots; few fine polished Fe concretions, few Mn and CaCo3 concretions; pH 7.4; clear smooth boundary.
AC	285 - 350	Very dark greyish brown (10YR 3/2)clay with very dark grey (10YR 3/1) slickensides; irregular angular peds breaking to weak medium subangular blocky; firm; common CaCo3 concretions; few polished Fe concretions and rare Mn concretions, pH 7.5; abrupt smooth boundary.
C1ca	350 - 467	Very dark greyish brown (10YR 3/2) gritty clay; massive; firm; abundant calcium carbonate lumps and concretions; pH 7.9; calcareous; clear smooth boundary.
C2ca	467 - 530	Very dark greyish brown (10YR 3/2) gritty clay loam; massive firm; numerous CaCo3 concretions and soft iron oxide coats, few Fe concretions; pH 7.9; abrupt irregular boundary.
C3	530 - 597	Weathered hornblende gneiss.

AKUSE SERIES (PELLIC VERTISOLS)

HORIZON	DEPTH (cm)	Particle Size Analysis %			pH 1:1	Organic Matter %				Cation exchange meq %					
		% Sand 2-.06	% Silt .06-.002	Clay .002		C	N	C/N	O.M %	T (CEC)	Ca	Mg	K	Na	S(TEB)
A11	0-20	36.4	18.8	44.8	6.60	.84	.055	15.3	1.44	43.24	32.02	15.07	.17	.88	48.14
A12	20-67	28.0	22.9	49.1	7.50	.60	.040	15.0	1.03	39.36	35.82	14.49	.10	8.20	58.61
A13	67-120	29.0	22.0	49.0	7.70	.45	.024	18.7	.77	43.68	33.48	17.98	.08	1.93	53.47
A14	120-191	31.0	19.2	49.8	7.80	.33	.022	15.0	.57	43.14	34.16	17.53	.12	2.41	54.22
A15	191-285	21.0	24.5	54.5	7.40	.38	.016	23.7	.65	46.54	34.02	18.64	.13	4.20	56.99
AC	285-350	22.4	20.8	56.8	7.50	.27	.007	28.6	.46	47.71	73.68	24.17	.11	5.16	105.12
C1ca	350-467	40.2	16.8	43.0	7.90	.07	.011	6.4	.12	40.53	73.61	22.86	.07	3.33	99.88
C2ca	467-530	41.2	21.8	37.0	7.90	.05	.001	4.5	.09	23.58	69.90	21.45	.11	4.04	95.51
C3	530-597	62.8	20.2	17.0	7.90	.04	Nil	Nil	.07	32.69	15.16	13.67	.05	2.22	31.11

1.10 Agawtaw Series

Locality: Accra Plains

Classification:
- Tropical Grey Earth (Ghana)
- Gleyic solonetz (FAO)
-"Vertisol à drainage extêrieur rêduit; sous groupe modal" (French)
- Natrustalf (USDA)

Parent material : Silt loam

Topo site	: Middle slope
Slope	: 1% to S.West
Drainage	: Imperfect to poor
Altitude	: 27m (90 ft.)
Vegetation	: Short-grass Savannah.
Rainfall	: 889 mm (35 inches)

Profile Description

Horizon	Depth (cm)	Description
A11	0 - 22	Dark grey (10YR 4/1) fine sandy loam; very weak fine granular; friable; many fine roots; pH 6.4; abrupt smooth boundary.
A12	22 - 37	Dark grey (10YR 4/1) sandy loam; weak fine granular; friable; common fine roots; pH 6.3; smooth boundary.
A13	37 - 67	Very dark greyish brown (10YR 3/2) loam; strong very coarse prismatic; firm fine roots; pH 6.5; abrupt smooth boundary.
B21	67 - 92	Dark greyish brown (10YR 4/2) loam; strong very coarse prismatic firm; common Mn concretions; pH 7.2; clear smooth boundary.
B22	92 - 140	Very dark greyish brown (2.5Y 3/2) loam coarse and medium angular blocky; firm; pH 7.4; clear smooth boundary.
B23	140 - 212	Dark greyish brown (2.5Y 4/2) clay loam; massive; firm; few CaCo3 and Mn concretions; pH 7.7; clear smooth boundary.
B24	212 - 297	Olive grey (5Y 5/2) sandy clay loam; massive; firm; few CaCo3 and Mn concretions; pH 7.9; abrupt smooth boundary.
B25	297 - 437	Olive grey (5Y 5/2) sandy clay loam; massive; firm; many Mn and CaCo3 concretions; pH 8.0; abrupt smooth boundary.
IICIca	437 - 525	Olive grey (5Y 5/2) loam; massive; firm; many CaCo3 and Mn concretions; common quartz gravel (about 40% by volume); pH 8.2; abrupt smooth boundary.
IIC2	525 - 562	Dark greyish brown (2.5Y 4/2) silt loam; massive; firm; lumps of CaCo3; pH 8.6; clear smooth boundary.
IIC3	562 - 610	Dark greyish brown (2.5Y 4/2) silt loam; massive pieces of decomposed schist and few CaCo3 and Mn concretions; pH 8.7; gradual boundary.
IIC4	610 - 680	Dark greyish brown (2.5Y 4/2) silty loam of decomposed mica schist; massive;firm; pH 8.8.

AGAWTAW SERIES (GLEYIC SOLONETZ)

HORIZON	DEPTH (cm)	Particle Size Analysis %			pH 1:1	Organic Matter %				Cation exchange meq %					
		% Sand 2-.06	% Silt .06-.002	Clay		C	N	C/N	O.M %	T(CEC)	Ca	Mg	K	Na	S(TEB)
A11	0-22	51.4	42.6	6.0	6.4	.55	.028	19.64	0.95	4.58	2.38	1.51	.14	.42	4.52
A12	22-37	51.4	41.1	7.5	6.3	.49	.020	24.50	0.84	5.67	2.58	1.64	.10	.56	4.93
A13	37-67	42.0	43.8	14.2	6.5	.65	.037	17.57	1.10	10.71	5.06	3.41	.10	.25	8.83
B21	67-92	45.4	33.6	21.0	7.2	.59	.026	22.69	1.01	14.95	7.65	4.49	.17	2.99	15.31
B22	92-140	39.4	36.6	24.0	7.4	.44	.019	23.15	.76	17.54	8.93	5.85	.17	4.71	19.66
B23	140-212	44.0	28.0	28.0	7.7	.09	.003	30.00	.15	20.71	12.16	8.16	.30	8.29	28.91
B24	212-297	46.0	26.0	28.3	7.9	.05	.004	8.00	.09	21.15	12.91	7.79	.15	8.67	29.52
B25	297-437	34.0	37.0	29.0	8.0	.04	.003	13.3	.07	21.95	23.04	8.24	.20	8.45	39.93
IIClca	437-525	36.8	39.2	24.0	8.2	.05	.008	6.2	.09	21.56	50.98	12.35	.28	7.92	71.53
IIC2	525-562	32.0	60.0	8.0	8.6	.04	.001	40.0	.07	12.41	25.82	5.53	.18	6.59	38.12
IIC3	562-610	35.0	59.7	5.3	8.7	.04	.003	13.3	.07	9.15	16.56	3.65	.15	5.39	25.75
IIC4	610-680	33.0	61.0	6.0	8.8	.03	.003	10.0	.05	8.21	18.22	3.82	.27	4.46	26.78

2. DESCRIPTIONS AND ANALYTICAL DATA OF SOIL PROFILES EXAMINED IN TOGO

2.1 Davie Series

Classification:

-"Sol ferrallitique moyennement appauvri" (Togo-French)
- Humic Nitosols (FAO)
- Savannah Ochrosol - concretionary phase (Ghana)
- Rhodic Paleustalf (USDA.

Parent Material : Tertiary sediment

Vegetation : 15 years old fallow land, grassland with scattered trees.

Locality : IRAT Station at Davie
Topo Site: Flat topography
Slope : Flat
Drainage : Somewhat excessively drained.
Altitude : 90 m
Rainfall : 850 mm

Depth (cm)	Description
0 - 20	Dark reddish brown (5YR 3/3) moist; sandy loam; medium crumb structure; friable; slightly sticky and non plastic moist, loose dry, many pores; intense biologic activities (earth worm, termites, ants) somewhat excessively drained; many roots; smooth gradual boundary; pH 6.1.
20 - 60	Dark reddish brown (2.5YR 3/4) moist; dark red (2.5YR 3/6) dry; sandy-clay loam; fine subangular blocky; slightly sticky, friable moist; well drained; many fine and medium pores; few insects and animals holes; many medium and fine roots; diffuse smooth boundary; pH 5.2.
60 - 210	Dark red (2.5YR 3/6) moist; sandy clay; fine to medium subangular blocky; slightly sticky and plastic friable moist; slightly hard dry; many tubular pores; moderately well drained; many fine and few medium roots; pH 5.0.

DAVIE SERIES (HUMIC NITOSOLS)

DEPTH (cm)	pH		H_2O %	Clay %	Silt %		Total Silt %	Sand %		Organic Matter %	Structural Stability
	H_2O	KCl			fine	coarse		fine	coarse		
0-20	6.1	5.1	1.072	15.750	3.750	7.860	11.610	28.010	42.180	3.99	1.482
20-60	5.2	4.25	1.177	23.000	1.950	5.975	7.925	22.880	41.970	1.22	2.758
60-140	5.05	4.3	1.816	44.500	2.500	4.240	6.740	17.550	31.035		3.443
140-210	4.8	4.2	2.106	50.500	1.000	4.965	5.965	14.015	25.950		3.708

DEPTH (cm)	Cation exchange meq %				S (CEC)	T (TED)	V S/Tx100	C%	N%	C/N	P_2O_5 Truog mg %
	Ca	Mg	K	Na							
0-20	2.658	1.110	0.143	0.039	3.950	6.6	59	23.176	1.708	13.5	0.0230
20-60	1.464	1.236	0.075	0.045	2.820	3.0	94	7.073	0.868	8	0.0250
60-140	1.830	0.834	0.078	0.065	2.807	8.5	33				0.0040
140-210	1.890	0.678	0.086	0.065	2.713	6.3	43				0.0130

2.2 Kpoglo Series

Classification:

- Sols bruns à tendance vertique(Togo-French)
- Tropical brown earth (Ghana)
- Humic Cambisols (FAO)

Parent Material : Precambrian rock formations.

Vegetation : Fallow land.

Locality : On Atakpamé-Tsevie road at 12km North of Tsevie.
Topography:undulating
Slope : 4 to 5%
Drainage : Moderately well drained to well drained.
Altitude : 110 m
Rainfall : 1050mm

Depth (cm)	Description
0 - 20	Dark grey moist; sandy-clay; fine crumb structure, slightly sticky and plastic; many pores; few gravels; many fine roots; gradual boundary; pH 6.00.
20 - 35	Light reddish grey moist; sandy clay; medium crumby structure, friable; many fine roots; gradual boundary; pH 6.40.
35 - 45	Brownish grey moist; sandy clay; weak subangular structure; few roots; pH 6.50
45 - 55	Reddish grey moist; sandy clay; many gravels (stone line); structureless, single grain; very few roots; abrupt, wavy boundary; pH 6.70.
55 - 85	Brownish grey moist; sandy clay; subangular blocky; clay skin; gradual boundary; pH 6.40.
85 - 125	Brownish moist; sandy clay loam; many weathered rocks; pH 6.90.
125 and more	Weathered rock.

KPOGLO SERIES (HUMIC CAMBISOLS)

Depth (cm)	pH		H_2O %	Clay %	Silt %		Total Silt %	Sand %		Organic Matter %	Structural Stability
	H_2O	KCl			fine	coarse		fine	coarse		
0-20	6.00	4.80	4.619	40.750	6.500	8.570	15.070	21.335	20.340	2.9	3.392
20-50	6.40	4.90	5.016	36.000	6.250	6.245	12.495	20.790	22.470	2.0	2.047
50-55	6.50	4.80	5.215	41.750	5.000	5.695	10.695	20.600	22.840	1.0	3.154
55-75	6.70	5.00	5.480	42.250	3.500	3.430	6.930	14.555	30.265	0.8	2.512
75-100	6.40	4.90	5.652	42.250	6.500	6.210	12.710	15.730	20.665		1.060
100-150	6.90	5.05	4.870	26.250	9.000	9.715	18.715	26.700	26.080		0.912

Depth (cm)	Cation Exchange meq %				S (CEC)	T (TED)	V S/Tx100	C%	N%	C/N	P_2O_5 Truog mg %
	Ca	Mg	K	Na							
0-20	10.500	3.348	0.115	0.071	14.034	18.4	76	16.900	1.694	9	0.350
20-50	9.852	3.222	0.150	0.071	13.295	18.8	70	11.992	1.260	9	0.0190
50-55	6.948	2.766	0.066	0.084	9.864	17.3	57	5.930	0.924	6	0.0040
55-75	9.060	4.230	0.122	0.150	13.562	17.9	75	4.595	0.937	4.9	0.0290
75-100	7.470	3.900	0.069	0.182	11.621	15.8	73				0.0210
100-150	8.760	4.680	0.069	0.165	13.674	14.0					0.0130

2.3 Nuatja Series

Classification :

- Sol ferrugineux hydromorphe induré (Togo - French)
- Regosolic ground water laterite (Ghana)
- Ferric Acrisols, petroferric phase (FAO)

Parent material : migmatite

Vegetation : Fallow land

Locality : Nuatja experimental station
Topo site : Flat
Slope : Flat
Drainage : Well drained
Altitude : 150m
Rainfall : 1200mm

Depth (cm)	Description
0 - 20	Black (10YR 2.5/1) moist; dark grey (10YR 4/1) dry; loamy sand; crumby structure, nonsticky nonplastic when moist; consistence soft when dry; many pores; very many roots; gradual boundary; pH 6.9.
20 - 50	Very dark greyish brown (10YR 3/2) moist; sandy loam; crumby structure; nonsticky nonplastic when moist; soft when dry; few concretions; many fine mottles (2.5YR 3/6) moist; many roots; gradual boundary; pH 6.30.
50 - 120	Dark reddish brown (5YR 3/3) moist; sandy clay; subangular blocky structure; slightly sticky and plastic; many fine tubular pores; very few roots; few fine and medium mottles (5YR 4/6) when moist; abrupt boundary; pH 5.70.
120 - 180 and more	Iron pan layer.

NUATJA SERIES (FERRIC ACRISOLS)

DEPTH (cm)	pH		H_2O %	Clay %	Silt %		Total Silt %	Sand %		Organic Matter %	Structural Stability
	H_2O	KCl			fine	coarse		fine	coarse		
0-20	6.90	5.60	1.461	9.250	7.000	10.245	27.245	43.195	29.205	4.3	1.697
20-50	6.30	5.00	1.395	14.250	4.500	10.140	14.640	41.470	24.750	1.8	1.715
50-120	5.70	4.70	4.605	47.500	4.500	5.030	9.530	16.720	17.930		2.624

DEPTH (cm)	Cation exchange meq %				S (CEC)	T (TED)	V (S/Tx100)	C%	N%	C/N	P_2O_5 Truog mg %
	Ca	Mg	K	Na							
0-20	6.750	1.278	0.384	0.045	8.457	14.8	57	25.202	1.568	16	0.3030
20-50	3.228	1.128	0.132	0.045	4.543	9.5	48	10.970	0.840	13	0.0450
50-120	5.700	2.628	0.200	0.165	8.691	19.1	45				0.0120

2.4 East Mono Series

Classification:
- Pellic Vertisol (FAO)

Parent Material: orthogneissic formation with biotites and amphibolites

Vegetation : cotton field

Locality : IRCT Research station
Topo site : Flat
Slope : Flat
Drainage : Well drained
Altitude : 160 m
Rainfall : 1.150 mm

Depth (cm)	Description
0 - 15	Black (10YR 2.5/1) moist and very dark greyish brown (10YR 3/2) when dry; sandy loam; crumby structure; slightly sticky and plastic when moist; slightly hard when dry; many pores; many earth worms; very many fine roots; abrupt boundary; pH 6.
15 - 45	Very dark grey (10YR 3/1) moist; sandy clay; subangular blocky; sticky and very plastic when moist; very to extremely hard when dry; few pores; very few roots; abrupt boundary; pH 7.3.
45 - 90	Dark grey (5 YR 4/1) moist; sandy clay; medium subangular blocky; very sticky and plastic when wet; very to extremely hard when dry; few calcareous nodules; and few quartz gravels; abrupt and irregular boundary; pH 7.3.
90 and more	Weathered rock.

KOLOKOPE SERIES (PELLIC VERTISOLS)

DEPTH (cm)	pH		H_2O %	Clay %	Silt %		Total Silt %	Sand %		Organic Matter %	Structural Stability
	H_2O	KCl			fine	coarse		fine	coarse		
0-15	6.80	5.70	2.863	18.250	7.250	18.060	25.310	43.075	12.415	3.7	3.462
15-45	6.3	5.1	8.024	42.250	5.250	8.115	13.365	21.570	20.285	2.2	3.385
45-75	7.3	6.2	6.956	40.000	4.250	9.540	13.790	25.985	16.180	0.6	2.157

DEPTH (cm)	Cation Exchange meq %				S (CEC)	T (TED)	V (S/Tx100)	C%	N%	C/N	P_2O_5 Truog mg %
	Ca	Mg	K	Na							
0-15	10.434	4.146	0.211	0.065	14.856	16.3	91	21.644	1.204	17	0.0640
15-45	16.734	9.936	0.183	0.163	27.016	29.54	91	13.046	0.868	15	0.0170
45-75	20.130	10.962	0.203	0.176	31.471	28.88	100	3.854	0.420	9	0.2190

2.5 Hiheatro Series

Classification :

- "Sol ferrallitique moyennement désaturé remanié modal" (Togo-French)
- Forest Ochrosol (Ghana)
- Humic Acrisols (FAO)
- Rhodustult (USDA)

Locality : Near Primary School of Hiheatro
Topo site : hillslope
Slope : 4 to 6%
Altitude : 350 m
Rainfall :

Parent Material : Quartzite

Vegetation : Imperata panicum.

Depth (Cm)	Description
0 - 10	Very dark greyish brown (10YR 3/2) moist and brown (10YR 4/3) dry; sandy loam; crumby structure, non sticky non plastic when moist; many tubular pores; very many fine roots; intense biologic activity; gradual boundary; pH 6.20.
10 - 30	Dark reddish brown (5YR 3/3) moist and reddish brown (5YR 4/4) dry; sandy, clay loam; medium to fine subangular blocky; slightly sticky and non plastic moist; many pores, many roots; gradual boundary; pH 5.35.
30 - 100	Dark reddish brown (2.5YR 3/4) moist; sandy clay; subangular blocky; slightly sticky and plastic when moist; many pores; many fine roots; gradual boundary; pH 5.5.
100 - 120	Yellowish red (5YR 4/6) moist; sandy clay; medium subangular blocky; slightly sticky and plastic; many fine pores; many fine roots; many medium mottles (2.5YR 2.5/2) abrupt boundary; pH 5.20.
120-140 and more	Boulder layers.

HIHEATRO SERIES (HUMIC ACRISOLS)

DEPTH (cm)	pH		H_2O %	Clay %	Silt %		Total Silt %	Sand %		Organic Matter %	Structural Stability
	H_2O	KCl			fine	coarse		fine	coarse		
0-10	6.20	5.00	1.295	13.500	4.250	7.325	11.575	28.755	39.035	3.7	1.493
10-30	5.35	4.20	2.295	28.000	6.250	4.980	11.230	20.065	41.330	2.4	2.112
30-100	5.50	4.40	3.613	42.750	7.250	2.480	9.730	14.060	27.015	0.8	2.896
100-120	5.60	4.30	3.175	38.000	2.250	3.005	5.255	15.470	31.510		2.626

DEPTH (cm)	Cation exchange meq %				S (CEC)	T (TED)	V (S/Tx100)	C%	N%	C/N	P_2O_5 Truog mg %
	Ca	Mg	K	Na							
0-15	3.288	1.254	0.384	0.039	4.965	9.5	52	21.970	1.736	12.6	0.0370
15-30	2.136	0.984	0.084	0.039	3.243	14.2	22	14.147	1.288	11	0.310
30-100	3.090	1.794	0.081	0.065	5.030	15.2	33	4.816	0.616	8	0.190
100-120	3.156	2.076	0.096	0.097	5.425	11.3	48				0.0120

2.6 Adeta Series:

Classification :

- "Sol faiblement ferrallitique, faiblement désaturé penévolué" (Togo-French)
- **Orthic Luvisols,** petric phase (FAO)
- Parent material : **micaschists**
- **Vegetation:** Teak forest

Locality : Adeta research station
Topo site : slightly undulating
Slope : 2 to 3%
Altitude : 250 m
Rainfall : 1600mm

Depth (cm)	Description
0 - 20	Dusky red (2.5YR 3/2) moist; sandy loam; crumby structure, friable, non sticky non plastic; many pores; many roots; intense biological activity; abrupt boundary; pH 5.6.
20 - 80	Reddish brown (2.5YR 4/4) moist; sandy clay loam; weak subangular blocky; few roots; gradual boundary; pH 5.2.
80 - 105	Light reddish brown (5YR 6/4) moist; sandy clay loam; subangular blocky; friable; slightly sticky and plastic moist; many quartz gravels; many mottles (10YR 6/2); gradual boundary.
105 - 150 and more	Weathered rock.

ADETA SERIES (ORTHIC LUVISOLS)

DEPTH (cm)	pH		H_2O %	Clay %	Silt %		Total Silt %	Sand %		Organic Matter %	Structural Stability
	H_2O	KCl			Fine	Coarse		Fine	Coarse		
0-20	5.6	4.6	1.266	16.000	3.000	6.220	9.220	23.550	42.280	2.888	4.704
20-40	5.2	4.5	3.275	27.250	12.250	11.450	23.700	16.390	31.220	1.086	2.500
50-80	5.7	4.6	3.050	38.500	7.250	4.215	11.465	16.320	26.700	0.434	1.255

DEPTH (cm)	Cation exchange meq %				S (CEC)	T (TED)	V (S/Tx100)	C%	N%	C/N	P_2O_5 mg %
	Ca	Mg	K	Na							
0-20	1.554	0.702	0.130	0.045	2.439	7.25	33	16.752	1.456	11	0.012
20-40	1.800	0.108	0.245	0.045	2.198	12.6	17	6.300	0.672	9	
50-80	3.750	2.868	0.138	0.104	6.860	10.9	62	2.520	0.448	5	0.006

2.7 Tove Series

Classification :

- "Sol ferrallitique moyennement désaturé humifére, remanié, induré" (Togo-French)
- Forest Ochrosol, concretionary phase (Ghana)
- Humic Nitosols, petric phase (FAO)
- Paleudult (USDA)

Locality: Tove school farm
Topo site: undulating
Slope : flat
Altitude : 182m

Parent material : granite

Vegetation : Cocoa plantation

Depth (cm)	Description
0 - 20	Dark reddish brown (5YR 3/4) moist; sandy loam; fine strong crumby structure; friable, slightly sticky and plastic; many gravels; many fine and medium roots; abrupt boundary; pH 6.6.
20 - 40	Reddish brown (5YR 4/3) moist; sandy loam; structureless, single grain; few quartz stones; few roots; abrupt boundary; pH 6.1.
60 - 90	Dark red (2.5YR 3/6) moist; sandy loam; structureless, massive; concretionary horizon with many quartz stones; gradual boundary; pH 6.2.
90 - 150	Red (2.5YR 4/6) moist; clay; structureless massive; concretionary horizon with many quartz stones and gravels.

TOVE SERIES (HUMIC NITOSOLS)

DEPTH (cm)	pH		H_2O %	Clay %	Silt %		Total Silt %	Sand %		Organic Matter %	Structural Stability
	H_2O	KCl			fine	coarse		fine	coarse		
0-20	6.6	5.6	5.571	15.250	19.750	9.210	28.960	23.310	28.770	10.608	12.585
20-40	6.1	5.0	2.283	15.500	12.750	6.375	19.125	18.490	46.650	1.047	12.154
40-90	6.2	4.8		15.500	2.750	2.200	4.950	4.355	23.335	1.329	
90-150	5.40	5.4	4.012	42.000	8.500	6.750	15.250	13.020	29.1620		4.094

DEPTH (cm)	Cation exchange meq %				S (CEC)	T (TED)	V (S/Tx100)	C%	N%	C/N	P_2O_5 Truog mg %
	Ca	Mg	K	Na							
0-20	19.380	5.100	0.668	0.085	25.233	38.05	66	61.520	4.788	12	0.940
20-40	5.022	1.950	0.234	0.046	7.252	11.6	62	6.078	0.812	7	0.0170
40-90	4.836	1.512	0.384	0.092	6.824	16.9	40	7.700	0.924	8	0.0025
90-150	2.868	2.316	0.280	0.032	5.496	17.5	31				0.0105

2.8. Agou Series

Classification :

- "Sol ferrallitique moyennement désaturé remanié (Togo - French)
- Forest Ochrosol (Ghana)
- Dystric Nitosols, petric phase (FAO)
- Rhodic Paleudult (USDA)

Parent material : gneiss

Vegetation : Coffee plantation.

Locality: at about 500 m of the intersection of the roads Agou-Nyongbo and the RN5.
Topo site: slightly undulating plateau
Slope : 3%
Altitude : 192m

Depth (cm)	Description
0 - 30	Reddish brown (5YR 4/4) dry; sandy clay loam; weak crumby structure, friable; non sticky non plastic when moist; many pores, many roots; many quartzise gravels; gradual boundary; pH 6.3.
30 - 60	Dark reddish brown (2.5YR 3/4) dry; clay, medium subangular blocky; many tubular pores; quartz gravels; diffuse boundary; pH 5.9.
60 - 250	Dark reddish brown (2.5YR 3/4) dry; clay; coarse to medium subangular blocky; clay skin; many fine pores; many quartz gravels; few roots; pH 6.5.

AGOU-CANTONNIER SERIES (DYSTRIC NITOSOLS)

DEPTH (cm)	pH		H_2O %	Clay %	Silt %		Total Silt %	Sand %		Organic matter %	Structural Stability
	H_2O	KCI			fine	coarse		fine	coarse		
0-30	6.3	5.3	2.150	27.000	4.750	4.180	8.930	18.710	39.800	4.7	8.361
30-60	5.9	4.70	3.318	93.500	6.750	2.580	9.330	11.195	24.010	1.4	7.295
60-120	5.8	4.4	3.348	58.250	3.500	2.155	5.655	10.740	24.100		5.376
120-250	6.5	5.00	3.219	57.250	4.750	2.145	6.895	10.805	24.455		4.609

DEPTH (cm)	Cation exchange meq %				S (CEC)	T (TED)	V (S/Tx 100)	C%	N%	C/N	P_2O_5 Truog mg %
	Ca	Mg	K	Na							
0-30	3.948	2.130	0.419	0.032	6.529	9.3	70	27.391	2.464	11	0.0310
30-60	3.024	2.136	0.147	0.026	5.333	11.4	46	8.428	1.092	8	0.0240
60-120	3.018	1.380	0.097	0.026	4.521	15.8	28				0.0065
120-250	2.442	1.518	0.036	0.045	4.041	11.9	33			traces	0.125

2.9 Gadjawoukpe Series

Classification :

- Forest brunosol / ochrosol intergrade (Ghana)
- Humic Nitosols (FAO)
- Tropudalf (USDA)
- Parent material : gneiss

Vegetation : cocoa plantation,

Locality : intersection of RN5 and Gadjawoukpe road cross.

Topo site : flat
Slope : flat
Altitude : 150m

Depth (cm)	Description
0 - 25	Black (10YR 2.5/1) moist; loam; crumb structure; moderately medium; many fine roots; diffuse boundary; pH 6.2.
25 - 50	Dark brown (7.5YR 3/2) moist; clay loam; medium subangular blocky; friable; slightly sticky and plastic; many fine pores; many roots; few small gravels; gradual boundary; pH 5.7.
50 - 110	Dark brown (7.5YR 3/2) moist; clay loam; moderate; medium subangular blocky; sticky and plastic moist; many tubular pores; few fine roots; few plinthites (7.5YR 4/4) moist; diffuse boundary; fine pH 6.2.
110 - 145	Dark brown (7.5YR 4/4) moist; sandy clay loam; subangular blocky; slightly sticky; plastic;many plinthites (7.5YR 5/6) moist ; clay skin; many pores; abrupt boundary; pH 6.6.
145 - 150 and more	Hard iron pan

GADJAWOUKPE SERIES (HUMIC NITOSOLS)

DEPTH (cm)	pH		H_2O %	Clay %	Silt %		Total Silt %	Sand %		Organic Matter %	Structural Stability
	H_2O	KCI			fine	coarse		fine	coarse		
0-25	6.2	5.1	6.360	27.000	30.250	9.570	39.820	16.010	13.015	6.1	8.749
25-50	5.7	4.7	6.347	31.500	19.500	9.680	29.180	18.685	13.585	4.3	6.430
50-110	6.2	5.1	5.689	37.000	17.000	10.305	27.305	18.235	13.380	1.7	2.281
110-145	6.6	5.2	4.686	33.500	16.250	10.985	27.235	18.535	18.480		1.440

DEPTH (cm)	Cation exchange meq %				S (CEC)	T (TED)	V (S/Tx100)	C%	N%	C/N	P_2O_5 Truog mg %
	Ca	Mg	K	Na							
0-25	14.646	7.608	0.434	0.130	22.818	33.95	67	35.580	2.716	13	0.0190
25-50	12.000	5.484	0.150	0.098	17.732	23.10	76	25.202	1.904	13	0.0170
50-110	8.628	4.920	0.084	0.098	13.730	18.15	75	10.377	1.106	9	0.0105
110-145	7.740	4.878	0.084	0.189	12.891	14.55	88				0.0105

2.1 Avetonou Series

Classification :

- "Sols ferrugineux tropicaux très lessivés hydromorphes"(Togo-French)
- Savanah Ochrosol (Ghana)
- Cambic Arenosols, petroferric phase (FAO)

Locality : Lilie farm
Topo site : slightly undulating plateau
Slope : 5 - 6%
Altitude : 112m

Parent material : gneiss

Vegetation : teak wood

Depth (cm)	Description
0 - 10	Grey (10YR 5/1) dry; loamy sand; structureless, single grain; many fine and medium roots; gradual boundary; pH 6.8.
10 - 60	Greyish brown (10YR 5/2) dry; loamy sand; weak crumb structure; non sticky; non plastic; many fine pores; many roots; gradual boundary; pH 5.8.
60 - 90	Light yellowish brown (10YR 6/4) dry; sand; weak subangular blocky; few roots; abrupt boundary; pH 5.9.
90 - 160	Hard iron pan of variable thickness; abrupt boundary.
160 - 250	Deeply weathered rock with variegated colours: (10YR 7/6) and (2.5YR 4/6); pH 6.2.

AVETONOU SERIES (CAMBIC ARENOSOLS)

DEPTH (cm)	pH		H_2O %	Clay %	Silt %		Total Silt %	Sand %		Organic Matter %	Structural Stability
	H_2O	KCI			fine	coarse		fine	coarse		
0-10	6.8	5.8	0.978	9.250	4.000	9.285	13.285	40.755	38.250	4.2	1.585
0-60	5.8	4.8	0.637	8.500	3.250	8.075	11.325	40.340	40.485	2.5	1.428
60-90	5.9	4.6	0.318	7.500	4.000	8.130	12.130	39.480	40.800		1.739
160-250	6.2	4.9	1.731	30.500	8.000	4.535	12.535	16.490	40.050		1.339

DEPTH (cm)	Cation exchange meq %				S (CEC)	T (TED)	V (S/Tx100)	C%	N%	C/N	P_2O_5 Truog mg %
	Ca	Mg	K	Na							
0-10	4.596	0.762	0.150	0.033	5.541	6.7	82	24.906	1.652	15	0.0475
10-60	1.728	0.582	0.127	0.026	2.463	3.2	76	14.816	1.232	12	0.0105
60-90	0.276	0.372	0.035	0.007	0.690	1.5	46				Traces
160-250	5.028	1.668	0.216	0.078	6.990	10.7	65				Traces

2.11 TB/PC Series

Classification :

Ferric Luvisols, petric phase (FAO)

Parent material : ferruginous sandstones

Vegetation : Grassland with few palm trees.

Locality : On Lomé-Palimé road 4 km north to Noepe

Topo site: Undulating plateau

Slope : 4%

Altitude : 80m

Depth (cm)	Description
0 - 10	Reddish brown (5YR 4/4); dry; sandy loam; weak crumb structure; many small gravels (40 to 50% by volume) many fine roots; few medium roots; gradual boundary; pH 7.2.
10 - 40	Dark red (2.5YR 3/6) dry; sandy clay loam; concretionary and massive horizon; gradual boundary; pH 6.3.
40 - 90	Dark red (2.5YR 3/6) dry; concretionary and massive horizon; abrupt boundary; pH 5.7.
90 - 160	Variegated horizons; many concretionary sandstone stones; concretionary and massive horizon; abrupt boundary; pH 4.9.
160 - 180	Concretionary sandstone boulders.
180 - 300	Deeply weathered rock formations; sandy loam; coarse subangular blocky; pH 5.0

NOEPE-BAGBE SERIES (FERRIC LUVISOLS)

DEPTH (cm)	pH		H_2O %	Clay %	Silt		Total Silt %	Sand %		Organic Matter %	Structural Stability
	H_2O	KCI			fine	coarse		fine	coarse		
0-10	7.2	5.6	1.518	15.750	4.000	6.205	10.205	23.065	50.065	5.3	
10-40	6.3	4.3		30.750	0.250	3.990	4.240	13.005	50.475	2.6	
40-90	5.7	4.7	4.749	61.250	2.750	2.995	5.705	7.935	24.370	2.5	
90-160	4.90	4.00	2.699	33.250	4.750	7.205	11.955	22.480	32.125		3.718
180-300	5.00	4.2	1.978	19.500	6.500	9.110	15.610	26.785	37.800		4.411

DEPTH (cm)	Cation exchange meq %				S (CEC)	T (TED)	V (S/Tx100)	C%	N%	C/N	P_2O_5 Truog mg %
	Ca	Mg	K	Na							
0-10	5.076	1.140	0.579	0.033	7.098	8.2	86	30.836	3.164	10	0.0250
10-40	4.158	1.668	0.303	0.072	6.181			15.418	1.288	11	0.0130
40-90	6.132	3.018	0.354	0.085	9.589	12.7	75	14.825	1.400	10	0.0240
90-160	1.890	1.392	0.111	0.052	3.445	8.6	40				0.0065
180-300	1.746	0.744	0.031	0.033	2.554	5.2	49				0.0105

APPENDIX C

FAO SEMINAR ON THE EVALUATION OF SOIL RESOURCES
IN WEST AFRICA (Kumasi - 1970)

RECOMMENDATION NO. 5

Recommendation No. 5:

International Standardization of Soil Survey Methods

The Seminar :

Recognising the need to standardize terminology, methodology and classification in the survey and interpretation of soils in order to facilitate exchange of knowledge and experience between countries,

Recommends that soil survey organizations throughout West Africa should actively encourage mutual acceptance of standardized techniques and, in particular, should adopt the Legend of the FAO/UNESCO Soil Map of the World as a system of reference to unify the cartography of soils in West Africa, correlating soils classified in existing national systems of soil classification with the units of this Legend; and

Suggests that the Director-General of the Food and Agriculture Organization could further this aim by appointing a soil correlator to the FAO Regional Office, Accra, for the specific purpose of assisting Member Countries of West Africa in this endeavour. This correlator should be asisted by a committee of three or four national correlators.

APPENDIX D

PAPERS PRESENTED BY DELEGATES

SOIL CORRELATION IN GHANA

By

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I. INTRODUCTION

Soil correlation is defined as "the scientific method by which the set (or combination) of all the significant characteristics of each soil is specifically compared with the sets of characteristics of the already defined and named kinds of soils in the natural or taxonomic system of soil classification and thereby the soil gets its name and its place in the system" (Kellogg, 1959). As defined above, soil correlation, therefore, seems to be indispensable to the development and maintenance of a system of soil classification designed to fulfil the objectives of soil survey and mapping within a particular country or environment. The basic essentials of soil correlation as intimated by Kellogg (Kellogg, 1959) are obviously setting of standards for describing the characteristics of soils within their environments, defining the kinds of soils as specific combinations of their characteristics by the synthesis and description of like soils and finally developing, maintaining and continuing revision of existing system of soil classification.

Soil correlation, to be effective in grouping similar soils in such a way that they can easily be placed under categories of a system of soil classification within a nation, must be organized on a precise plan of field work. Firstly, the soils of an entirely new area being surveyed must be identified and given tentative names based on the five factors of soil formation. Secondly, they must be correlated with similarly identified soils within that particular soil survey region of the country and finally they must be correlated in relation to the soils of the ecological zone of the country for which they form a part. The criteria used in identifying and naming soils on the series level in the past depended upon the background or special interests of the scientists responsible for classifying the soils. Since earlier workers in Ghana were either geographers or geologists, there was, therefore, a greater reliance on environmental features e.g. geomorphology and geology than on actual soil characteristics as observed from the soil profile. Serious problems were therefore encountered in the development of a local system of soil classification which could be designed to allow an easy evaluation of the soils in terms of their practical utilisation.

II. EARLY TRENDS IN THE CORRELATION AND CLASSIFICATION OF THE SOILS OF GHANA

1. General

Organized soil surveys in Ghana with a view to taking an inventory of the soil resources of the nation as a basis for efficient development of agriculture began some twenty-seven years ago. This was at a time when very little systematic soil surveying had been carried out in the tropics and since it was not deemed enough to transfer systems successfully used in temperate latitudes, earlier workers had to devise ways and means by which the soils of the country could be investigated and mapped as accurately and as quickly and cheaply as possible.

2. Soil mapping and correlation

The system of soil survey employed consisted of mapping soil associations on a preliminary or reconnaissance scale and then examining by detailed methods small sampled areas within each association with a view to obtaining a more accurate pattern of the soils in relation to, especially, relief and drainage. By this technique practically all the soils of a region were recognised and described, their relationship to one another worked out and their general distribution and areal significance determined. Regional soil surveys of such a nature provided the framework with which more detailed surveys of particular areas of the country were undertaken for immediate agricultural development.

The pioneers in the field of soil survey and classification in Ghana as intimated earlier were mainly geographers and geologists. There was an obvious bias, therefore, in relying more on environmental factors rather than on the characteristics of the soil profiles in the identification and naming of soil series and in the development of a local system of soil classification. Too much emphasis was laid, especially, on geomorphology and geology. Many soil series were established mainly due to observed differences in geology and land features. Such environmental characteristics were often without quantitative basis. There were,therefore, obvious difficulties with later attempts to correlate existing soil series with similarly developed soils in neighbouring countries and with groups established in the local classificatory systems notably the U.S. (U.S.D.A., S.C.S., 1960, 1967) and the French system (Aubert, 1965).

3. Charter and Brammer's local classification system

By 1954, considerable data had been accumulated to justify an attempt at developing a local scheme of soil classification. C.F. Charter,the first Director of the Soil and Land-use Survey Department in the then Gold Coast (now Ghana) therefore, took the opportunity to prepare a colloquium on soil classification with particular reference to the tropics based mainly on his experiences in West Africa and the Carribean Islands. Charter had hoped to present his soil classification scheme at the VIth International Soil Congress in 1956 but died before the Congress was held. Brammer who succeeded Charter as the head of the soil survey organization in the then Gold Coast compiled the scheme from notes Charter left behind (Brammer, 1956).

The approach to Charter's scheme described in detail by Brammer (1956, 1962) is mainly based on ideas underlying some of the earlier European and American systems of soil classification primarily on one or a combination of the factors of soil genesis instead of on characteristics or properties of the soils which can be observed and/or quantitatively determined.

Although several attempts were made by various soil scientists in Ghana to classify some major soils of the country into the scheme proposed by Charter e.g. Obeng (1959, 1960), Ahn (1961), Brammer (1962) and Smith (1962), it was difficult to correlate individual soils so classified, with similar soils developed elsewhere in the world. This was because during the time of Charter and Brammer and until 1962, detailed soil profile description as in use in temperate regions was not done in Ghana. Soil horizons were simply divided into topsoil, subsoil and weathered substratum in cases of well developed profiles which have been developed in situ, often referred to as sedentary soils.

The topsoil referred to a horizon showing accumulation of organic matter and this was further subdivided into topsoil I and II based mainly on differences in colour and feeder root density. The subsoil was considered to contain no appreciable amount of organic matter but altered by soil forming processes to such an extent as to leave no trace of the weathered or the unweathered parent rock. This horizon was further subdivided into subsoil I and II and occasionally III in the so-called sedentary soils. This subdivision, was however deleted in cases where a soil is characterized by a homogeneous subsoil. Such soils were considered to have been developed in transported materials rather than in situ over the underlying rock. These were locally referred to as "drift soils". Finally, the weathered substratum was considered to be the horizon made up of the weathered parent material but retaining some characteristics of the parent rock. Although this system of horizon differentiation could have been fitted into the ABC nomenclature with the elimination of the old concept that only horizons distinctly illuvial with respect to A should be considered as B, no positive attempt was made. If this attempt had been made there would not have been much difficulty in fitting the soils of the country into recent classification where the ABC horizon designations have been employed in describing soil profiles.

Obeng *et al.* (1963) in reviewing the scheme proposed by Charter and Brammer (Brammer, 1962) found a weakness in basing their main criteria on factors of soil genesis and processes of pedogenesis. This they considered as undesirable since as rightly stated by Asamoa (1961) in the choice of factors, Charter and Brammer have allowed theories to over-rule observable facts. At the then stage of soil studies in Ghana it is generally agreed that Charter and Brammer could not have based their scheme on any other criteria than those they employed.

III. CURRENT TRENDS IN THE CORRELATION AND CLASSIFICATION OF THE SOILS OF GHANA

1. General

Late in 1959 there developed a growing feeling among soil scientists in Ghana, notably de Endredy, Obeng and Smith, that it was high time an improvement was made on the correlation of the soils of Ghana and on the existing local classification system introduced by Charter and Brammer (Brammer 1962). The main reason was to try to base the criteria for the classification of the soils of the country on current concepts of soil genesis with a definite bias towards quantitative criteria which could be evaluated in terms of efficient development of agriculture.

2. Correlation of soils on the series level

Currently soil profiles are being described in more detail employing the ABC horizon nomenclature. Identification and naming of individual soil series are also being based on the characteristics of the soils themselves as observed from the profile and quantitatively from laboratory data without being too much influenced by environmental factors like geology and land forms. Several soil series separated in the past, mainly because of differences in topsoil texture and in the geology of the area, are now being grouped together with a view to eventually reducing considerably the number of established soil series. Most of these groupings of soil series into one or a few series, mainly, concern colluvial and alluvial soils which have similar profile and physico-chemical and mineralogical characteristics but occur within different geological formations.

3. Correlation of local soil groups with similar groups of other world soil classificatory systems

In an effort to improve upon the scheme proposed by Charter and Brammer, several attempts were made to define the categories in terms of internal attributes in the hope of finding a practical basis for the classification. These attempts, however, as stated by Obeng et al (1963) were time consuming and consequently had to be restricted to a limited number of soils, as such the results were far from conclusive. In 1960 therefore, on the introduction of the U.S.D.A. Seventh Approximation on a comprehensive system of soil classification, it was decided to attempt to place the categories of Charter and Brammer into this more recent system in which the criteria have been based upon directly observable attributes.

Before attempting such a task, however, the horizons occurring in a number of representative soils of Ghana had to be identified according to the ABC horizon nomenclature of the U.S.D.A. system (USDA, SCS, 1960, 1967). As stated elsewhere, Charter and Brammer did not encourage the use of the ABC horizon nomenclature since they felt that a structural B-horizon was seldom easily recognised in the majority of the soils of the tropics. Obeng et al (1963) however, in evaluating data on particle size distribution of a number of soil profiles in Ghana noted that in non-eroded soils, a fairly conspicuous textural B-horizon was present, usually in combination with an argillic horizon within this B. de Endredy (1963) obtained further evidence by estimating 'free' iron oxides in the B-horizon or within the boundary between B and C.

Having established evidence for the presence of B-horizons in the soils of Ghana, attempts were made to fit some of the Great Soil Groups of Charter and Brammer into the likely categories of the new U.S. system (USDA, SCS, 1960, 1967). Those readily lending themselves to such an attempt were the Tropical Black, Brown and Grey Earths (Obeng et al 1963, Obeng 1970b). The Groundwater Laterites, Oxysols and Ochrosols however, presented innumerable difficulties. Firstly, the criteria for their classification within the new U.S. system especially so far as the lower categories are concerned, have not been well defined. Secondly, much of the required data on them are unavailable due to the fact that the necesaary equipment for determining the properties concerned cannot be obtained locally. It has therefore been decided to wait until sufficient quantitative laboratory data as required in the new U.S. system are available before attempting any placement of the soils within the lower categories of the system. As shown on the attached soils map of Ghana a successful attempt has, however, been made on the higher categorical levels in correlating the existing Soil Groups with those under the U.S. system (USDA, SCS, 1960, 1967), the French system (Aubert, 1965) and the FAO/UNESCO legend of the Soil Map of Africa (FAO/UNESCO, 1968, 1970).

IV. SUMMARY AND CONCLUSION

Soil correlation as intimated earlier is indispensable to the development and maintenance of a soil classification system worthy of fulfilling the aims of soil survey and mapping within a particular country. In most developing countries soil surveys and mapping are mainly undertaken with a view to evaluating existing soils in terms of their suitability for increased and sustained crop and livestock production. Soil correlation must, therefore, in these less developed areas of the world, aim at grouping soils with similar characteristics which can easily be evaluated in terms of the practical agricultural utilisation.

In Ghana soil correlation and classification in the past were not based on criteria which could be quantitatively determined and thus easily evaluated in terms of the suitability of the soils for increased agricultural production. Recent efforts in employing quantitative criteria based on profile characteristics and chemical and mineralogical properties have enabled soil scientists not only to correlate existing soil series more accurately but also to successfully correlate the local Soil Groups on the highest categorical levels with others within existing world classificatory systems. It is hoped that such legend construction in which local soil groups have been successfully correlated with similar groups of other world soil classification systems will help in quickly drawing from experience elsewhere in the practical utilization of indigenous soils.

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LES RESSOURCES EN SOLS DU TOGO ET LEUR IMPORTANCE DANS LE DEVELOPPEMENT AGRICOLE REGIONAL

par

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1. LE CADRE GEOGRAPHIQUE

1.1 Position et Superficie : Situé dans l'hémisphère Nord, en Afrique Occidentale, le Togo s'étend entre 6° et 11° de latitude Nord et en longitude entre le méridien de Greenwich et le méridien 1°40'. La majeure partie du territoire est cependant comprise entre 0°30 et 1°30' Est. Pour une superficie de 56.000 km2, le Togo a une longueur d'environ 600 km de la Côte Occidentale d'Afrique (Golfe du Benin) aux frontières de la République de Haute-Volta au Nord; une largeur de 45 à 140 km des frontières du Ghana à l'Ouest à celles du Dahomey à l'Est (Fig. n° 1). Administrativement le Togo est divisé en cinq régions groupant dix-sept circonscriptions.

1.2 Géologie:- Le Togo est essentiellement formé de terrains précambriens sur lesquels s'étendent au Nord la bordure primaire de la pénéplaine de Mango, au Sud la bordure sédimentaire du Territoire.

1.2.1 Les séries précambriennes de direction N.NE - S.SO sont constituées par quatre formations qui reposent en discordance les unes sur les autres. La plus ancienne de ces formations : le "Dahomeyen" est très métamorphisé. Il est formé de gneiss et de micaschistes de toutes sortes.

"L'Atakorien" est une série de quartzites et de micaschistes interstratifiés qui constitue la barrière montagneuse des Monts Togo de direction N.NE - S.SO (Fig.no.2). Les sols dérivés de ces formations sont le plus souvent des lithosols et des sols peu évolués.

La série dite de Kandé forme une zone pénéplainée d'une dizaine de kilomètres de largeur à l'Ouest des Monts Togo. Elle est essentiellement formée de roches schisteuses (séricitoschistes et chloritoschistes) avec parfois intercalation de quartz et de quartzites. Leur altération permet la formation de sols sableux à sablo-argileux plus ou moins profonds.

Le "Buem", la plus récente des séries précambriennes, est formé de grès quartziteux dont l'altération donne naissance à des sols peu évolués avec, aux pieds des collines, des sols sablo-argileux rouges.

1.2.2 Le Primaire : Il est représenté au Togo par le Cambrien et l'Ordovicien. Le Cambrien de nature schisteuse et grèseuse forme la vaste pénéplaine de Mango alors que l'Ordovicien essentiellement grèseux donne naissance à une ligne de falaise : cuesta de Bombouaka, de Nano.

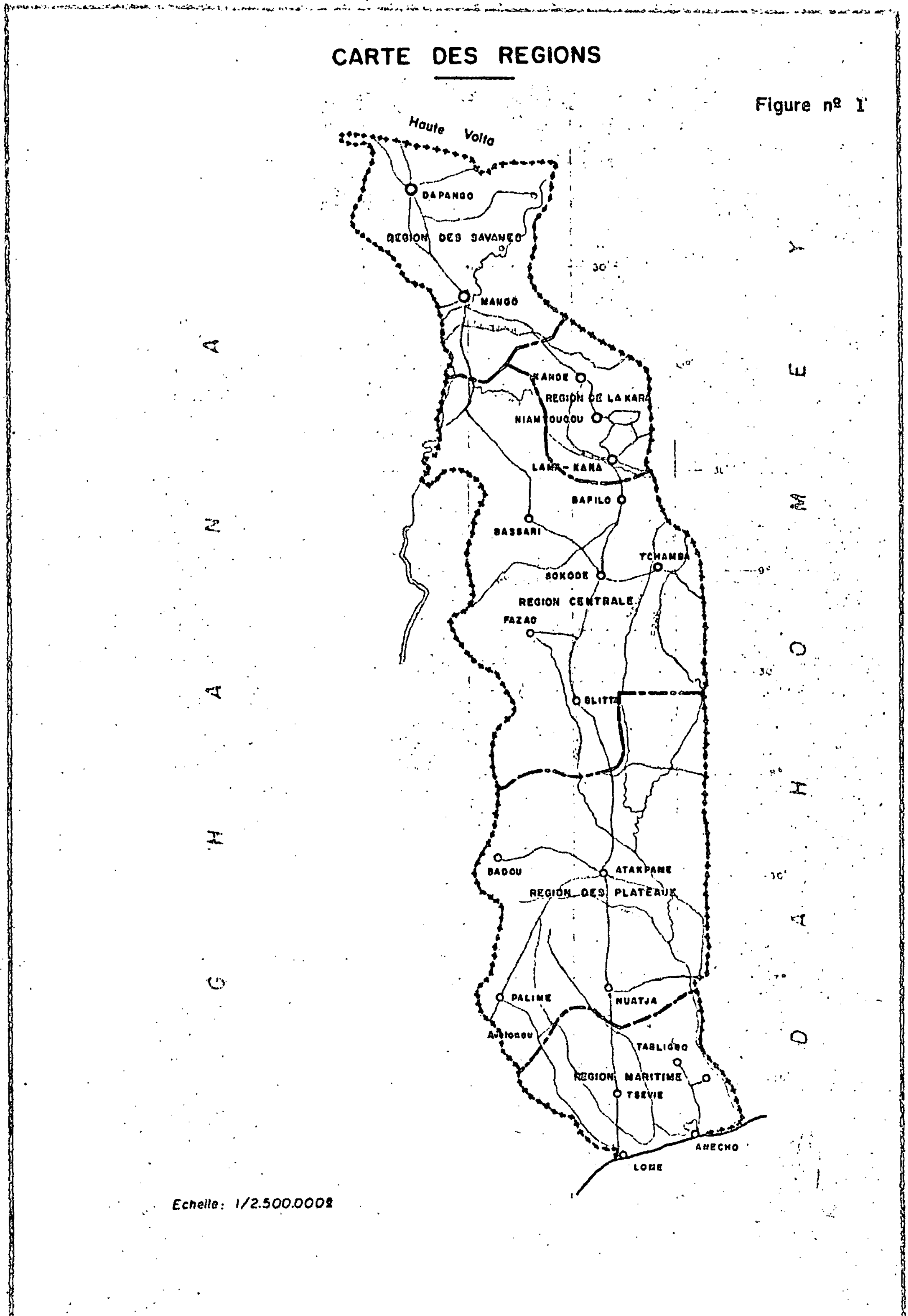
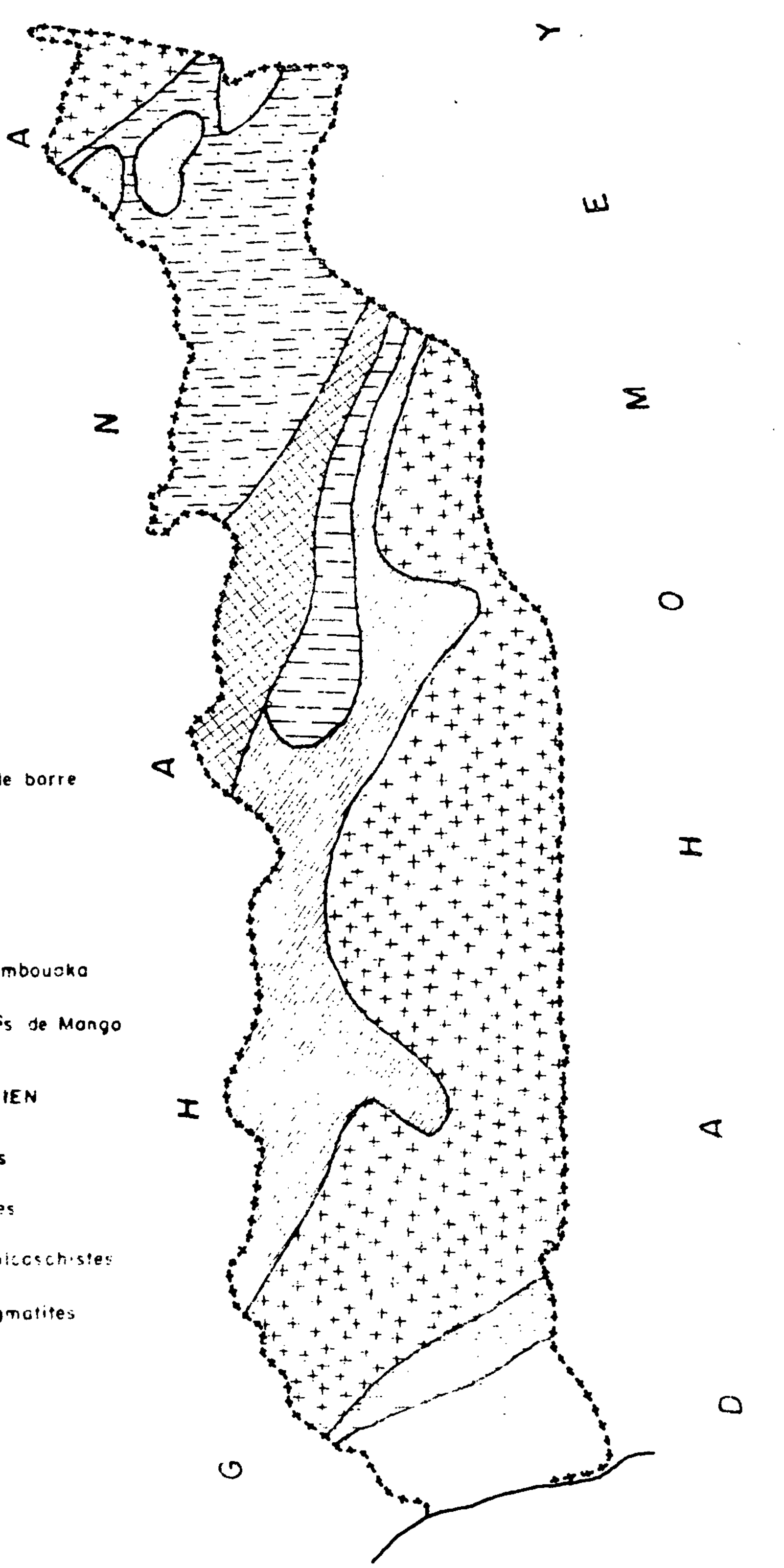

CARTE DES REGIONS
Figure nº I
Haute Volta
DAPANGO
REGION DES SAVANES
MANGO
KANDE
REGION DE LA KARA
NIAMTOUGOU
LAMA-KARA
BAFILO
BASSARI
TCHAMBA
SOKODE
REGION CENTRALE
FAZAO
BLITTA
BADOU
ATAKPAME
REGION DES PLATEAUX
PALIME
NUATJA
TABLIGBO
REGION MARITIME
TSEVIE
ANECHO
LOME
G H A N A
D A H O M E Y
Echelle: 1/2.500.000

Figure nº 2

ESQUISSE GEOLOGIQUE DU TOGO



LEGENDE

TERTIAIRE

Post - Eocène = " Terre de barre

Eocène = Calcaire

PRIMAIRE

Ordovicien = Grès de Bombouaka

Cambrien = Schistes et grès de Mango

PRECAMBRIEN

Buem = Grès et quartzites

Serie de Kandé = Schistes

Atakorien = Quartzites micaschistes

Dahomeyen Gneiss, migmatites

Echelle: 1/2.500.000e

1.2.3 Le Tertiaire: Il est formé d'une part de dépôts marins, argilo-marneux et calcaires qui longent le socle de Togblékopé à Tokpli, et, d'autre part, de formations détritiques sablo-argileuses du "Continental Terminal" qui constituent les Terres de Barre du Sud Togo.

1.2.4 Le Quaternaire : Il forme le cordon littoral sablonneux sur lequel se trouve les agglomérations de Lomé et d'Anécho.

1.3 Relief : D'une façon générale, le Togo est un pays de faible altitude. En effet, plus de la moitié du territoire a une altitude inférieure à 200 m tandis que le sixième à peine dépasse 400 m. Le point le plus élevé du Togo culmine à environ 1000 m (Atilakoutsé).

1.4 Hydrographie : Les rivières du Togo se groupent en trois réseaux appartenant à trois régimes distincts :

- au Nord, le réseau de l'Oti à régime tropical; débit d'étiage très faible mais non nul, maximum en Septembre .

- au Centre et au Sud-Est, le réseau du Mono; régime tropical de transition : étiage très faible, crues en Septembre - Octobre.

- au Sud, le réseau du Sio et du Haho, régime équatorial, crues en Juin ou Juillet et en Octobre.

Les lits de ces différents cours d'eau sont plus ou moins importants suivant les types de terrains qu'ils traversent. Au Sud nous trouvons la plaine du Sio et du Mono, la Kara au Nord-Est a un lit très encaissé, tandis que l'Oti, plus au Nord, traverse une plaine alluviale large d'au moins 10 km.

CLIMAT

1) Généralités

Le Togo subit l'influence de deux aires anticycloniques :

- au Nord : l'anticyclone du Sahara qui dirige les alizés du Nord-Est et l'harmattan.
- au Sud : l'anticyclone de Saint-Hélène qui dirige la mousson du Sud-Ouest, vent océanique, humide qui apporte la pluie.

La zone de contact entre ces deux aires anticycloniques : le Front Intertropical, règle les variations climatiques sur le Togo. En effet ce Front se déplace suivant le mouvement apparent du soleil ; en été il atteint sa position septentrionale extrême ; les masses d'air humides de l'anticyclone Sud amènent les pluies; en hiver le Front est au voisinage de la côte ; c'est la saison sèche, bien connue par son vent desséchant: l'harmattan.

Ainsi donc, deux types de climat se partagent le Togo ;

- de la côte à la latitude 8°20 N règne un climat de type équatorial caractérisé par deux saisons pluvieuses et deux saisons sèches d'inégale durée.
- de 8°20 N à la latitude 11° N règne un climat de type tropical caractérisé par une saison pluvieuse et une saison sèche.

2) Les Données du Climat

Les Précipitations - Elles présentent les caractéristiques suivantes :

- hauteurs de pluie assez faibles dans le Sud; pluies abondantes dans le moyen Togo, faibles au Nord.
- pluies assez bien réparties si l'on considère les moyennes.
- pluies irrégulières par suite des variations inter-annuelles trop importantes.

Les pluies sont inférieures à 1 000 mm sur la côte malgré sa position par rapport à l'équateur; sur la pénéplaine précambrienne elles varient de 1 100 mm. à 1 400 mm jusqu'à la latitude de Bassari (9°15N) pour décroître ensuite et être de l'ordre de 1 000 mm à la latitude 11°N. Les régions montagneuses du Klouto, de l'Akposso et de la Kara reçoivent des pluies supérieures à 1 500 mm.

Températures

Les températures moyennes mensuelles enregistrées sont les suivantes :

Mois / Poste	Janv	Fev.	Mars	Avril	Mai	Juin	Juil	Août	Sept.	Oct.	Nov	Dec.
Lomé	26,6	27,9	28,2	27,9	27,5	26,0	25,3	24,8	25,4	26,3	27,0	26,8
Atakpamé	26,6	27,7	27,5	26,5	26,0	24,4	23,8	23,5	24,0	24,9	26,1	26,4
Sokodé	26,2	27,6	28,5	27,9	26,8	25,5	24,5	24,2	24,8	25,7	26,4	25,6
Niamtougou	26,7	28,3	29,3	28,6	27,3	25,5	24,3	23,9	24,6	25,8	26,6	26,4
Mango	27,4	29,3	31,8	31,6	30,5	27,3	26,2	25,7	26,2	27,5	28,2	26,9

L'examen du tableau ci-dessus fait ressortir :

- un gradient thermique du Sud au Nord
- un maximum en Mars à toutes les stations
- un minimum en Août
- une amplitude saisonnière assez faible (3 à 6°) indiquant une constante thermique remarquable.

Humidité relative : - Le tableau suivant résume les valeurs moyennes obtenues à partir des données disponibles.

Mois / Régions	Janv.	Fev.	Mars	Avril	Mai	Juin	Juil	Août	Sept	Oct	Nov	Dec
Lomé	80	80	79	79	77	84	85	85	84	81	80	80
Atakpame	58	61	63	73	76	81	84	82	82	79	70	64
Sokodé	40	45	55	66	73	79	84	86	84	77	63	47
Niamtougou	31	35	50	64	68	76	82	82	82	73	61	40
Mango	27	28	38	53	64	73	78	83	87	74	53	31

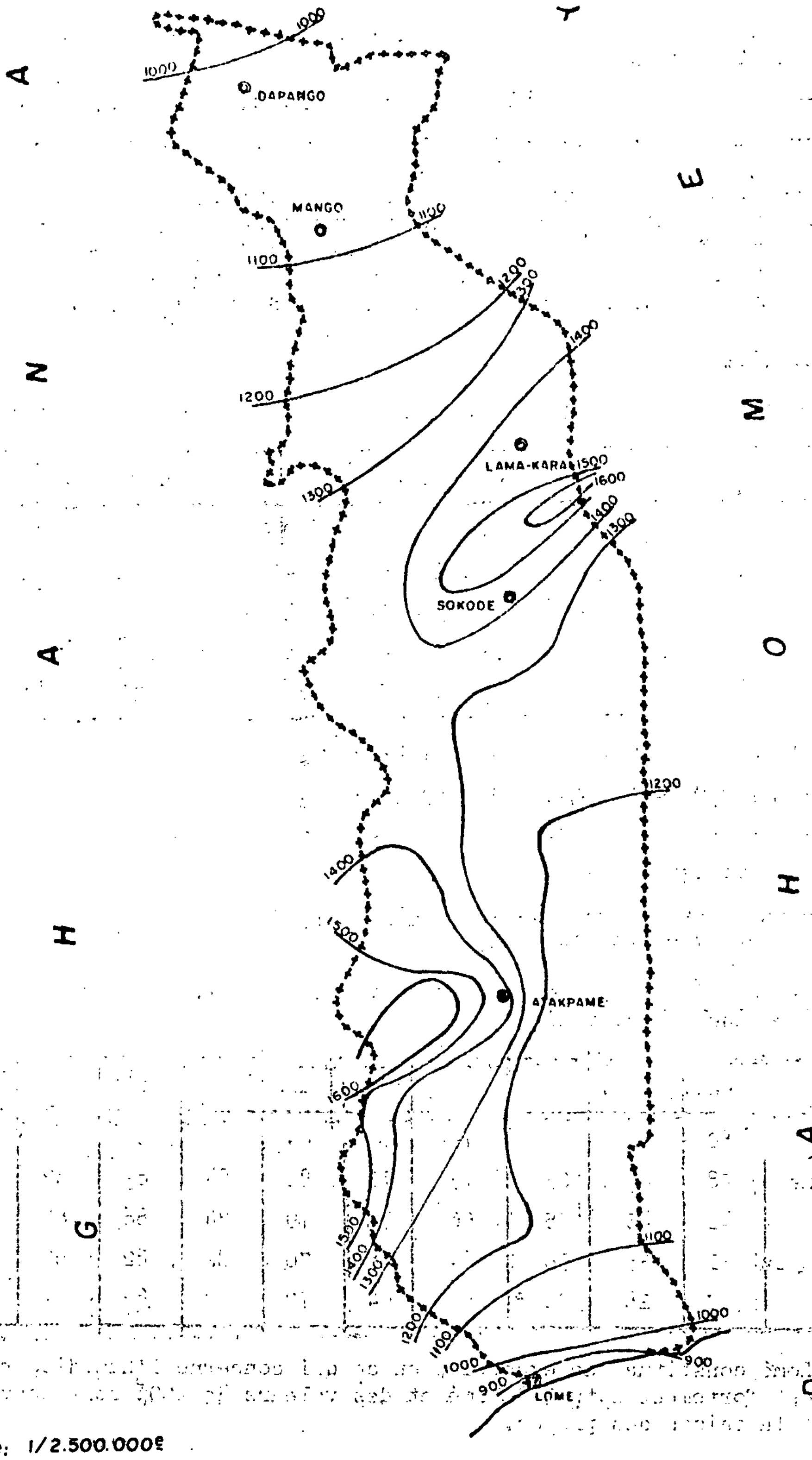
Lomé constitue une exception en ce qui concerne l'humidité relative. En effet l'air est fortement saturé à Lomé et des valeurs de 100% sont souvent atteintes pendant la saison des pluies.

CARTE PLUVIOMETRIQUE

Figure n° 3

ISOYETTES NORMALES

FIN 1970



Echelle: 1/2.500.000e

En dehors de cette exception, nous pouvons constater que dans les autres stations l'air est plus sec, donc plus évaporant de Novembre à Mars, qu'il existe ici aussi un gradient qui va d'Atakpamé vers le Nord.

La Végétation

Aucune étude systématique n'ayant été entreprise sur la végétation du Togo, nous nous référons aux approches très générales d'Aubreville, de Hutchinson et Dadziel, de G. Roberty et de nos propres relevés sur le terrain pour caractériser les types de formations végétales que l'on rencontre au Togo. Du Sud au Nord nous avons :

- Le Lido : c'est le domaine du cocotier (coco-Nucifera) avec en sous bois du Chiendent des Bermudes (Cynodon Lactylon), de la Pervenche de Madagascar, des Opuntia et des Passiflores.

- La jachère arbustive des terres de barre. C'est une formation extrêmement dense et généralement non stratifiée, constituée d'arbustes de 2 à 5 mètres de haut suivant l'âge du recru et sans tapis herbacé. On y recontre : Sterculia Tragachanta, Milletia Thoningii, Fagara Xanthaloïdes, Uvaria Chamos, Dichrostachys Glomerata que dominent ça et là, Adansonia Digitata, Irvingia Gabunensis et Elaeis Guinensis.

La Savane boisée

Elle est de loin la plus importante des formations végétales du Togo. Elle s'étend du Nord des plateaux des Terres de Barre jusqu'à la latitude 11° N. Au niveau des Monts Togo elle laisse la place à une forêt soudano-guinéenne très secondarisée. Elle est plus ou moins dense en fonction de l'emprise de l'homme et de la pluviomètrie. On y rencontre : Afzelia Africana, Pterocarpus Erinaceus, Butyrospermum Parkii, Adansonia Digitata, Parkia Billobosa, Burkea Africana, Lophira Alata, Daniella Oliverii, Isoberlinia Doka en formation principale. La strate arbustive est à base d' Hymenocardia Acida, Terminalia Avicennoïdes, Vitex Cienkowskyi, Bauhinia Reticulata, Gymnospora Maytenus, Combretum Micrathum.

La strate herbacée comprend : Andropogon sp., Pennisetum Polystachyon, Loudetia Togoensis, Ctenium Elegans et ..... Imperata Cylindrica.

La Forêt Guinéenne des Monts Togo

Il s'agit d'une formation très secondarisée sur laquelle l'influence de l'homme est prépondérante. Elle occupe les zones pluvieuses et montagneuses des régions des Plateaux et Centrale. Les espèces caractéristiques de cette formation qui abrite les caféiers et les cacaoyères du Togo sont : l'Antiaris Africana, le Chlorophora Excelsa, Triplochyton Scleroxylon, Ceiba Pentadra, Terminalia Superba, Cola Cordifolia, Khaya Senegalensis, etc.

II. LES SOLS

A) GENERALITES ET DIFFERENTS TYPES

Nous devons à Monsieur LAMOUROUX un inventaire systématique des sols du Togo au 1/1 000 000. Les études sectorielles détaillées entreprises par la F.A.O. et le concept Géopédologique adopté par la D.P.E.G. pour ses prospections ont permis de mieux localiser les différents types de sol de même que leurs aptitudes culturales.

Les sols du Togo sont intéressés par tous les phénomènes classiques de pédogenèses à savoir : la ferruginisation, la ferrallitisation, l'induration, le lessivage, les remaniements, l'hydromorphie, la salinisation.

Parmi les onze classes de la classification française, huit ont pu être reconnues au Togo. Ce sont par ordre d'importance :

1-1) La classe des sols ferrugineux tropicaux (Ferric, Plinthic Luvisols) : environ 35 000 km2 localisés au socle précambrien granito-gneissique sous une pluviométrie de 1 000 à 1.300 mm, à deux saisons très marquées, du 11° parallèle jusqu'au niveau de Chra (7°30) et à deux saisons de pluie d'inégale durée suivies de trois à quatre mois de grande saison sèche de Chra jusqu'à la latitude 6°35 Nord.

1-2) La classe des sols peu évolués (Fluvisols et Regosols) : 9 670 km2 généralement associés aux sols minéraux bruts ou développés sur les colluvions et alluvions diverses. On les rencontre à peu près partout à travers le territoire national.

1-3) La classe des sols ferrallitiques (Ferralsols, Nitosols), 6 360 km2, géographiquement se présente soit sous forme d'une série de plateaux dans le bassin sédimentaire de la Région Maritime, soit sous forme d'îlots reliques dispersés sur le socle précambrien ou de sols de pentes ou de plateaux développés à partir d'un matériau schisteux ou quartzito-micacé des Monts Togo et de l'Atocora.

1-4) La classe des vertisols (Vertisols) 2 400 km2 environ, relativement abondants dans le Moyen Togo où ils se répartissent "en pastilles échelonnées suivant des axes N.S. le long de l'Anié, du Mono et de l'Ogou". Dans la Région Maritime ils occupent la majeurs partie de la dépression de la Lama et se rencontrent aussi dans les vallées du Sio et du Mono. Dans la Région de la Kara, ils se localisent autour des Monts Assiré et dans la Plaine de Pagouda.

1-5) La classe des sols hydromorphes (Gleysols) : environ 2 200 km2 soumis à l'action de l'eau sur la presque totalité du profil pendant toute ou partie de l'année Géographiquement, ils sont eux aussi dispersés à travers le Togo et le plus souvent localisés soit dans des zones déprimées ou des talwegs plus ou moins soumis à l'action de l'eau, soit le long de presque toutes les rivières du territoire sous forme d'un mince ruban.

1-6) Classe des sols à Mull (Cambisol) 200 km2 environ représentés surtout par des sols bruns eutrophes développés sur roches-mères riches en base.

1-7) Classe des sols minéraux bruts (Lithosols) 300 km2 environ localisés dans les zones à forte pente soumises à l'érosion et sur les affleurements du socle granito-gneissique.

1-8) Classe des sols halomorphes (Solonetz) : 50 km2 environ formant les prés salés de la Région Maritime du Togo.

B. REPARTITION REGIONALE DES DIFFERENTS TYPES DE SOLS

Les différentes catégories de sols se répartissent approximativement comme suit à travers les cinq régions du Togo.

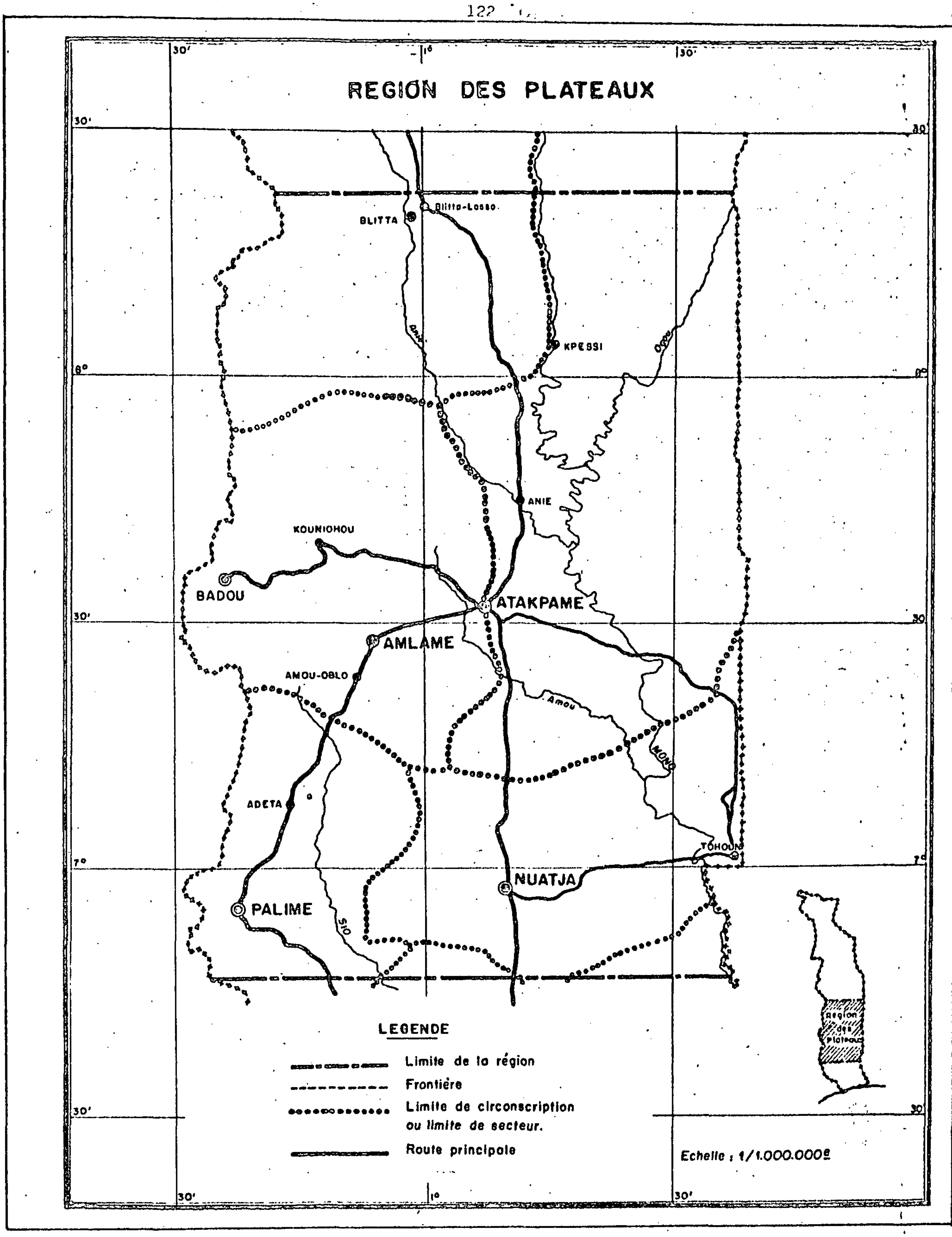
Catégorie de sols en Km2 Régions	Sols Ferrugineux tropicaux	Sols peu évolués Sols Min. Bruts	Sols Ferralli-tiques	Vertisols	Sols Hydromor-phes	Sols à Mull	Sols Halo-morphes
Maritime	2 840	500	1.890	150	600	0	50
Plateaux	11 000	2 200.	2 150	1 510	260	120	0
Centrale	13 000	5 070	1 360	530	250	20	0
Kara	2 230	1 050	940	130	60.	0	0
Savanes	6 000	1 260	0	0	1 120	50	0

L'importance de la classe des sols ferrugineux tropicaux est prépondérante dans toutes les cinq régions du Togo. Plus de la moitié de ces sols est affectée par des phénomènes de lessivage et de concrétionnement et par l'érosion.

Quant aux autres classes de sols ils se rencontrent plus ou moins dans les différentes régions.

Les sols togolais sont, pour une grande part, menacés par l'érosion. Suivant les différentes régions, cette menace est plus ou moins marquée. En appliquant la formule proposée par Fournier (1962) dans l'évaluation quantitative des tonnages de terre relevée chaque année par les eaux, nous obtenons les ordres de grandeur suivants et par région.

Régions	Erodibilité des Sols Tonnes /Km2	Types de Sols en cause le plus souvent
Maritime	1 000	- Ferrugineux et - Ferrallitiques surtout
Plateaux	1 000	- Ferrugineux - Peu Evolués - Ferrallitiques
Centrale	1 000	- Ferrugineux - Peu Evolués
Kara	1 000	- Ferrugineux et - Peu Evolués et Ferrallitiques
Savanes	1 000	- Ferrugineux surtout


REGION DES PLATEAUX
BLITTA
Blitta-Losso
KPESSI
ANIE
KOUNIOHOU
BADOU
ATAKPAME
AMLAME
AMOU-OBLO
Amou
MONO
ADETA
TOHOUN
NUATJA
PALIME
SIO
LEGENDE
Limite de la région
Frontière
Limite de circonscription ou limite de secteur.
Route principale
Echelle : 1/1.000.000e

Il ressort de ce tableau que les régions de la Kara et des Savanes sont de loin les plus menacées; le problème est plus aigu dans la Kara qui compte plus de 50 habitants au km2.

Les sols du Togo sont cultivables dans une proportion de 50 à 90% suivant les régions, alors que les superficies cultivées sont de l'ordre de 6 à 40%.

C. DESCRIPTION DES TYPES

1. Les Sols Ferrugineux Tropicaux

Comme il a été dit dans le chapitre précédent, ils sont de loin les plus importants au Togo. Ils sont de nature très variés et sont dans leur ensemble affectés par des processus d'hydromorphie, très souvent par le lessivage du fer et son individualisation sous forme de concrétions ferrugineuses.

Etude d'un type

Sols Ferrugineux Tropicaux Lessivés sans concrétions

Profil type : Série FOKPO

Non loin de Fokpo (zone d'Avétonou) dans le domaine de Togo Plantation, sous une savane boisée à Butyrospermum Parkii, Anogeissus Leocarphus nous avons observé :

0 - 15 cm	10 YR 5/2 gris brun sableux, structure particulaire, consistance friable, perméabilité rapide, enracinement abondant; horizon uniforme à démarcation distincte; pH 6,65.
15 - 50 cm	10 Y/R 6/4 beige sableux avec des grains grossiers délavés; structure particulaire, consistance friable, perméabilité rapide, enracinement moyen, horizon uniforme à limite nette; pH 7,3.
50 - 110 cm	10 YR 6/4 beige sableux légèrement argileux, structure faiblement grumeleuse; consistance friable; perméabilité rapide; enracinement faible; horizon uniforme à passage distinct; pH 6,5.
110 - 140 cm	10 YR 6/3 beige, sablo-légèrement argileux structure massive; consistance faiblement friable; perméabilité modérée; nombreuses taches 10 YR 6/8 contrastantes; pH. 6,4.

La principale variation observée résulte d'une part de l'intensité du lessivage d'argile et de la présence, **parfois** à moins d'un mètre, d'un horizon argilo-graveleux.

Données Analytiques

La granulométrie montre une prédominance du sable sur les éléments fins. Le taux d'argile est presque toujours important aux environs de 100 cm .

La matière organique est moyennement abondante en surface, le taux d'azote est moyen à faible, tandis que le rapport C/N est satisfaisant.

Le complexe absorbant de capacité faible à moyenne est à dominance de calcium et de magnésium; le taux de potassium est faible; le pH est souvent de l'ordre de 6.

Aptitudes Culturales

Malgré leur pauvreté en éléments minéraux, il s'agit d'assez bons sols qui conviennent partout où la pluviométrie est suffisante à des cultures pérennes. Toutefois, les zones de pentes longues même peu déclives, devront être protégées de l'érosion.

2. Les Sols peu Evolués d'Erosion

Profil type : Série AGBE

Dans l'Akposso, sous une savane herbeuse claire soumise à l'action périodique des feux de brousse, nous avons décrit un sol sableux, gris brun, peu profond, à drainage excessif se présentant comme suit :

0 - 10 cm	10 YR 5/2 (sec) gris brun clair, sable généralement grossier, peu humifère; structure particulaire; peu cohérent; cailloux de quartz, blocs de quartzite anguleux; quelques concrétions de très petites tailles; horizon ondulant à passage distinct.

Au dessous de 10 cm. Quartzites fissurés dans lesquels pénètrent les racines des Andropogonac et de quelques jeunes pousses de Lophira Alata.

Variations

La profondeur de ces sols est très variable suivant les endroits, la nature de la roche et la position topographique. A Kandé ils atteignent au moins 40 cm sur les grès du Buem.

Données Analytiques

La granulométrie est dominée par la présence d'une forte proportion d'éléments supérieurs à 2 millimètres, formés principalement de cailloux anguleux qui sont des débris de roche. Le taux d'argile varie de 4 à 8%.

La matière organique a un taux suffisant en surface, le taux d'azote est faible.

Le complexe adsorbant a une capacité d'échange moyenne en surface, qui diminue fortement au-dessous. Le taux de saturation est supérieur à 70 en surface, mais très bas au niveau de la zone altérée, suivant les variations du pH.

Aptitudes Culturales

Ces sols doivent être mis en défens, afin que la végétation arbustive puisse s'y développer et surtout qu'ils ne constituent plus une menace d'apports grossiers sur les sols voisins.

3. La Classe des Sols Ferrallitiques

Ils sont tous plus au moins désaturés et forment dans la Région Maritime la série sidérolithique des Terres de Barre; dans la région montagneuse togolaise on les trouve en position de pente ou sous forme de vastes plateaux; sur la pénéplaine précambrienne ils se présentent sous forme de "buttes-témoins", restes d'une époque plus humide. Ces sols occupent une place importante au Togo, moins par la surface qu'ils couvrent que par leur valeur agricole.

3.1 Sols Ferrallitiques Typiques

Ils se forment sous une pluviométrie de 1 300 à 1 700 mm dans les Monts Togo et dans l'Atacora. De couleur rouge, ils sont généralement bien drainés. Les roches-mères qui leur ont donné naissance sont de nature très diverses : roches riches en bases, micaschistes et schistes quartzeux, colluvions variées.

3.1.1 Sols Ferrallitiques moyennement désaturés, remaniés

Profil type : Série DOUME

Le long de l'axe routier Copé-Doumé (Akposso-Plateau) sous une jeune cacaoyère à aspect très satisfaisant que dominent de beaux spécimens de Chlorophora Excelsa, de Terminalia Superba, nous avons observé un sol sablo-argileux brun rouge d'aspect suivant:

0 - 13 cm	7,5 YR 5/1 (humide) brun sablo-argileux; structure grumeleuse fine, friable et meuble; poreux; enracinement abondant, bonne perméabilité et bonne activité biologique ; horizon uniforme à passage graduel; pH 5,90.
13 - 44 cm	7,5 YR 7/6 (humide) brun clair; sablo-argileux; structure polyédrique grossière; consistance friable; nombreux cailloux de moyennes dimensions, enracinement abondant; bonne activité biologique; horizon uniforme à passage distinct; pH 5,80.
44 - 100 cm	10 R 5/8 (humide) rouge, argileux, structure massive mais secondairement polyédrique grossière; perméabilité moyenne, consistance friable; légère adhérence; présence de quelques cailloux de quartz; horizon uniforme à passage net; pH 4,90.
100 - 180 cm	10 R 6/8 (frais) rouge, argileux, structure massive, perméabilité moyenne; consistance friable, enracinement nul; pH 5,10.

Les variations observées concernent surtout la couleur et l'épaisseur des horizons.

Données Analytiques

La teneur en argile, de l'ordre de 20% en surface, passe à 60% aux environs de 50 cm.

La matière organique est présente en forte quantité dans l'horizon de surface et décroit très rapidement avec la profondeur.

La complexe adsorbant de moyenne capacité est bien pourvu en calcium et magnésium. Il est bien saturé en surface mais décroit vite avec la profondeur. La teneur en potasse est partout très faible.

Aptitudes Culturales

Profonds, argileux et bien structurés, bénéficiant d'une pluviométrie assez forte, ces sols sont d'excellents supports pour les cultures pérennes telles que le cacao, le café, le palmier à huile.

4. Classe des Vertisols

Ces sols se rencontrent surtout dans le Moyen-Togo et dans la région maritime. Ils sont généralement très argileux et se sont développés à partir de formations riches en bases (pyroxénites, amphibolites, diorite, calcaires, etc.).

4.1 Vertisols topomorphes à drainage externe imparfait, de la dépression de la Lama

SERIE D'ELIA

On rencontre les sols de la série d'ELIA exclusivement dans la dépression de la LAMA, à l'exception d'une petite zone dans la pénéplaine précambrienne, sur roche-mère différente (diorite à gabbro). La roche-mère de ces sols est une marne à attapulgite dans laquelle sont souvent concentrés d'assez gros nodules calcaires. Ceux-ci peuvent parfois être si abondants qu'ils constituent la véritable roche-mère du sol; il en est ainsi à l'Est du Lac ELIA et à l'Ouest d'AKLADJENOU, dans des zones limitées. Aucune des autres roches constituant les étages géologiques du Paléocène à l'Iprésien n'a été reconnue dans les sondages. Il est probable que les affleurements ont été fortement remaniés, des éléments à texture argileuse les ayant recouverts à peu près en totalité. De nombreux bancs calcaires peu épais, probablement nodulaires, sont intercalés dans l'argile.

En général les sols de cette série occupent le dessus des croupes et des zones de bas-plateaux. Le microrelief est généralement plat, avec des fentes de petites dimensions découpant des surfaces polygonales d'un diamètre moyen variant entre 2 et 5 cm sous couvert naturel, un peu plus large sous culture.

Le couvert naturel est une savane boisée moyennement dense. La croissance de la végétation est très rapide dès les premières pluies.

Morphologie

Le profil suivant a été pris sur une croupe avec pente de 0,25 pour cent :

0 - 20 cm	5 Y 2/1 ou 2/6, noir; argile ou "loam" argilo-sableux; structure grumeleuse fine, forte; plastique; peu adhérent; perméabilité moyenne; enracinement abondant; épaisseur uniforme; limite nette avec l'horizon sous-jacent; pH de 5,9 à 6,9.
20 - 50 cm	2,5 Y 2/0 ou 3/0, noir ou gris foncé s'éclaircissant progressivement vers le bas; argile ou argile sableuse; structure grumeleuse ou nuciforme, moyenne, à cassure terne, modérément développée, légère tendance prismatique; peu adhérent; plastique; enracinement moyen; épaisseur uniforme; limite nette; pH 6,2 à 7,1.
50 - 120 cm	5 Y 2/1 et 5/1, gris très foncé et gris par petites taches peu contrastantes; argile ou argile sableuse; structure massive à grossièrement polyédrique; cassure brillante; peu adhérent, très plastique; enracinement peu important; épaisseur uniforme, limite nette pH de 4,8 à 7,1.

120 - 160 cm   5 Y 4/1, gris foncé sans taches; argile ou argile sableuse; structure comparable à celle de l'horizon précédent; très plastique; épaisseur uniforme; limite nette; pH 6,4 à 7,8.

160 - 220 cm   5 Y 5/1 et 2,5 Y 7/8 bariolé gris et jaune-beige; argile ou argile sableuse s'enrichissant en nodules calcaires jusqu'à 200, s'appauvrissant au delà; épaisseur variable; limite nette; autres propriétés identiques à l'horizon précédent; pH de 7,4 à 7,6.

220 - 340 cm   Horizon identique au précédent non calcaire, représentant la partie inférieure non enrichie en calcaire de la couche de 160 à 340.

340 - 370 cm   5 Y 5/1 gris fortement tacheté de 7,5 YR 6/8 ocre; argile sableuse; couche riche en gros nodules calcaires; autres propriétés comme l'horizon précédent. La couche précédente et celle-ci alternent jusqu'à 400 cm.

Les variations du profil en général sur la profondeur du profil, qui peut se réduire jusqu'au 50 centimètres seulement au-dessus d'une épaisse couche calcaire de nodules soudés comme c'est le cas à l'ouest d'AKLADJENOU, en bordure de la zone alluviale du MONO. En d'autres lieux le profil varie entre 120 et 250 centimètres d'épaisseur. On observe également des variations dans la profondeur d'apparition des nodules calcaires, ces derniers ne remontant pas plus haut que 80 à 70 centimètres dans les profiles suffisamment profonds. Quelques concrétions manganésifères et nodules d'apatite apparaissent quelquefois.

On observe de long des pentes un passage de séries ELIA à LAMA et en zone de plateau un passage de LAMA à GLADJOE, sans que cette disposition ait une caractère obligatoire.

Le drainage superficiel de ces sols est lent à cause de leur pente faible. Le drainage interne est rapide au début des averses si le sol est sec, car la surface qui est alors fortement craquelée permet une pénétration rapide de l'eau. Dès que le gonflement de l'argile a fermé toutes les fissures, ces sols deviennent absolument imperméables. Par contre, le pouvoir de rétention de l'eau de ces sols est très élevé. Le régime d'humidité est considéré comme étant imparfait.

Données analytiques

Cinq profils de la série ELIA ont été analysés :

- la granulométrie est très argileuse (45 à 65 pour cent d'argile dans la LAMA, un peu moins sur gabbros) et les limons fins atteignent ou même dépassent 10 pour cent. Les nodules calcaires représentent 13 à 50 pour cent en poids en profondeur, en mélange avec quelques concrétions.

- la matière organique est abondante, varie de 3,5 à 8,5 pour cent dans l'horizon de surface, et ne diminue notablement qu'au-dessous d'un mètre de profondeur; le taux d'azote est également élevé et le rapport C/N est supérieur à 10 dans la plus grande partie du profil.

- le complexe adsorbant présente une très forte capacité d'échange (40 à 50 milliéquivalents): il est fortement saturé, très riche en calcium et en magnésium, moins bien pourvu en potassium, qui est peu abondant en profondeur; le pH est assez proche de la neutralité.

- les réserves minérales sont bonnes en calcium, magnésium et phosphore, mais également déficientes en potassium.

Aptitudes culturales

Grâce à leur bonne structure en surface et leur bonne teneur en matière organique et en éléments minéraux, ces sols sont particulièrement aptes à la culture, et leur extension suffisante permet d'envisager la mécanisation; elle sera indispensable pour disposer les terres en planches bombées permettant un assainissement suffisant. Des précautions devront être prises pour le travail du sol à cause de l'engorgement possible. On pourra y cultiver: maïs, riz pluvial, coton, canne à sucre, éventuellement igname, tabac et bananier, ou même cultures maraichères. Certaines de ces cultures demanderont cependant des apports potassiques.

5. Classe des Sols Hydromorphes

Ces sols qui sont périodiquement influencés par l'eau sont de nature texturale très variée; en effect ils peuvent être:

- sableux, quand il s'agit de colluvions de bas de pente ou d'alluvions de bourrelets de berges.
- limoneux, alluvions non loin des berges
- très argileux, alluvions des zones deprimées.

Ils peuvent former des mélanges ou des alternances de textures variées, suivant les fantaisies de l'alluvionnement.

Ils appartiennent aux sous-classes moyennement organiques à gley et minéraux à gley et/ou pseudo-gley d'ensemble ou de profondeur.

Profil Type : Serie SIO

Les sols de la série du SIO ont la même origine que les sols des séries d'AGNI et CANNE,mais ils en diffèrent parce que le drainage est très mauvais. On les trouve dans les mêmes zones que ces derniers.

Les sols de la série de SIO occupent les parties basses des plaines de débordement et sont inondés pendant plusieurs mois chaque année.

La végétation est essentiellement à base d'espèces hygrophiles,surtout des cypéracées. Dans les zones arborées à Mitragyne Inermis, une litière de feuilles recouvre le sol.

Morphologie:

Un profil sous végétation herbacée se présente comme suit :

0 - 10 cm   3/0 gris très foncé; argile humifère ou "loam" argileux; structure grenue ou nuciforme moyenne, modérée; très adhérent et très plastique; enracinement très dense; perméabilité moyenne en début d'averses; porosité tubulaire; épaisseur variant de plus ou moins 5 cm; Passage graduel l'horizon sous-jacent; pH de 5,2 à 6,2.

10 - 30 cm	4/0, gris foncé; nombreuses taches de 7,5 YR 5/6 brun vif et 2.5 Y 8/8 jaunes, diffuses, de dimensions moyennes; argile; structure nuciforme moyenne, faible; très adhérent et très plastique; enracinement moyen; épaisseur très variable; limite distincte; perméabilité faible jusqu'à la base du profil; pH de 5,7 à 6,1;
30 - 50 cm	5 YR 5/1 et 7,5 YR 6/8; bariolé gris et ocre; argile; structure massive; adhérent et très plastique; quelques concrétions moyennes; enracinement faible; épaisseur uniforme; passage graduel à l'horizon sous-jacent; pH de 5,1 à 6,5.
50 - 90 cm	2,5 Y 6/2; gris-beige clair, nombreuses taches de 7,5 YR 5/8 brun-ocre de taille moyenne, argile; massif adhérent, très plastique; quelques concrétions moyennes; épaisseur uniforme; passage graduel à l'horizon sous-jacent; pH de 5,1 à 6,4.
90 - 130 cm	5 Y 6/2, gris olive clair, quelques fines taches, 2,5 Y 5/1, gris et 7,5 YR 5/6 brun vif; texture et structure comme l'horizon précédent; concrétions ferrugineuses et manganésifères; pH de 6,9.

Une variation importante de cette série, c'est la phase sableuse du profil où environ 5 à 24 centimètres de sable ou de "loam" sableux, gris très foncé à l'état humide, constituent la couche superficielle de la série du SIO sableux. Le changement est net avec le "loam" argileux gris et ocre. On trouve la phase sableuse dans l'axe des talwegs où la vitesse de l'eau semble suffisante pour y apporter et y déposer le sable. La phase sableuse a un microrelief particulier avec des buttes de 15 à 60 centimètres de hauteur. L'horizon supérieur noir pénètre dans les horizons sous-jacents. Les limites en sont marquées par un éclaircissement progressif, plus diffus que dans les séparations horizontales des horizons. La présence de quelques gravillons et morceaux de cuirasse a été parfois observée. Dans toutes les zones d'eau stagnante avec végétation de marais; le gley domine dans tout le profil et les mouchetures ocres ou rouilles sont rares. Le long des talwegs qui débouchent sur les lagunes, il arrive parfois que les sols de la série du SIO soient inondés d'eau saumâtre. Quelques centimètres de la surface sont alors salins après le retrait des eaux, jusqu'à ce que le sol ait été lavé par les pluies. Enfin, dans le secteur du Bas-MONO, les sols de la série du SIO ont un sous-sol salin à plus d'un mètre; dans les mêmes secteurs l'on trouve les séries CANNE et d'AGNI à sous-sol salin. Le pH du sous-sol salin est supérieur à 6,5 et la structure du sol est cubique ou prismatique grossière.

Les sols de la série du SIO sont liés aux séries CANNE, d'AGNI, de DOUKPO, de SEME, de KEZON, d'ADJOBLA et de WATIGOME. Le passage à la série de SEME se fait parfois par l'intermédiaire de la série du SIO sableux.

Le drainage externe de ces sols est très lent et le mouvement interne de l'eau est presque nul, aussi le régime d'humidité est-il très mauvais. Les processus de gleyification qui mettent le fer à l'état ferreux y sont dominants. Ces sols sont engorgés d'eau plusieurs mois par an.

Données analytiques

Cinq profils de la série du SIO ont été analysés :

- la granulométrie est encore argileuse, mais le taux d'argile est parfois plus faible que celui des séries d'AGNI et CANNE, voisin de 40 pour cent; la fraction sableuse est plutôt riche en sables fins.

- la matière organique est très abondante, en particulier dans l'horizon proche de la surface qui contient des matières mal décomposées; le taux d'azote élevé et le rapport C/N subit les mêmes variations que dans les séries d'AGNI et CANNE.

- le complexe absorbant, de capacité moyenne à forte, est riche en calcium et magnésium, mais pauvre en potassium; l'ion Na est assez abondant en profondeur dans la vallée du MONO; le taux de saturation est peu supérieur à 50 pour cent, bien que le pH soit généralement voisin de 6, et parfois plus élevé en profondeur.

- les réserves minérales sont élevées en calcium et magnésium, faibles à moyennes en potassium, mais parfois très faibles en phosphore; l'argile est constituée pour une forte proportion par de la montmorillonite associée à la kaolinite et à un peu d'illite; les traces de goethite observées proviennent de concrétions fines qui sont assez fréquentes dans ces sols.

Aptitudes culturales

En raison de leur très mauvais drainage, ces sols ne peuvent convenir actuellement qu'à la riziculture inondée ou comme paturages de saison sèche. La culture de la canne à sucre nécessitera des aménagements importants, ainsi sans doute que des apports d'engrais, surtout potassiques. Un léger drainage devrait en outre permettre de les cultiver sur billons en saison sèche, pour les cultures vivrières.

6. Classe des Sols à Mull

Ils appartiennent à la sous-classe des sols à "Mull" des pays tropicaux et au groupe des sols bruns eutrophes tropicaux. Ils sont, suivant les endroits, ferruginisés et/ou hydromorphes.

Profil Type: Serie WOUKPE

A l'angle de la route Palimé - Avetonou et de la piste menant à Woukpé à 30 m environ du croisement et sous cacaoyers en très bon état nous avons décrit :

0 - 50-cm — 5 YR 3/1 gris sombre humifère à grumeleuse; friable bien poreux; perméable; bonne activité biologique; bon enracinement; horizon uniforme, démarcation graduelle.

50 - 110 cm — 5 YR 4/4 brun rougeâtre, argileuse, vers le bas quelques concrétions de petite taille, polyédrique anguleux; friable; quelques racines; moins poreux que l'horizon précédent, mais quelques gros pores dû à l'activité des vers; perméable; moyennement adhésif; bonne activité; biologique; démarcation graduelle.

110 - 140 — 7,5 YR 5/4 brun beige; horizon argileux-concrétionné mais assez perméable aux racines.

Les sols de cette série sont assez variables quant à la couleur de l'horizon superficiel qui peut être grise, la présence ou non de concrétions dans le second horizon, le régime d'humidité variant du modérément bon au bon.

Données Analytiques:-

La texture est le plus souvent à dominance d'éléments fins. La somme limon + argile est souvent supérieure à 50%.

Les pH sont de l'ordre de 6.

La matière organique est présente en assez forte proportion.

Le complexe absorbant est variable suivant la nature du matériau originel; il est généralement assez riche en bases et très saturé.

Aptitudes Culturales :-

De par leur richesse, ces sols conviennent à tous les types de culture pourvu que la pluviométrie s'y prête. Dans la région des plateaux, ils sont plantés en cacaoyers, caféiers et palmiers.

7. Classe des Sols Halomorphes

Ce sont des sols riches en sel (chlorures) et qui couvrent 5.000 hectares environ en bordure des lagunes du Sud-Togo. Ils sont généralement argileux à argilo-sableux.

Profil Type : Serie LEBE

Les sols de la série de LEBE occupent une bande étroite dans la plaine de débordement inondée à la fois par la rivière du SIO et le Lac TOGO, l'argile de ces sols salins est d'origine alluviale et semble être d'une grande épaisseur. Elle provient de l'accumulation, en eau saumâtre, des sédiments que transportent les eaux de la rivière du SIO. Ces sols occupent la première plaine de débordement située à quelques dizaines de centimètres seulement au-dessus du niveau normal de la rivière du SIO en saison sèche.

Seuls quelques arbustes aquatiques et des herbes de marécage croissent sur ces sols.

Morphologie : Le profil sous végétation herbacée est le suivant :-

0 - 5 cm. 10 YR 2/2 et 3/3 brun très foncé et brun foncé, mélange d'argile et de matière organique filamanteuse partiellement décomposée; structure polyédrique, grossière, faible; consistance ferme à l'état humide; plastique et faiblement adhérent; perméabilité moyenne; limite distincte; épaisseur variant de plus ou moins 2 centimètres; enracinement et résidus de tiges abondants; pH de 5,2; chlorures présents.

5 - 16 cm 10 YR 2/1 noir, argile; massive; adhérent et plastique; perméabilité lente; limite distincte; épaisseur uniforme; enracinement modéré; pH 5,2; chlorures présents.

16 - 100 cm 10 YR 4/1 gris foncé; argile; mouchetures fines et rares de 10 YR 5/4 brun et taches de gley grandes et abondantes de 2,5 gris-brun clair et 10 YR 6/1 gris clair; structure massive très adhérente et très plastique; perméabilité faible; enracinement rare; pH 5,2; chlorures présents.

100 cm Masse vaseuse liquide sur laquelle flotte la couche supérieure qui ondule sous les pas. Ce profil a peu de variations qui soient dignes de mention.

Le drainage externe est très lent et le mouvement interne est presque nul. Le régime d'humidité est très mauvais. La nappe phréatique d'eau stagnante est, à la fin de la saison sèche, à environ 70 centimètres de surface. Ces sols sont complètement gorgés d'eau pendant 6 à 8 mois par année.

Aptitudes culturales:

A cause de l'inondation prolongée de ces sols, il est difficile de les utiliser mieux qu'ils ne le sont actuellement, c'est à dire comme pâturages de saison sèche. La salinité et le contrôle de la nappe phréatique sont les problèmes les plus importants à résoudre pour permettre éventuellement la culture du riz.

LA CORRELATION DE SOLS DU TOGO A L'ECHELLE NATIONALE ET INTERNATIONALE

Après avoir situé le Togo et donné une idée sur ses ressources en sols nous nous attacherons dans les lignes qui vont suivre à parler de la corrélation de ces sols tant sur le plan national que régional.

Corrélation sur le plan national: Deux organismes, l'un national (la DPEG) et l'autre étranger (ORSTOM), s'occupent de la cartographie des sols du Togo.

La Division des Etudes Pédologiques et de l'Ecologie Générale utilise le système français de classification des sols (ORSTOM) avec, toutefois, certaines nuances tant au niveau de ses unités supérieures qu'inférieures. Ainsi au concept central d'ordre morphologique et génétique de la série des sols définie par l'ORSTOM, la DPEG en introduit un autre d'ordre technique et pratique qui autorise le regroupement de "plusieurs séries" autour d'une même technique d'aménagement. Ceci ne reste pas sans poser des problèmes d'identification des unités employées pour la réalisation d'autres cartes et leur corrélation sur le plan national.

Fort heureusement, ces problèmes se résolvent d'eux-mêmes au niveau des études de reconnaissance.

Un effort reste tout de même à faire pour harmoniser les deux façons d'approche d'une part et d'autre part pour les rendre complémentaires.

Corrélation sur le plan régional

Sur le plan régional, le Togo de par son étirement en latitude constitue à nos yeux un modèle où doivent se retrouver tous les types de sols appartenant aux pays voisins tels que le Ghana, le Dahomey, la Haute Volta .... etc. La corrélation au niveau régional suppose d'abord une bonne identification de ces types de sols et leur harmonisation au sein d'un même système de classification tel que celui proposé par le séminaire de Kumasi.

C'est pour cela que la carte au 1/200 000 du Togo qu'entreprend actuellement la DPEG a beaucoup de choses à emprunter à la légende FAO/UNESCO de la Carte mondiale des sols.

CONCLUSION

Ce document, malgré son imperfection, met en évidence les différents types de sol du Togo et l'importance qu'ils peuvent revêtir dans le cadre d'une corrélation au niveau régional. La position latitudinale du pays se prête d'ailleurs très bien à une telle entreprise.

Souhaitons tout simplement que les différents délégués y trouvent matière à reflexion pour l'établissement de cartes pédologiques pratiques d'une part et, d'autre part, la base nécessaire aux discussions de ce séminaire.

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DE QUELQUES SOLS SENEGALAIS : LEUR EXTENSION EN AFRIQUE DE L'OUEST

par

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INTRODUCTION

L'antériorité des études pédologiques effectuées au Sénégal par rapport à nombre de pays de l'Afrique de l'Ouest (surtout francophones)(1), a fait qu'un certain nombre de types de sols qui y ont été observés et étudiés, ont de bonne heure et toujours servi de référence et de définition à certaines unités pédologiques dans les différentes classifications françaises des sols.

Il s'agit principalement, tels qu'ils ont définitivement été retenus dans la dernière Classification française des sols (Classification des Sols - édition 1967 - Travaux CPCS 1963-1967), du groupe des Sols bruns arides de la classe des Sols Isohumiques, et du groupe des sols Ferrugineux Tropicaux Peu ou Non Lessivés de la classe des Sols à Sesquioxydes de Fer.

Malgré les vicissitudes qu'a connu la classification française des sols (on peut estimer à plus de quatre, officielles, les différentes classifications qui ont été proposées entre 1956 et 1967), ces deux groupes de sols ont connu, quant à leur position dans les différentes classifications, une étonnante stabilité, qui tient, très probablement dès le départ, à la précision de leur définition et à la particularité de certaines de leurs conditions de formations (climatique et édaphique notamment).

Ces deux types de sols, en raison de la contiguïté de leur aire climatique d'existence et du fait de l'identité de leur matériau originel, sont parfois si intimement associés (en séquences ou chaines de sols) qu'il est parfois difficile de les distinguer (2) (MAIGNIEN - GAVAUD - AUDRY - BOULET - PIAS). Très fréquemment ils représentent, réciproquement les uns par rapport aux autres des cas particuliers en fonction de certaines conditions du milieu.

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(1) "En 1822, l'administration du Sénégal désirant faire constater la nature des terres du pays Walo... a envoyé au Ministère de la Marine cinq caisses contenant des échantillons tirés au hasard de divers points de ce territoire. (Extrait d'un rapport de l'Administration d'Histoire Naturelle en date du 9 décembre 1823).

(2) M. GAVAUD - Au Niger la distinction morphologique entre sols ferrugineux non lessivés et sols subarides brun-rouge est difficile, extrêmement empirique et cela parce que ces sols se sont formés sur les même matériaux, ont le même passé, et ne subissent de nos jours qu'une évolution très faible.
(Etude pédologique du Niger Occidental - Rapport général t. II p. 172.)

Mais la tendance la plus marquée est de considérer les sols bruns subarides (du moins certains sols brun-rouge subarides) comme des cas particuliers de sols ferrugineux tropicaux peu lessivés (1) (PIAS - AUDRY).

Ces seuls faits et analogies justifient l'étude groupée de ces sols au sein d'un ensemble que l'on pourrait désigner par "Sols des régions semi-arides tropicales" ou mieux "sols des régions tropicales sèches à conditions d'aridité marquées".

C'est dès 1923 que deux auteurs (SHANTZ et MARBUT) ont signalé la présence de sols bruns steppiques au Sénégal, les confondant d'ailleurs avec les sols d'argile noire de la région de Bargny.

En fait, il faut attendre les années 1945 - 46 pour trouver la première fois en Afrique de l'Ouest une caractérisation précise des sols bruns subarides tropicaux (G. AUBERT, S. DUBOIS, R. MAIGNIEN).

De la même époque datent également les premières caractérisations des sols de type Dior, identifiés comme étant des sols ferrugineux tropicaux peu ou pas lessivés.

De 1946 à 1959, R. MAIGNIEN poursuivant ses études sur les sols subarides, a dégagé en 1959 dans un remarquable article de synthèse, les grands traits de la morphologie ainsi que les facteurs qui président à la genèse des sols bruns subarides tropicaux. Il a été amené (en discutant leur position dans une classification générale des sols) à les séparer au niveau de la sous-classe des sols steppiques qui se développent dans les régions sèches septentrionales et méditerranéennes caractérisées par un climat frais pendant la saison pluvieuse (à la différence des zones subarides tropicales à température élevée en saison des pluies).

Depuis 1959, divers travaux de cartographie pédologique effectués dans les Républiques de Mauritanie, de Haute-Volta, du Niger et du Tchad (DUGAIN, GAVAUD, AUDRY, BOCQUIER, BOULET, LEPRUN, PIAS) ont permis de préciser quelques caractéristiques morphologiques et analytiques des sols subarides tropicaux ainsi que certains de leurs processus évolutifs.

Les Sols Ferrugineux tropicaux s'ils n'ont pas connu la même fortune d'avoir fait l'objet d'une étude de synthèse, ont, par ricochet, bénéficié, du fait de leur contiguité et de leur association avec les subarides tropicaux, des mêmes études.

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(1) PIAS - Les Sols brun-rouge apparaissent comme d'anciens Sols Ferrugineux Tropicaux peu lessivés où l'individualisation du fer résulte d'une pédogenèse antérieure se traduisant par une évolution différente de la matière organique à l'origine de la steppisation... (In Contribution à l'Etude des Formations Tertiaires et Quaternaires de la Cuvette Tchadienne et des Sols qui en dérivent - Thèse de Doctorat 1968).

I. CONDITIONS ET FACTEURS DE FORMATION - PROCESSUS PEDOGENETIQUES DES SOLS DES REGIONS TROPICALES SECHES A ARIDITE MARQUEE

Tels qu'ils ont d'abord été dégagés, au Sénégal, les conditions de formation ainsi que les processus pédogénétiques qui en résultent, des sols des régions tropicales sèches à aridité plus ou moins marquée se retrouvent avec une remarquable analogie, voire une identité presque absolue dans tous les pays de l'Afrique de l'Ouest où ces sols ont été cartographiés et étudiés.

Au point de vue climatique

Sur toute la zone d'extension de ces sols règne le climat Sahélien qui, Sahélo-Saharien au nord, passe au sous-climat Sahélo-Soudanien au sud.

Ces deux sous climats se caratérisent par une saison pluvieuse brève (deux à trois mois) avec des pluviométries (comprises entre 200 et 500 mm pour le sous-climat Sahélo-Saharien, 500 et 700 mm environ pour le sous-climat Sahélo-Soudanien), réparties en trente ou quarante jours de précipitations. Le maximum se situe en Août ou Septembre. A cette saison, fait suite une longue saison à sécheresse excessive.

Les températures moyennes annuelles sont de l'ordre de 27 - 28°C avec un minimum absolu en Décembre-Janvier de l'ordre de 15°C et un maximum en Avril-Mai en fin de saison sèche où il n'est pas rare de voir le thermomètre atteindre 45 à 48°C.

Le rythme climatique est donc caractérisé par une saison de pluie chaude, brève, suivie d'une très longue saison sèche qui représente le facteur limitant à la végétation et l'évolution de la matière organique.

Le drainage possible à travers les sols, quasi nul à très faible entre 200 et 500 mm, ne peut excéder trois mois dans les zones méridionales plus humides, et les quantités d'eau susceptibles d'y participer sont très faibles.

Il s'agit donc typiquement d'un climat tropical dont la dégradation vers l'aridité s'accentue en se dirigeant vers le nord.

- Concernant les roches-mères et les matériaux originels

Le Sénégal comme en Mauritanie, en Haute-Volte, au Niger et jusqu'au Tchad, les Sols Bruns Subarides Tropicaux comme les Sols Ferrugineux Tropicaux peu Lessivés sont presque exclusivement associés aux formations sableuses d'origine essentiellement éolienne (erg ancien ou récent).

Le terme Ouolof de Dior qui a été adopté et très utilisé dans la littérature pédologique française pour désigner les sols ferrugineux tropicaux, signifie du reste sols sableux.

Mais au sein de ces formations sableuses la nature du matériau joue un rôle déterminant dans la différenciation des sols à l'intérieur d'un même groupe. C'est ainsi qu'en zone subaride, la répartition des sols, en bruns et brun-rouge est étroitement liée à la nature physique et chimique du matériau originel et de la roche-mère. Les sols brun -rouge ont une texture plus légère que les sols bruns et viennent généralement sur roche plus acide que les sols bruns.

Des études plus approfondies reconnaissent cependant dans la différenciation de ces deux types de sol le rôle determinant du Ca et du drainage.

S'agissant des Sols Ferrugineux Tropicaux Peu Lessivés ils ne se développent typiquement que sur des formations généralement très sableuses. En zone subaride ils peuvent occuper des positions assez particulières qui les éloignent un peu de leur milieu édaphique de prédilection.

Facteurs biologiques

La végétation est un facteur de genèse des sols. Pour les sols qui nous concernent (surtout subarides) elle est considérée comme le facteur dominant de leur formation. Cette végétation est représentée par des formations arbustives très ouvertes à base d'épineux et d'un tapis graminéen assez dense mais de faible hauteur qui constitue en fait la source principale de matière organique (davantage par la décomposition du système racinaire):

Quant à l'activité microbienne, elle joue un rôle beaucoup plus important qu'on ne le pensait il y a quelques années.

Plusieurs études ont montré que les processus de minéralisation de la matière organique peuvent se prolonger fort loin dans la longue saison sèche, ce qui explique les faibles teneurs en matière organique.

Dans la zone climatique d'existence de sols subarides, une augmentation de l'humidité aura donc pour effet de réduire encore davantage les teneurs en matière organique. C'est précisément ce qui se passe dans les provinces Ouest du Sénégal où les influences marines, réduisant les caractères de continentalité du climat, favorisent une minéralisation plus rapide de la matière organique. Les sols de ces provinces ont alors tendance à passer rapidement vers les types Ferrugineux Tropicaux Peu Lessivés (R. MAIGNIEN).

Ces derniers se trouvent donc caractérisés par rapport aux sols bruns subarides par une minéralisation plus intense de la matière organique pour laquelle leurs horizons supérieurs accusent des teneurs généralement plus faibles ou du moins une moindre pénétration.

Pour mémoire, comme l'ont signalés certains auteurs, un autre facteur est considéré comme ayant une grande importance dans la pédogenèse des sols bruns subarides tropicaux. Il s'agit du facteur temps.

Des principaux facteurs de formation que nous venons d'examiner, on peut dégager quatre processus pédogenètiques principaux qui contribuent à la caractérisation des sols des régions tropicales sèches à aridité marquée. Il s'agit :

1°/ de la steppisation

2°/ de la carbonatation

3°/ de la ferruginisation

4° du lessivage.

Un cinquième processus : l'hydromorphie intervient très fréquemment qui a pour effet d'accélérer ou de freiner les autres processus. Enfin il faut noter le processus d'alcanisation relativement fréquent.

Alors que les trois premiers processus conduisent à la formation de sols bruns subarides typiques, les deux derniers par contre contribuent plus strictement à la caractérisation des Sols Ferrugineux Tropicaux.

1°/ La Steppisation - traduit une minéralisation assez intense (même aux très faibles humidités) de la matière organique (d'origine essentiellement herbacée) qui conduit à la formation d'acides humiques relativement stables et qui confèrent au sol une coloration foncée dans la gamme des bruns (10 YR du code Munsell).

Des études effectuées sur le fractionnement et la décomposition des produits organiques ont montré que les Sols Subarides Tropicaux étaient avant tout caractérisés par l'importance d'acides humiques H_2 très polymérisés et stables et que le passage aux sols Ferrugineux Tropicaux s'effectuait par une diminution des formes hautement polymérisées, donc un complexe argilo-humique moins stable, et par conséquent, une augmentation des formes peu polymérisées et relativement mobiles qui seront en partie responsables des phénomènes de lessivage (Ch.THOMANN - R. MAGNIEN).

D'autres auteurs quant à eux (DUCHAUFOUR Ph, et DOMERGUE Y.) ont estimé que les sols subarides et les sols ferrugineux tropicaux étaient très comparables du point de vue constitution de l'humus.

Des études plus approfondies restent donc à faire mais quoi qu'il en soit la minéralisation très intense d'une matière organique d'origine essentiellement herbacée (système racinaire) demeure une des caractéristiques des sols de ces régions tropicales sèches à aridité très marquée.

2°/ La Carbonatation - très tôt (R. MAIGNIEN 1948) le rôle du calcium a été mis en évidence dans la répartition des deux types principaux de sols subarides tropicaux.

C'est ainsi que dans le Nord du Sénégal à 10 mètres l'un de l'autre et dans la même position topographique, on a pu décrire un sol brun-rouge subaride nettement défini sur sable faiblement argileux, et un sol brun bien caractérisé sur marno-calcaire.

D'une façon générale, on observe fréquemment à plus ou moins grande profondeur dans les sols subarides tropicaux, un horizon d'accummulation de $Ca\ CO_3$ même lorsque le matériau originel est pauvre en calcium.

Les processus de carbonatation sont cependant beaucoup plus fréquents en sols bruns qu'en sols brun-rouge et sols ferrugineux tropicaux peu lessivés.

Le calcium peut provenir du lessivage des horizons de surface qui sont souvent décalcarisés. Il semble aussi que l'individualisation des carbonates puisse être liée à l'action des racines et à l'activité biologique. Ce serait alors un phénomène spécifique de la pédogenèse des sols subarides.

En zone subaride on peut avoir aussi accumulation de carbonate par le processus de lessivage oblique (P. AUDRY 1961).

Mais il apparait en ce qui concerne les sols ferrugineux tropicaux, que les processus de carbonatation sont surtout liés à des actions de réduction qui se réalisent au niveau des horizons colmatés profonds, proches du matériau originel.

Assez fréquents au Sénégal, Mauritanie, Haute-Volta et Niger, les phénomènes de carbonatation semblent très rares au Tchad. Les rares fois qu'ils ont pu être observés, ils étaient liés soit à un drainage défectueux, soit à des actions de nappe (ancienne ou actuelle).

L'abondance du Ca et du Ca CO_3 joue un rôle important sur l'accumulation et l'évolution de la matière organique et du fer.

3°/ <u>Ferruginisation</u> - La ferruginisation désigne avant tout une assez forte individualisation du fer des roches et des sols. Elle se définit de façon plus précise comme "cette altération moindre où le stade kaolinique n'est jamais dépassé et où la fraction argileuse est composée de ce premier produit pouvant s'associer à de l'illite, de la montmorillonite et des hydroxydes de fer" (PIAG 1968).

Cette individualisation du fer se produit dans un grand nombre de sols.

Dans les sols qui nous concernent elle contribue à donner la couleur brune ou rousse aux sols subarides, plus rouge ou rouge-jaunâtre aux sols ferrugineux.

La couleur plus rouge ne se traduit pas nécessairement par des teneurs en fer libre plus élevées, mais est plus vraisemblablement liée à des formes différentes des hydroxydes (GAVAUD).

4°/ <u>Lessivage</u> - Dans la zone climatique qui nous concerne, les processus de lessivage sont extrêmement réduits dans les sols. L'étude du bilan hydrique montre que les périodes où le drainage peut se réaliser sont très courtes, et que ce drainage n'intéresse que des quantités d'eau extrêmement faibles.

Cependant, l'étude des profils montre que certains éléments ou matériaux sont redistribués entre les différents horizons, ce qui montre la réalité d'un certain lessivage interne; mais celui-ci ne se poursuit généralement pas par une exportation hors des profils. C'est ainsi que l'accumulation du calcaire dans certains horizons de profondeur peut provenir du lessivage des horizons de surface qui se décalcarifient même en roche calcaire. On constate également une certaine redistribution du fer à travers les profils et parfois même un léger lessivage oblique (en sols ferrugineux essentiellement).

Par contre, le lessivage ne porte presque jamais sur l'argile. L'allégement de la texture en surface dans certains de ces sols semble lié à des phénomènes d'appauvrissement dus à l'érosion.

En profondeur, l'augmentation des teneurs en argile correspondrait plutôt à l'apparition des phénomènes de néosynthèse argileuse en milieu plus ou moins engorgé.

Ainsi, en relation avec les caractéristiques du climat, les migrations sont réduites dans les sols des régions tropicales sèches à très forte aridité.

Le jeu des différents processus pédogénétiques que nous venons d'évoquer interfèrent réciproquement pour donner des caractéristiques (morphologiques et analytiques) bien particulières aux sols.

II. CARACTERISTIQUES MORPHOLOGIQUES ET ANALYTIQUES

(Adoptant la classification de R. Maignien)

Le groupe des sols bruns subarides tropicaux est divisé en deux sous-groupes d'après le degré d'évolution de la matière organique répartie à travers les profils, sur la base de la plus ou moins grande rapidité de minéralisation de celle-ci.

Sont distingués :

- des sols bruns proprement dits;
- des sols brun-rouge, dont les horizons humifiés, moins épais, à matière organique plus rapidement minéralisée, laissent apparaître en profoundeur une coloration due à l' individualisation des sesquioxydes de fer.

Les caractéristiques générales de ces sols sont les suivantes :

A. - Sols bruns "sensu stricto"

- Différenciation du profil de type AC, sur une faible épaisseur (moins de 100 cm).
- Coloration foncée des horizons dans les teintes brunes de notations Munsell moyennes: 10 YR 5/3; 4/3 humide. La gamme 7,5 YR est quelquefois utilisée, la gamme 5 YR ne l'a jamais été. La différence de coloration entre les états sec et humide est faible, ne dépassant pas une unité en valeur et en intensité. Cette coloration se maintient jusqu'au matériau originel.
- Horizon de surface généralement bien structuré, à tendance feuilletée dans les premiers centimètres, de type grumeleux à polyédrique en profondeur, à degré de développement généralement faible à moyen.
- Présence fréquente, mais non constante, de carbonate de calcium en quantité variable, sous forme de pseudomycélium, de concrétions ou de nodules, souvent à partir de 30 cm.
- Teneur en matière organique totale faible (inférieure à 1%) mais bonne répartition à travers les horizons - Rapport C/N 10 .
- Individualisation du fer importante (70-75% de fer libre par rapport au fer total), sa couleur est masquée par la matière organique.
- Lessivage des bases faible.
- Milieu généralement bien tamponné.
- Acidité pH neutre à basique.

On observe les variations suivantes liées à la texture du matériau originel :-

- Sur matériaux argileux, les processus de carbonatation sont de plus en plus fréquents et plus développés; ils s'affirment en bas de pente ce qui semble indiquer une certaine migration latérale. Par contre, l'individualisation de CO_3Ca est rarement observée en matériaux sableux.

La structure est également plus développée lorsque le matériau est plus argileux, elle devient de type cubique et s'élargit (sol brun "tirsifié). Une diminution du drainage liée à une texture plus argileuse détermine alors fréquemment le passage graduel à un vertisol.

- En matériau sableux, par contre, une diminution du drainage provoque le passage des sols bruns subarides à des sols hydromorphes à tâches, caractérisés par des horizons humifères plus gris, à C/N plus élevé et pH plus acide. Les horizons profonds des sols hydromorphes présentent également un plus fort durcissement par dessiccation.

B. Les sols brun-rouge.

- Epaisseur plus grande des profils (parfois 200 cm).
- Présence de deux horizons distincts :

Un horizon de surface humifère d'au moins 50 cm d'épaisseur, de couleur gris-brun à brun. Les colorations sont fréquemment de type 5/4; 4,4 humide, mais étalées dans plusieurs gammes entre 2,5 YR et 10 YR.

Un horizon rouge pouvant atteindre plus de 100 cm dont la teinte rousse caractéristique - approchant souvent la notation Munsell 2,5 YR 4/6 ou 4/8 - provient non pas d'une accumulation du fer mais de la disparition de la matière organique en profondeur.

- Structure des horizons superficiels légèrement feuilletées, puis souvent mal développée (non fragmentaire) et instable.
- Importante individualisation du fer (80 à 85% de fer libre/fer total)
- Teneur en matière organique totale encore plus faible que celle des sols bruns ($< 0.5\%$). Rapport C/N < 10.
- Début de lessivage des bases.
- Milieu souvent mal tamponné.
- Acidité pH neutre à faiblement acide.

Les sols brun-rouge se développent plus particulièrement sur des matériaux sableux et les variations observées sont liées soit à une limitation du drainage avec passage aux sols bruns ou aux sols hydromorphes, soit à une diminution générale des conditions d'aridité avec passage aux sols ferrugineux tropicaux. Dans ce dernier cas, la caractérisation des profils se fonde sur l'utilisation des critères morphologiques suivants, appartenant aux sols ferrugineux tropicaux :

C. Sols ferrugineux tropicaux peu lessivés

- Horizon humifère moins épais, de 25 à 30 cm, de coloration plus grise; les seules gammes utilisées jusqu'à présent en notation Munsell sont 7,5 YR - 10 YR et 2,5 Y; les valeurs sont plus élevées, comprises entre 4 et 7 et les différences entre état sec et humide atteignent fréquemment 3 unités en valeur et 2 en intensité.
- Horizon sous-jacent peu coloré marquant un début de lessivage en fer
- Horizon profond de coloration jaune à rouge représentant une forte individualisation et même une accumulation de fer.

Vers le sud, les sols subarides passent progressivement aux sols ferrugineux tropicaux non lessivés, dont ils se distinguent difficilement. Les critères de discrimination employés s'appuient sur les données de la pédogenèse;

Horizon humifère :

Sols subarides : épaisseur à moins 50 cm, couleur brune, matière organique bien évoluée, assez bien structurés.

Sols ferrugineux tropicaux non lessivés : épaisseur moins de 30 cm couleur gris-noir; matière organique plus minéralisée, structure instable.

Horizon sous-jacent :

Sols subarides : couleur rousse caractéristique : jamais durci, parfois accumulations calcaires en profondeur.

Sols ferrugineux non lessivés : couleur ocre-rouge, souvent légèrement durcis par dessiccation jamais d'accumulation calcaire .

III. CLASSIFICATION ET PROBLEME DE CORRELATION

Dans le cadre de la dernière Classification des sols utilisée par les pédologues français et qui a été mise au point de 1964 à 1967 par la Commission de pédologie et de cartographie des sols à partir du cadre de la classification déjà élaborée par G. AUBERT et Ph. DUCHAUFOUR , les Sols Bruns Subarides Tropicaux appartiennent à la classe des Sols Isohumiques définis par une teneur progressivement décroissante de la matière organique très évoluée sur plus de 30 cm,un profil de type 1C. (horizon humifère reposant sur la roche-mère) ou A(B)C (horizon humifère séparé de la roche-mère par un horizon B structural).

Au niveau de la sous-classe faisant intervenir les effets du pédo-climat du sol : teneur plus ou moins élevée en matière organique, saturation plus ou moins élevée du complexe absorbant, libération plus forte des sesquioxydes de fer, ils ont été classés dans les Sols Isohumiques.

- à complexe saturé (principalement en Ca)
- à pédoclimat à température élevée en période pluvieuse.
- à teneur er matière organique est très fortement humifiée et à humus très concentré.
- à altération minérale assez poussée (teneur en "fer libre" relativement élevée), d'où résulte une couleur souvent plus rouge du sol.

Un seul groupe a été retenu pour cette sous-classe qui se divise en 5 sous-groupes.

- Brun sub-aride modal
- Brun rouge sub-aride
- Brun sub-aride à pseudogley
- Brun sub-aride vertique
- Brun sub-aride faiblement salé ou alcalisé.

R. MAIGNIEN qui en avait proposé la première classification les subdivise de la façon suivante :

SOUS-CLASSE DES SOLS STEPPIQUES

Groupe des Sols bruns subarides tropicaux

a) Sous-groupe des Sols bruns proprement dits

- Sols bruns typiques
- Sols bruns tirsifiés
- Sols bruns à marbrures
- Sols bruns à taches en profondeur
- Sols bruns à nodules calcaires

b) Sous-groupe des Sols brun-rouge

- Sols brun-rouge typiques
- Sols brun-rouge à concrétions
- Sols brun-rouge à taches et traînées en profondeur
- Sols brun-rouge à nodules calcaires en profondeur

Plus détaillée, cette classification ne permet cependant pas d'englober tous les sols pouvant appartenir à ce groupe. Elle rend davantage compte de la particularité sénégalaise où les phénomènes d'alcalinisation sont rares, mais par contre plus fréquents à l'intérieur du continent (Niger, Tchad, etc.).

Dans la Carte des Sols de l'Afrique au 1/5 000 000 de S. D'HOORE, les Sols subarides tropicaux tels que nous les avons définis appartiennent aux unités G. Sols bruns et châtains des régions arides et Sub-arides divisés en :

- Sols bruns des régions arides et subarides tropicales.
- Sols bruns et châtains des régions arides et subarides méditerranéennes

Enfin, dans la classification mondiale des sols FAO/UNESCO, les sols isohumiques se retrouvent dans l'unité des Xérosols à corréler avec les Mollic Aridisols de la classification américaine.

Pour ce qui concerne les Sols ferrugineux tropicaux peu ou non lessivés, ils sont rangés dans les différentes classifications considérées :

- dans la classe des Sols à Sesquioxydes de fer (ou de manganèse) de la classification française

Sous-classe des Sols Ferrugineux (tropicaux)

Et groupe des Sols Ferrugineux tropicaux peu lessivés

- dans la carte des Sols d'Afrique au 1/5 000 000 les Sols Ferrugineux Tropicaux peu Lessivés n'ont pas été différenciés de façon précise, mais plutôt assimilés aux Sols Ferrugineux sur matériaux sableux.

Dans la Classification mondiale on ne trouve pas d'unité équivalente satisfaisante.

IV. UTILISATION

Les analogies mentionnées au niveau pédologique (processus, évolution et caractéristiques) à travers toute l'Afrique de l'Ouest à propos des sols continuent de jouer quant à leur utilisation.

Elles peuvent être très utiles pour employer ici et là certaines méthodes de mise en valeur utilisées ailleurs avec succès.

L'intérêt principal des sols que nous venons d'étudier est qu'ils sont meubles et faciles à travailler, ils sont aussi généralement profonds et bien drainés. Ces facteurs de fertilité font que malgré les conditions d'aridité, ils sont très largement utilisés et portent des cultures très variées dans les régions relativement humides (Sols Ferrugineux Tropicaux) et dans les zones où les conditions hydriques du sol ne constituent pas un facteur limitant trop important (Sols bruns en zone subaride). Dans les zones plus septentrionales à aridité excessive les sols sont presque exclusivement réservés au paturage de saison des pluies.

L'amélioration de tous ces sols de régions arides peut être obtenue suivant les cas par des jachères protectrices et améliorantes, des soins culturaux, une fumure organique et minérale, le développement de la culture attelée.

Dans tous les cas ils doivent faire l'objet de protection efficace contre l'érosion (hydrique ou éolienne).

Comme nous en avons fait allusion tout au début de notre exposé, et c'est par cette même conviction que nous voulons terminer, la maîtrise et le contrôle absolu de l'eau dans les zones subarides feront d'elles les greniers du monde. Pour la plupart d'entre elles ne l'ont - elles pas été pour les civilisations aujourd'hui disparues?

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SOIL SURVEY AND LAND CLASSIFICATION IN NIGERIA AND ITS CORRELATION PROBLEMS

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I. INTRODUCTION

Land Classification Survey Procedures have remained sensitive to advances in technology. This is why different soil surveyors have different approaches to land classification survey which are geared to the type of soil survey that has proven well where the system was first devised. As a result, Nigeria today has many systems of soil survey. Needless to say, Nigeria, like any other country, has great interest in the development and use of soil survey for the purpose of formulating Agricultural Development Projects throughout the Federation, and particularly in the current 4 Year Development Plan and the subsequent ones. For this reason, a new Division in the Federal Department of Agriculture called Land and Water Resources Division has been created. One of the functions of this Division is to co-ordinate the States' development activities in the field of land capability surveys.

Nigeria is therefore keenly interested in the progress of soil survey and in the development and improvement of methods and techniques which this seminar and subsequent ones may succeed in evolving.

In any attempt to present the problems of soil correlation in Nigeria, a look at the soil survey and/or land classifications used or currently being used in Nigeria is necessary.

Land classification in Nigeria has been carried by principally two organizations:-

a) Nigerian Institutions concerned with soil surveys and consequently land classification, and

b) Outside Agencies giving assistance or contracted to carry out specific surveys for the purpose of advising the Federal Government on places that could be profitably developed.

2. THE NIGERIAN INSTITUTIONS

The Institutions which deal with soil survey and land classification in Nigeria are :-

a) Institute of Agricultural Research, Samaru (to be known as Samaru)

b) Agricultural Research Stations Moor Plantation, Ibadan (to be known as Moor Plantation), and

c) Agricultural Research, Umudike (to be known as Umudike).

These three institutions are now attached to Ahmadu Bellow University, Ife University, and Federal Agricultural Research respectively. They used to be responsbile for Soil Surveys and Land Classifications in the former Northern, Western (Mid-Western inclusive) and Eastern Regions of Nigeria respectively. With the creation of States, Samaru Station became responsible for the Six Northern States (Benue-Plateau, Kano, Kwara, North Central, North-Eastern and North-Western States), Moor Plantation became responsible for theWest and Lagos States and Umudike Station has records covering the three Eastern States (East-Central, South Eastern, and River States). Soil Survey of Mid-Western State which used to be a part of the former Western Region, is being covered by the Soil Section of the Ministry of Agriculture and Natural Resources in the State; of course patterned after the system used at Moor Plantation.

(a) Samaru Method:

The description of Soils in the 6 Northern States by Samaru is done in terms of the D'Hoore Legend. Initially, the method of survey and terminology used was based on either U.S. Soil Survey Manual or G.R. Clarke, Study of the Soil in the field. Today, a modified method based on the two has evolved.

Samaru Soil Survey is mainly at the reconnaissance level with the detailed survey limited to Government experimental farms. For the reconnaissance soil survey, traverses are kept to existing roads and paths wherever possible and trace cutting is resorted to only in exceptional circumstances. On a half degree sheet of approximately 1,200 square miles area, the total length of traverses surveyed is between 100 and 130 miles (14). At the same time, note is taken of the geological boundaries and geomophological pattern of the area being surveyed. As series are met sample pits at a depth of 8 feet are dug in each series. In addition the vegetation encountered is also recorded. The series encountered then are demarcated on the basis of :-

i) Texture of the B horizon

ii) Presence or absence of iron concretions

iii) Difference in soil colour

iv) Depth of soil.

b) Moor Plantation Method:

The classification of soils by Moor Plantation is also at the Reconnaissance level. It is patterned after Moss and Vine's systems of classification. 4 factors are used to classify thesoils into series. These four factors are :-

i) Drainage

ii) Parent material

iii) Major differences in the sub-soil layers and

iv) Minor differences in the sub-soil layers themselves or in their relation to the layers above.

In the field if aerial photos are available, grid survey with traverses at 4 miles are used with inspection holes made every 10 chains. Observations of crops grown are made along the traverse lines so that an idea of what crops are being grown in what series is obtained. On this basis, it has been possible to demarcate soil series that are suitable for cocoa growing in the West; a crop of major economic importance. It has also been possible to place other crops in series that are most suitable to them using the same approach.

(c) Umudike Method:

Like the other soil surveys, the soil survey being done by Umudike is also at the reconnaissance level. Method of survey is Duth oriented but in general it is a combination of Moor Plantation and Samaru system with some modifications. The soil survey method currently in use is that devised by Jungerius. The classification however is adapted from d'Hoove's soils map of Africa (1960). Field observation with serial photos where possible are made at 1 mile intervals along major roads. The series are then classified on the basis of :-

i) Parent material

ii) Drainage

iii) Colour

iv) Climate (rainfall).

3. OUTSIDE AGENCIES

It has been stated earlier that many agencies have had contracts in, or assisted Nigeria to carry out some form of Soil Surveys. It has also been pointed out that these surveys may be for specific areas or general land surveys for the purpose of pointing out specific areas for development and thereby providing guidance for more detailed investigation later. Some of these outside agencies are:-

a) Overseas Development Adminstration (formerly known as Land Resources Division in U.K.)

b) Nedeco (Dutch)

c) U.S.A.I.D.

d) Bureau of Reclamation of the United States Department of Interior

e) F.A.O.

Each of these agencies on arrival starts with a review of the past work done if any and later devises its own system patterned wholly or partially after its home system. As a result of this procedure there are many systems of land classification which at first sight might look similar, but on looking at each closely it would be observed that there are significant differences particularly in the method for gathering data.

4. PROBLEMS IN SOIL CORRELATION FOR PLANTING AND EXECUTING AGRICULTURAL DEVELOPMENT PROGRAMMES

An attempt was made to start soil correlation in Nigeria in the early '60s by Nigerian institutions concerned with Soil Survey. Meeting between Moor Plantation and Umudike were made. Similar meetings were being arranged to get all interested institutions involved but this met with failure as a result of the Civil War. Since then, nothing has been done in this direction though the need for soil correlation is well known by all interested in the field.

However, problems that seem pertinent to soil correlation in Nigeria, particularly in using the data for planning and executing agricultural development programme, could be briefly stated as follows :-

a) Standards, terminology, methodology and interpretation of data differs and as a result it becomes difficult to equate one series with the other. Moss, a Soil Scientist, and a formulator of one of the Soil Survey Systems in use in Nigeria has "tried unsuccessfully to modify the classification evolved during the Otta Survey to incorporate that of Vine, and also to apply Vine's classification as it stands to the Otta Soils" (1). From this it follows that a reclassification is required in most cases when one system of classification is to be fitted to the other; a technique which is both time consuming and costly.

b) Some of the series described are based on scanty information whereas others are based on studies of many soil samples from an extensive area. From this it could be seen that the danger of such a classification is obvious because the definition may not be applicable elsewhere even though the soils could be so closely related as to be of the same series.

c) Some surveys are for specific crops whereas others are for general purposes.

5. CONCLUSION

An important objective of a soil survey is the interpretation of the completed maps. Soil Survey interpretations furnish the map user with information about each kind of soil. They explain the behaviour of the soils and point out alternative uses. The interpretations are predictions and their reliability is only as good as the data used in their preparation. If the data is abundant and accurate the interpretations will have more lasting value than if the predictions are based on opinions or scanty evidence.

The survey methods used in Nigeria so far as has been pointed out are at the reconnaissance level and lack uniformity. For correlation work to start in Nigeria soil survey systems, a start should first be made to unify the method of data collection, interpretation and reporting so that series named by one survey party are understood by another without having to go through a re-classification exercise.

May be this seminar may consider it necessary first to request each country to unify its soil survey methods and classifications if this has not been done, before thinking in terms of Zonal Soil Correlation like the one this first sub-committee meeting intends to do.

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OPPORTUNITIES OFFERED BY FAO/UNESCO SOIL MAP OF THE WORLD FOR REGIONAL COOPERATION IN EVALUATING SOIL RESOURCES IN WEST AFRICA

BY

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The FAO/UNESCO World Soil Map Project is a commendable example of international collaboration and cooperation. Its major achievement was to evolve and arrive at an internationally accepted soil nomenclature and definition.

The presentation of the Soil Map of West and East Africa at the FAO Soil Evaluation Seminar, Kumasi (1970) and at the Soil Fertility Meeting sponsored by the East African Community, Morogoro, Tanzania (1972) led to the adoption by the above conferences of the international soil legend as a system of reference to unite the cartography of soils in the respective regions and to correlate soils classified in existing national systems with the units of this legend. These are encouraging trends for furthering international collaboration in matters of soil evaluation in the region. The aim of this paper is to rapidly summarise the concept of the Soil Map of the World and focus attention on the possibility of utilizing the international legend as a base for initiating soil correlation at national and regional level; such correlation should aim at a better understanding and evaluation of major soil units in the Region.

The FAO/UNESCO Soil Map of the World

The legend of the Soil Map is based on a monocategorical classification of soil units based on morphological definitions of the profile; efforts have been made to have them correspond to major soil genetic groups.

Soil definitions have been made as concise as possible by using, on the one hand American diagnostic horizons and, on the other hand, a system of designating horizons by letters O, A, E, B, C, etc. This system is about to become international since it is proposed by Commission V of the International Society of Soil Science. The French, Belgian and other soil classification systems have contributed to the sub-divisions and the nomenclature which were adopted. For soils which gave use to no ambiguity the old Russian, American, European names have been retained, for the rest a new nomenclature has been created with the use of Greek and Latin roots. Therefore we do not speak of classification, since the units are not in any particular order. The aim was to define soil titles and types occupying a sufficient area to be presented on a map with a scale of 1:5,000,000, having in addition an ecological significance, and approximating to or identifying with soil types already described in other classification.

At present the FAO/UNESCO Soil Map legend contains 105 soil units under which most of the main World Soil formations can be grouped. With the publication of the

Soil Maps of the World covering South America, Canada, United States and now Africa, the definitions of the international soil legend had been fixed and would not allow for modification at this stage. Nevertheless, there are scopes to enlarge this legend for larger scale maps by introducing new sub-divisions within each major soil units, in order to accommodate greater amount of details as necessitated by the scale of the map to be produced. An example is set by the compilation of the Soil Map of Europe at the scale of 1:1,000,000 by utilizing the FAO/UNESCO Soil legend. The compilation of this map by a panel of European soil scientists, necessitated the introduction of sub-units which were progressively evolved and defined through working sessions and field correlations since 1959. Thus, for example, a calcaric sub-unit has been proposed within the soil unit of pellic and chromic vertisol; whereas in order to cover orthic luvisols which are strongly acid in the surface without showing a degrated B horizon, the introduction of dystro-orthic luvisol sub-unit was proposed.

Therefore, depending upon the scale of the map to be produced, the actual international soil legend provides scope for introduction of new sub-units or even sub-sub-units if necessary, and phases for classifying soils, provided that they are internationally agreed upon and adequately defined.

The Soil Map of Africa

The World Soil Maps of Africa and the notice have been finalized, and are under publication. The African continent will be covered by three sheets. The mapping unit is actually a soil association designated by the symbol of the dominant soil accompanied by a number; this latter symbolises the soils associated with the dominant soils as well as the soil inclusions which are described in the legend. By definition, the dominant soil covers an area larger than each of the other associated soils taken individually; associated soils occupy an area exceeding 20 percent of that of the association and the inclusion occupies an area of less than 20 percent; the association takes the colour of the dominant soil. By convention, the texture is that of the dominant soil; texture is represented by a figure (1, coarse texture; 2, medium; 3, fine). Slope and phase are those of the association; slope is denoted by a letter (a, from 0 to 8 percent; b, from 8 to 30 percent; c, 30 percent and above). Phase is represented by an overprint, it indicates often an important characteristic of the principal soil, such for example the presence of a hardened horizon in the profile; thus, the petroferric phase means the presence of a hard pan at less than 1.25m. deep, the petric phase denotes the presence of concretions or quartz debris in large quantities in the top first metre of the profile, etc.; but the salinity phase, for example, indicates that certain soils of the association (not necessarily the dominant ones) are affected by salinity.

Aspect of Soil Evaluation in the Region

The Abidjan Conference (1968), the Soil Evaluation Seminar for West Africa (1970) and the seminar on Research on Tropical Soils (1972) indicate that considerable amount of survey and research work has been done on soils of Africa; however there is still much to know on technology of soils and their response to specific sets of management, particularly when fallow period practised under traditional system of agriculture is reduced, and lands are brought under continuous cultivation.

A very large number of agricultural experiments on crop management and fertilizer use are carried out throughout the region by numerous agricultural research station or pilot projects. However, as it was brought out at the above conferences, most of these experiments have not either taken into account all the soil characteristics and other environmental parameters or not described and classified adequately the soil, in any standard procedure. Therefore due to lack of uniformity and standardization in soil survey procedure, classification and interpretations, and also due to the absence of coordination between soils studies and soil management trials only very few correlation do exist at present between well defined soil unit and their behaviour under specific sets of managements. However, one can mention commendable work on this aspect carried out in Upper Volta, Senegal, Ghana on crop soil and fertilizer use and in Ivory Coast on soil erosion.

Possibilities offered by the World Soil Map for an inter-regional collaboration for initiating works on soil correlation aiming at a better evaluation of major soil units in the Region

The soil map of West Africa depicts the distribution and extent of major soil units in the Region. The legend and the notice describe in details at soil series level all the major soil units (dominant soil, associated soils, soil inclusions) occuring within the West African Sub-Region by using an internationally agreed terminology.

The present pace set for increased food and agricultural production in the region necessitates a better know-how on tropical soil technology which at present is not yet clearly defined. Better knowledge on soil evaluation can be achieved in the shortest time and with limited finance through an inter-regionally coordinated research programme by carrying out experiment on soil management laid in carefully selected sites representing the main soils formation at series level within a well defined ecological zone. Experiments on such bench mark sites should be directed to determine soil potential under improved management and also to obtain a clear picture on production limiting factors, and on the ways and means to overcome such limitations. The bench mark sites can be selected on a regional basis so as to represent most of the major soil and environment units of West Africa with the help of the World Soil Map and the international legend.

The following steps for achieving this aim are tentatively proposed :

1. Inventory of all agricultural experimental centres in the West African sub-region. Correlating soil series described in the national systems at those centres, into the international soil legend.

2. Critical review of research and experiment works carried out on soil management at the above experimental sites in view to assess the work carried out so far in matter of soil evaluation in the region.

3. Selection by a panel of inter-regional soil scientists, of bench mark sites, within the existing experimental centres for fully-fledged research and experimental work on all aspects of soil management including soil conservation measures but utilizing as much as possible the existing data on this aspect.

4. Selection of new bench mark sites representing the remaining major soil units in the region which are not covered by the above sites at the existing experimental centres.

This work which at first instance requires mainly adequate soil correlation can be initiated by a panel of inter-regional soil scientists under the auspices of the Soil Correlation Committee for West Africa. Such soil correlation work can lay the foundation for a regional project on soil management and conservation on major bench mark sites.

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(cont. from inside front cover)

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MR/F2972/E/10.74/1/600