FO:SF/NIR 16
Technical Report 5

SAVANNA FORESTRY RESEARCH STATION

NIGERIA

THE USE OF SOIL SURVEYS IN ASSESSING SITES FOR FORESTRY POTENTIALS IN SOME AREAS OF THE NORTHERN STATES OF NIGERIA

UNITED NATIONS DEVELOPMENT PROGRAMME
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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

based on the work of

A. Barrera
Soil Surveyor

UNITED NATIONS DEVELOPMENT PROGRAMME

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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This technical report is one of a series of reports prepared during the course of the UNDP/SF project identified on the title page. The conclusions and recommendations given in the report are those considered appropriate at the time of its preparation. They may be modified in the light of further knowledge gained at subsequent stages of the project.

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ABSTRACT

The report describes work done between 1965 and 1971 by the soil survey section of the Savanna Forestry Research Station as part of a project undertaken by the Federal Government of Nigeria, with assistance from the Food and Agriculture Organization of the United Nations under the United Nations Development Programme.

Semidetailed soil surveys were carried out over 13 scattered forest reserves with an area of 384 401 acres covering the different ecological zones of northern Nigeria, and 86 individual soil profiles, mostly in research plots, were described. The soil units in each forest reserve were classified into capability classes according to suitability for afforestation, and maps of each showing the classification are included.

The soils in the Sudan and part of the Sub-Sudan Zones are considered marginally plantable due to the dry climate. Neem (*Azadirachta indica*) has had some success. Those soils in the Northern and Southern Guinea Zones developed from basalt are usually fertile but have limitations in depth and drainage. Teak (*Tectara grandis*) and *Gmelina arborea* appear well adapted in the Southern Guinea zone. The sandy soils common in the Southern Guinea and derived savanna zones, though sometimes deep, are very permeable and of low fertility. The soils and the climate of the Banchi Plateau zone appear to favour the growth of pines.

The soil units classified as plantable are mostly of low fertility and experiments have shown the benefits of additional organic matter and fertilizers and the importance of the correct choice of species.

The Food and Agriculture Organization is greatly indebted to those organizations and individuals who assisted in the implementation of the project by providing information, advice and facilities.

TABLE OF CONTENTS

TABLE

LIST OF MAPS

LIST OF ABBREVIATIONS

C.E.C	cation exchange capacity
cm	centimetre
ft	foot
g	gramme
in	inch
mEq	milliequivalent
ppm	part per million

1. INTRODUCTION

1.1 GENERAL

A project to establish a Savanna Forestry Research Station was started in 1964 by the Federal Government of Nigeria, with assistance from the Food and Agriculture Organization of the United Nations under the United Nations Development Programme, with the object of carrying out research programmes to provide the bases for the selection and afforestation of suitable areas to meet the anticipated wood requirements of the savanna region, for which soil is a controlling factor.

A soil survey section was set up under the project in 1965 and was under the charge of Mr. A. Barrera, an FAO soil surveyor, for the period August 1966 to March 1971. The tasks of the section were:

i. to carry out soil surveys in selected forest reserves to determine, by examination and sampling, those areas likely to have soils suitable for plantation development;

ii. to carry out detailed soil surveys in selected research areas to determine the soil pattern in such areas to allow subsequent growth and other factors to be related to soil types;

iii. to train counterpart staff.

Soil surveys were carried out in the 13 forest reserves listed in Table 1, which have an area of 384 401 acres, and numbers of individual soil profiles from research sample plots were studied and described. Map 1 shows the sampling sites which cover the main climatic and ecological zones of northern Nigeria. Map 2 is a geological map of Nigeria and Map 3 shows the general soil types in the northern States.

In selecting forest reserves for soil survey the main factors were climate and geological formation. To determine the soil conditions in a selected reserve it was necessary to:

i. describe, classify and map the soils on a semidetailed scale;

ii. to classify the soils according to their capabilities and record this information on maps;

iii. interpret the characteristics of the soil in terms of suitability for plantation tree growth;

iv. prepare detailed reports of the areas surveyed.

The results of the soil surveys, more details of which are given in Appendix 9, have been and will be used initially as a basis for selecting sites for experimental plots or pilot planting and in the longer term for possible large scale plantation developments. Maps 4-15 show the classification of plantable ares. The soil records may also allow the correlation of growth and soil and may provide guidance in soil conservation practices and in setting up trials of fertilizer applications.

An important function of the section was the training of counterpart staff for which both on the job training and specific courses were given. A full time counterpart, Mr. S.T. Amujo, was available from 1965 to 1968, since when Mr. A.B. Momodu was counterpart for the soil survey and the soil physics sections.

Table 1

THE DIFFERENT PLANTABILITY AREAS OF THE DIFFERENT FOREST RESERVES SURVEYED
(acres)

Forest Reserve	Plantable 1/ (No restriction)	Plantable 1/ (minor limitations)	Plantable 1/ (major limitations)	Marginally Plantable 1/	Not Plantable 1/
Afaka		5 665	5 662	11 429	3 450
Nimbia	2 554	462	848	1 558	18
Sanga River		21 824	24 197	8 084	4 301
Mokwa		14 635		400	88
Osara		946	10 913	35 809	71 372
Doma		58 807	67 651	78 792	42 686
Rafin Bauna		10	17	334	2 116
Gindiri-Langai		763	1 004	964	540
Mongu			348	583	402
Dekina		11 975		532	14 104
Okura-Iyale		43 691			5 237
W. Okura		20 182	2 112		1 175
Yambawa				385	

1/ For definitions, see Section 2.1.

1.2 PREVIOUS SOIL SURVEY STUDIES

Soil surveys in the northern States of Nigeria are recorded as early as 1956 in a report of Higgins (1956) on the Lafiagi tree crop project in Ilorin Province. This was later followed by a work of Tomlinson (1957) on a soil survey of the experimental area in the Afaka Forest Reserve. The staff of the Soil Section of the Institute for Agricultural Research (I.A.R.) conduct reconnaissance soil surveys in different parts of the northern States of Nigeria at a scale of 1:100 000. Such surveys are usually reported in land units of one degree of latitude by one degree of longitude. Detailed soil surveys are done in the case of special projects such as selecting sites for experimental farms, farm settlement schemes or resettlement projects and the scales used ranged from 1:20 000 to 1:50 000.

The Resource Division of the Directorate of Overseas Surveys also conducts reconnaissance soil surveys on much the same basis as the I.A.R. Their area of survey is confined to the northeastern part of Nigeria bounded by the Benue River in the south and by longitude 10° E in the west.

Some of the forest reserves in the savanna areas of Nigeria were surveyed, but primarily on the basis of vegetation cover and possible site potential; simple descriptions of profiles in the reserve were included but in most cases no soil map was made. Certain of the forest reserves ranging in size from 1 000 to 8 000 acres, such as the Anara, Nimbia, Jebba, Kabama and Mokwa, were classified and mapped by W.J. Howard.

2. THE SOIL SURVEY PROGRAMME

2.1 WORKING METHODS

The soil surveys in the forest reserves are done on a semidetailed basis at mapping scales ranging from 1:20 000 to 1:50 000. A few reconnaissance surveys were at scales of 1:50 000 to 1:62 500. In most cases, however, the final map included in the individual soil reports is reduced to a scale of 1:100 000. Aerial photographs were used generally in mapping soils and vegetation. The photographs are available at a scale of 1:40 000 (approximately) and on prints 9 x 9 inches, which are generally fair in quality. Boundaries of land forms, soils and vegetation are usually marked on overlays which are assembled subsequently into mosaics. Mosaics, which are of larger scales than base maps, are reduced either by pantograph or projector. If boundaries of land forms, soils and vegetation were drawn directly on to photographs, such detail could be transfered to the base map using the projection machine.

Before starting field work, maps of the reserve showing the location and boundaries were requested from the Divisional Forest Officer of the area where the forest reserve is situated. The boundaries of the reserve are traced on Nigeria contour maps, if available, or simply on to planimetric maps. The section of the map where the area of the forest reserve is recorded is reproduced and three copies are made as base maps for soils, for land capability and for vegetation.

The soil type was used as the mapping unit. This unit represents an area of soil developed from one type of parent material noting class of soil drainage, profile and external characteristics such as slope, stoniness and erosion. Soils with different characteristics are mapped under different mapping units. The characteristics of each of the soil mapping units are further classified so that soil units with similar characteristics of suitability for plant growth and similar responses to the same kinds of treatments or soil management practices will form a land capability class. There are five land capability classes used in Nigeria and these have been broadly related to capability for forestry plantation development. The capability classes are recorded in the base maps of land capability. The basic scheme for land capability classification is a modified version of that used by the United States Department of Agriculture, with the number of classes reduced to five. An attempt has been made to relate the five classes to Savanna forestry plantation capability as follows:

Class	Agricultural suitability	Savanna Forestry Plantation suitability
Class I	Very good land with minor or no physical limitations to mechanized cultivation	Plantable (without restriction)
Class II	Moderate to good land with some physical limitations to mechanical cultivation which can be corrected	Plantable subject to minor limitations
Class III	Fair lands best suited to perennial vegetation, can only be cultivated with care and require intensive conservation practices	Plantable subject to major limitations
Class IV	Lands not suited to mechanical cultivation but suited to perennial crops or limited clearing grazing or hand cultivation	Marginally plantable
Class V	Land precluded from use for commercial plant production	Unplantable

The forestry suitability is only indicatory and may be further defined or refined by silvicultural work which may allow correlation of plantation tree growth and soil factors.

The important criteria considered in the land capability classification are climate, soil depth (effective depth for root growth), drainage condition, soil erosion, slope, stoniness and the soil profile characteristics (texture, structure, permeability, salinity, parent material, and inclusions). The definitions for the different classes of drainage, soil erosion, slope, stoniness and profile characteristics are from the FAO Guidelines for Soil Descriptions. The classes of soil depths used are those from the Institute for Agricultural Research as follows:

Very shallow	....	0	- 12	in
Shallow	....	12	- 20	"
Moderately deep	....	20	- 36	"
Deep	....	36	- 60	"
Very deep	....	60	- and over	

In the land capability classification proposed for the northern States of Nigeria, there are five capability classes, namely, class I to class V. The risk in soil damage or limitations in use becomes progressively greater from class I to class V. Under this scheme, classes II to IV are each further classified according to the kind of hazard or limitation the land has. Thus class II land with erosion problems is classed as IIe. Land with water as the main problem is classed as IIw and land with soil conditions in the profile as the limitation is classed as IIs. Classes III and IV are each similarly subdivided. Class I and class V do not have any subclass.

The land capability classes are:

Class I

This consists of very good lands with minor or no physical limitations to mechanical cultivation. The soil is moderate to high in productivity and can be sustained with a few but good management practices. The land has deep to very deep soils that are well drained and of medium textures. The land is level to gently sloping.

Class II

This includes good lands with few physical limitations to mechanized cultivation which can be easily corrected. The land may have either moderate to high erosion hazard, poor internal drainage, slight salinity, moderately deep or moderately low holsing capacities for moisture or fertility. It has moderate productivity but can be improved following simple soil conservation practices to correct the limitations.

Class III

This consists of lands best suited for perennial cultivation but can be mechanically farmed under great care. The soil may either be liable from moderate to high erosion, poorly or excessively drained, shallow, gravelly or low in water holding capacity or low in fertility. The productivity of the soils may be maintained following intensive soil conservation practices to reduce the effect of the limiting factors.

Class IV

This consists of lands not suited to mechanical cultivation but can be cultivated by hand for limited crops but best suited to grazing or tree planting. The land may have soils which may be severely eroded, very poorly drained, very low capacity for both moisture and fertility or may be very shallow The productivity of the soils for perennial crops may be maintained following very intensive soil conservation practices with special care in planning long rotation crops.

Class V

These are lands with very severe limitations or hazards so that they can not be recommended for cultivation to crops nor for the planting of trees. These lands are better left alone to conserve the natural vegetation for the protection of watershed, for wildlife, and for recreation.

2.2 SOIL SURVEY PROGRAMME

The programme of work envisaged to cover the objectives of the project was:

1. to conduct semidetailed soil surveys in as many selected forest reserves as possible located in the main climatic ecological zones of the savanna area of Nigeria;

2. to prepare land capability maps of the forest reserves surveyed to indicate the suitability of the soils for afforestation purposes; and

3. to prepare reports of the areas surveyed. As part of the studies on soils in the forest reserves, the measurements of depths of water tables in these areas were also included and detailed studies of the fluctuations in water table depths were made in some of the principal forest reserves.

Another aspect of the programme of work was the training of counterpart staff in soil surveying, classification and mapping. Part of this training included the use of equipment. Although not part of this project as originally planned, seven other forest officers from different States of Nigeria took advantage of the training in the field work and in analysis of soil samples at the soils laboratory in the Forest Research Station.

2.3 COLLABORATION WITH OTHER SECTIONS OF THE RESEARCH STATION

While carrying out the objectives in soil surveys, the section staff worked in cooperation with the other disciplines of the project. Using the hydraulic powered soil coring machine, 26 aluminium pipes of 20 ft length were set vertically into the soil in different forest reserves for the soil physics section studies of soil moisture. In addition, 10 soil profiles (10 feet deep) adjacent to the sites of some of the pipes were described in detail.

The soil survey unit also took part in selecting sites for tree planting experiments at Afaka, Miango, Rafin Bauna, Mokwa and Mongu forest reserves. Descriptions of the soils in the selected sites were recorded. (Soil report Nos. 1, 5, 7 and P66).

2.4 GENERAL OUTLINE OF SOIL UNITS BY ECOLOGICAL ZONES

Nigeria has been divided into zones according to the types of vegetation (Keay and Walter). These zones, of which seven are recognized in the northern States of Nigeria, follow the climatic conditions closely; the zones are: (1) Sahel, (2) Sudan, (3) Sub-Sudan, (4) Northern Guinea, (5) Southern Guinea, (6) Bauchi Plateau and (7) Derived Savanna 1/. The Sahel Zone is considered too dry for any economic forest plantation and therefore will no longer be discussed in this report. The Sudan and Sub-Sudan Zones will be treated under the heading of Sudan Zone only. The conditions of the climate, vegetation and soils in the Sudan and other zones are as follows:

2.4.1 Sudan Zone

The mean annual rainfall in this zone ranges from 20 to 40 in occurring from May to September with the remaining months receiving less than 1 in a month (Appendixes 1 and 2). The maximum temperature exceeds 100°F in March to May and the minimum temperature falls below 60°F from December to January. The mean relative humidity at 1200 hours G.M.T. is low (10 to 17 percent) from November to March and is high (32 to 68 percent and over) for the rest of the year.

1/ See Map 1.

Most of the forest reserves where trial plantings are established are situated on areas covered by Aeolian Drift Sands of the Chad Formation. The Chad Formation occurred during the last arid phase of the Quarternary when the Sahara extended southward into Nigeria (Clayton, 1957). A drift of Aeolian Sand was deposited upon the Post-Eocene sand and clays. Its surface is gently undulating with a slight hummocky micro-relief. A remarkable feature of the topography is the occurrence of seif dunes of Aeolian Sands aligned in an east-north-easterly direction.

The vegetation is generally characterized by the presence of Guiera senegalensis, Combretum glutinosum, Piliostigma reticulata and Hyphaene thebaica. The most common grass is Pennisetum pedicellatum. Where cultivation is very intense Guiera becomes more abundant with occasional Balanites aegyptica. Towards the eastern part (Maiduguri) open woodland comprising Boscia senegalensis, Capparis spp, Lannea humilis and Combretum aculeatum occurs. On fine textured soils, Acacia arabica and A. seyal become the common hedge plants.

Three soil units were recognized in this zone, namely: (1) Dystric Regosols, (2) Pellic Vertisols and (3) Gleyic Solonchaks 1/. The sandy deposit can be more than 20 feet deep and is generally somewhat excessively drained. While the sand in the central part of this zone is whitish (Yambawa F.R. No.4 and P58), that in the eastern part is dominantly reddish (P 62). In both cases, the sandy soil is made up mainly of quartz and, as such, has very low reserve for weatherable minerals. The soil reactions range from strongly acid (pH 5.1 to pH 5.5) to neutral (pH 6.6 to pH 7.3). The organic matter contents are generally extremely low (less than 1 percent). In general the cation exchange capacity (C.E.C.) of most of the sites examined showed extremely low values (less than 10 mEq/100 g soil). The profiles showed very little development which place them to Juvenile Soils on Aeolian Sand or as Dystric Regosol. Some of the forest reserves under this classification are Yambawa, Gabasawa, Maigasari, Hadejia Fuel Plantation, Pompomari, Maiduguri Fuel Plantation and Fuchu.

Small areas of concave topography having clayey soils derived from alluvium or lacustrine deposits occur in some forest reserves. These areas have slow drainage and the surface soil usually cracks upon drying. These soils are referred to as cracking clays or Vertisols (P 62-A). This particular soil has a calcareous C horizon although some Vertisols in this region are noncalcareous. Soil texture in the entire depth of the profile is clay which is dark grey on the surface but becomes lighter in colour with depth. Soil consistency is very hard when dry but becomes soft and plastic when wet. The clay fraction is dominantly montmorillonite. The C.E.C. is in the order of over 10 mEq/100 g soil. Calcium and magnesium are both high in the exchangeable bases which may account for the medium alkalinity of the soil horizon between 13 and 66 in. The organic matter and total nitrogen are both low.

This soil unit may present some problems when used for forestry especially during the early period of growth of the trees. Young roots usually break when the soil cracks open. Balanites aegytiaca and Acacia seyal are the most common trees trees in this soil unit while other trees found in the loose, well drained and sandy soils are conspicuously absent.

1/ Some characteristics of the soil unit are shown in Appendix 10.

The third type of soil unit (Halomorphic Soils) is found in close association with the Vertisols. Both soils occupy lower topographic positions under moderately well drained conditions. The colour of the soils in their profiles is brown to pale brown with the C horizons almost white. Both soils also have fine texture in the lower horizons of their profiles. The A horizon usually varies in texture due to alluvial depositions or by drift sands.

These Halomorphic soils as classified by Tomlinson (1957) may be the equivalent of either Solonets or Solonchaks soil units in the Soil Map of the World. Several forest reserves (Hadejia, Azare, Maiduguri, Pompomari and Fuchu) are known to possess these types of soil units. Near Azare (P No. 64)[1/] is a representative profile for a Gleyic Solonchaks. This particular soil has a sandy loam Ap horizon but the succeeding horizons are pale brown clay to almost white sandy clay which are mottled and calcareous. The strongly alkaline reaction (over pH 8.5) in the lower parts of the profile suggests considerable amounts of soluble sodium present. This characteristic places this soil under Solonchaks. The soil reaction ranges from neutral for the Ap horizon to strongly alkaline for all the horizons below 17 in depth. The C.E.C. varies between 6 to 14 mEq/100 g soil and the extractable cation is dominated by calcium. It can be expected that the amount of extractable sodium is also high in view of the strongly alkaline reaction (over pH 8.5). The organic matter and total nitrogen contents are both low in the Ap and B horizons.

The utilization of this soil for forestry purposes presents some serious problems both from the stand point of physical conditions of the soils for cultivation as well as the chemical condition due to presence of too much soluble salts. Cassia siamea grown on the site seems to be adaptable to these conditions of the soil.

Fertilizer tests in some of the Regosols (Yambawa F.R.) planted to neem showed response to the addition of animal manure (Jackson, 1970) and produced adverse effects on the application of either urea or superphosphate. Jackson attributed this to the lack of soil moisture. This may be also attributed to the low clay or organic matter content of the soil.

2.4.2 Northern Guinea Zone

The annual rainfall in this zone (Appendix 3) ranges from 40 to 50 in with 4 to 6 months of dry season. Minimum temperatures ranging from 57° to 60°F occur during the period from November to February while the maximum temperature reaches 96°F in April. The relative humidity at 1200 hours G.M.T. is low (15 to 23 percent) from November to March and increases gradually to its maximum (77 to 82 percent) during the May to August period.

The vegetation in this zone is more luxuriant than in the Sudan zone. It is characterized by the prevalence of trees such as Isoberlinia doka, Monotes kerstingii, Swartzia madagascarensis and Uapaca togoensis. Both Tree Savanna and Savanna Woodland types occur with shrubs like Terminalia spp, Gardenia spp, Piliostigma thonningii and Dachrostachys spp intermixed. The herbaceous layer is covered mainly by Andropogon and Hyparrhenia species of grasses.

1/ A detailed description of the profile can be seen in Appendix 11.

The zone is dominated by the Pre-Cambrian igneous and metamorphic rocks known as the Basement Complex. The soils developed in this formation had suffered several cycles of erosion and in the area surrounding Zaria the pediplain is called Post Gondwana (Clayton 1957). An indurated plinthite or ironpan was developed near the surface of the pediplain and on occasions is exposed as outcrops. Subsequently loess material was deposited and covered the old surface, including the ironpan and valleys. The soils developed from this drift are yellowish brown, fine sandy to clayey and are classified as Ferruginous Tropical Soils on Sandy Parent Material. They are characterized by the presence of a plinthite layer below the A horizon. This plinthite hardens when dried, becomes soft on wetting but may be permanently hard if exposed. This plinthite may be from one to 5 ft from the surface and 2 to 6 ft in thickness. It can be a continuous layer or broken as pockets. The roots of some trees (Acrocarpus, Isoberlinia and Albizzia) do not appear to penetrate this layer but Eucalyptus species appear to be capable of such penetration. Below the plinthite, however, are layers of soft, yellowish brown, generally mottled brown, clayey soils extending down 10 to 20 ft from the surface. The weathered rocks of the Basement Complex lie below this soft clayey mass.

The soil developed from the sandy drift is classed as Ferruginous Tropical Soils on Sandy Parent Material or Eutric Cambisols. (Soil report No.1, P42, P44, P65, P72, P90). In some areas of this soil unit, drainage is restricted, and the water table fluctuates in the profile. The soil has a light colour but with reddish mottles and the plinthite is soft. Such soils are often called groundwater laterite which may be the equivalent of Plinthic Luvisols (Soil Report No. 1, P26, and P92). The well drained Ferruginous soils are on the upper slopes, whereas the Luvisols are on lower slopes.

Ferruginous Tropical Soils have dominantly keolinitic type clays and usually show iron accumulation in some part of the profile. There is a textural and structural B horizon with an appreciable reserve of weatherable minerals. Average analyses of soils in this zone show that the reaction for the A horizon ranges from medium acid (pH 5.6) to neutral (pH 6.8) while the B horizon ranges from strongly acid (pH 5.1) to medium acid (pH 6.5). The average organic matter content is 2.4 percent for the A horizon and 1.3 percent for the B horizon. The cation exchange capacity has an average of 6.2 mEq/100 g soil for the A horizon and 5.2 mEq/100 g soil for the B horizon.

The Afaka, Kabama and Mairabo forest reserves are three important experimental and plantation areas in the Northern Guinea Zone. Many different branches of research are pursued including testing various exotic species and the use of fertilizers at the establishment phase (Jackson, 1970). To control dieback on eucalypts, 56g of borate per tree was found effective in establishing Eucalyptus citriodora and E. torelliana but had no effect on E. deglupta where the original incidence of die back was low. Borate was also tried in combination with phosphorus and was correlated with up to 50 percent increased height growth and up to 90 percent increased basal area in E. robusta planted at Kabama F.R. Most experiments failed to show any response from potash fertilizer. Phosphate with nitrogen produced a significant increase in the growth of teak. Urea alone produced an adverse effect on Pinus caribaea, whereas phosphate promoted growth.

2.4.3 Southern Guinea Zone

The annual rainfall (Appendix 4) in this zone ranges from 45 to 55 in with 3 to 4 months of dry season. The minimum temperature from November to January ranges from 62 to 65°F while the maximum from November to April ranges from 92° to 99°F. The relative humidity at 1200 hours G.M.T. from November to March has a monthly mean of 29 percent while the rest of the year has monthly mean ranging from 44 to 77 percent.

This zone has a complex type of vegetation due to the effect of extensive seasonal burning and cultivation. Numerous vegetation communities were recognized including closed woodland and shrub woodland. An important observation was the absence of Isoberlinia (Clayton, 1957). Common trees are Daniella olivieri, Monotes kerstingii, Uapaca togoensis, Parkia clappertoniana, Parinari curatellifolia, Pterocarpus erinaceous and Afrormosia laxiflora. A closed woodland of Anogeissus leiocarpus occurs. Dominant Afzelia africana, Pterocarpus erinaceus and Butyrospermum parkii were noted in soil areas developed from sandstone within this zone.

There are two principal geological formations in the Southern Guinea Zone, namely: (1) Pre-Cambrian metamorphic and igneous rocks of the Basement Complex and (2) Turonian - Senonian Cretaceous sandstone. The former formation occurs as separate wide areas both north and south of the Niger and Benue Rivers trough. These areas, like those in the Northern Guinea Zone, have undergone a series of erosion cycles known as Post Gondwana surface development at 2 000 to 2 300 ft. The landscape is one of rolling peneplain broken by granite hills and outcrops of ironstone.

The Ferruginous Tropical Soils around Tegina, Zungeru, Minna to Keffi were developed under poor drainage. The soil profiles are greyish and prominently mottled red (P74). These soils may be classed under Plinthic Gleysols due to such characteristics as greyish colour, fine texture and occurrence of mottles. Associated with this soil are areas of similar characteristics which are very poorly drained with reddish mottles in the B and C horizons and may be classed under Hydromorphic Soils (Gleyic Luvisols).

Better drained Ferruginous Tropical Soils on Crystalline Acid rocks may be found on the upper slopes of the peneplain or where the topography is well elevated over the poorly drained plains. Such areas near Abujia are well drained, but numerous ironstone gravels are present as inclusions in the profile (P73).

The Ferruginous Tropical Soils located south of the Niger River trough are well drained but shallow (soil report No.6). The landscape is characterized by topography dominated by blocks of dissected hill country in the south, from which the land descends to the Niger River by steps - suggesting that the land has been intermittently uplifted in the past (Clayton, 1962). This soil unit may be classed under Eutric Cambisols, Plinthic Luvisols and Eutric Fluvisols.

The soil reactions in this particular area vary from medium acid (pH 6.0) to neutral (pH 6.8) for the A and B horizons. The organic matter content is low ranging from 0.71 percent to 1.01 percent for the A horizon and from 0.3 percent to 1.0 percent for the B horizon. The cation exchange capacity ranges from 4.3 to 6.9 mEq/100 g soil for the A horizon and from 3.4 to 6.9 mEq/100 g soil for the B horizon. These values are rated low to medium.

The Ferruginous Tropical Soils located south of the Benue River are similar to those around Zaria in that sandy material was deposited over the Basement Complex and has given rise to Ferruginous Tropical Soils on Sandy Parent Material or Eutric Cambisols.

The Cretaceous Formation found within this Southern Guinea Zone comprises mostly sandstone with some shales resting directly upon the Pre-Cambrian metamorphic rocks in the Niger and Benue River troughs. This sandstone sediment is known as the Niger surface and developed at 750 - 950 ft above sea level. The landscape in this formation is characterized by a gently rolling plain with occasional flat topped hills capped with ironstone standing some 800 to 900 ft over the plain. The soils developed from this coarse and fine grained sandstone are uniform in colour (reddish brown to red) with some variations in texture (loamy sand to sandy loam) and are generally very deep and well drained. The clay fraction is of the 1:1 lattice type. There is very little reserve for weatherable minerals. There is slight textural development in the B horizon and very little horizon differentation. This soil unit was classified as Red, Weakly Ferrallitic Soils on Loose Sandy Sediments (Rhodic Ferralsols) (soil report No.5, P67 and P78).

The reaction of the A horizon varies from medium acid (pH 6.0) to neutral (pH 6.9) while the organic matter content of both the A and B horizons is extremely low (0.40 to 1.07 percent). The cation exchange capacity is extremely low to low (1.7 to 4.5 mEq/100 g soil) for the A horizon and very low to medium (2.5 to 7.5 mEq/100 g soil) for the B horizon.

The Mokwa F.R. is an important experimental area for the Southern Guinea Zone and for soils of the Cretaceous sandstones. In the fertilizer trials made, phosphate was found to produce significant increase in growth in teak on all soils (except Takumah), whereas, nitrogen gave a significant increase in growth of teak planted on Takumah soils. A combination of nitrogen and phosphorus applied on Kulfo soil gave significant increased growth of Pinus caribaea. When applied to Gmelina, however, a combination of nitrogen and phosphorus gave good growth but caused some kind of chlorosis in the leaves.

Cretaceous sandstone may also develop Ferruginous Tropical Soils (soil report No.8 and Soil Survey Bulletin No. 39). This type of soil occupies the area along the Benue River trough. This type of Ferruginous Tropical Soils is found on the upper slopes of the pediplain as knolls of ironstone debris. They may represent the last vestige of the so called African surface developed at 1 300 to 1 600 ft. But the soils developed from this formation are moderately shallow to shallow and brownish in colour. The soils are generally moderately well drained although some areas are well drained. The bedrock is ferruginized sandstone. The soils are low in fertility. The cation exchange capacity ranges from 4.2 to 5.9 mEq/100 g soil for the A horizon and from 3.5 to 6.6 mEq/100 g soil for the B horizon and these values are rated as low to medium. The organic matter content range is low from 1.46 to 1.72 percent for the A horizon and from 0.64 to 1.01 percent for the B horizon.

2.4.4 Derived Savanna Zone[1/]

There are two areas in the northern State of Nigeria classified as Derived Savanna, namely:

1/ This is a transitional zone between the Forest Zone and the true Savannas as termed by Keay (1953) and Clayton (1957). The original forest was mostly cut down and burned to give way for cultivation of crops. Later, the land was abandoned and reverted to forest again but the composition of the forest was very different from the original one although some relic species of the true forest type are still found.

i. an area lying just below the southwestern slope of Jos Plateau and

ii. an area lying south of the Niger and Benue Rivers.

In the former area the elevation ranges from 2 000 to 3 000 ft above sea level and the rainfall ranges from 50 to 70 in a year with only 3 to 4 months having less than 1 in of rain. The temperature has a maximum ranging from 78°F in August to 100°F in February and a minimum from 55°F in December to 74°F in April. The relative humidity ranges from 30 percent in February to 84 percent in August (Appendix 5).

The geology of the area below the southwest escarpment of Jos Plateau was described as similar to the Basement Complex found in the Northern Guinea Zone and that it also has undergone the erosion cycle known as the Gondwana surface. During the Tertiary Period, however, a series of volcanic lava flowed down the escarpment and covered part of the Gondwana surface. Thus, two different kinds of materials were produced, the Ferruginous Tropical Soils on Crystalline Acid Rocks were developed from rocks of the Basement Complex and the Eutropic Brown Soils of the Tropics were developed from the Newer Basalt or the volcanic lava. There are three important forest reserves located in this part of the Derived Savanna, namely:

i. Nimbia,

ii. Sanga River and

iii. Chanji.

The Ferruginous Tropical Soils here (Nimbia and Sanga River F.R.) possess the same characteristics as the other Ferruginous soils of the other vegetation zones in relation to depth of soil over the plinthite layer and drainage conditions. The well drained Ferruginous Tropical soils (Eutric Cambisols) are reddish brown soils with a hard and indurated plinthite in the C horizon. Mica are sometimes present. The poorly drained soils or Ground Water Laterite (Plinthic Luvisols) have profiles with the characteristic brown A horizon and greyish brown B and C horizons which are mottled. The reddish mottles are more in the C horizon. Gravels of ironstones may be found as inclusions in the C horizon (soil report Nos. 2,3).

The Eutrophic Brown Soils (Haplic Phaeozen or Eutric Cambisols) are very deep and usually well drained, with textures ranging from sandy clay loam to clay loam. The clay fraction is of the Montmorillonite type and the C.E.C. is medium to high. Eutrophic Brown soils are relatively young, high in organic matter and rich in plant nutrients. Further development of the profile under good drainage may convert this soil to Ferruginous Tropical Soil but under poor drainage, may produce Vertisols. This soil unit is found in Nimbia, Sanga River and Chanji forest reserves. Some of these soil units may occur in the Nindam and Kafanchan F.R. Lithosols or soils on ironstone outcrops, inselbergs and Hydromorphic soils are associated with the three main soil units. The Lithosols and Hydromorphic soils are of little value for afforestation.

Fertilizer experiments (Jackson 1970) were laid out in Nimbia F.R. but results with a range of species varied. For example, it was found that a combination of 50 g of urea and 100 g of superphosphate applied per tree proved beneficial to Gmelina spp but 100 g of potassium chloride per tree had an adverse salinity effect on Pinus caribaea.

The latter area of Derived Savanna Zone located south of the Benue and Niger Rivers(Clayton 1957) is described as "African and Niger Lateritic Tableland". The plateau where some forest reserves are located (Igala Division) rises up to 1 200 ft and falls 800 ft to the lower valleys.

Rainfall in this area ranges from 46 to 56 in a year with the peak in September. The rainy season lasts 220 to 240 days (Walter 1969).

The forest in this particular zone is uniformly Derived Savanna vegetation. Albizia adianthifolia, A. zygia and Bombax buonopozense are among the most abundant trees, and Daniellia oliveri is distributed widely (Clayton, 1962). The under story is evergreen thicket and some of associated species are Alchornea cordifolia, Baphia pubescens, Chlorophora excelsa, Cola gigantea, Elaeis guineensis, Musanga smithii and Smilax kraussiana. The grassy ground layer under the woody savanna vegetation is commonly dominated by Andropogon tectorum.

The soil (Red Ferraltic Soil on Loose Sandy Sediments or Rhodic Ferralsols) is characterized by its reddish colour, sandy texture and good drainage. The clay fraction is the keolinite type (1:1 lattice). Having developed from sandstone, the C.E.C. is very low (2 to 10 mEq/100 g soil, (soil report No.9 and Soil Survey Bulletin No. 30). There is very little reserve of weatherable mineral. As usual, ironpans are present either as cappings on flat topped hills or as outcrops in the surrounding lands.

An important characteristic of this zone is the presence of high forest. In other zones such as Southern Guinea and Derived Savanna, only riparian forests are found. An important contributary climatic difference is the relatively high percentage humidity throughout the year, varying only from 46 to 75 percent at 1200 hours G.M.T. and from 82 to 93 percent at 06.00 hours G.M.T.

Trial growth plantings of teak, Gmelina and Eucalyptus in this area have not shown as good results as at Nimbia Forest Reserve.

2.4.5 Bauchi Plateau Zone

This zone is located on the Jos Plateau where the rainfall ranges from 45 to 55 in a year and the dry season lasts from 4 to 5 months. The elevation on the plateau varies from 3 000 to 4 300 ft and this has a profound effect on the local temperature. The maximum temperature (Appendix 6) ranges from 88°F in April to 75° in August while the minimum temperature ranges from 57°F in January to 66°F in April. The relative humidity at 1200 hours G.M.T. varies from 14 percent in January to 76 percent in August.

The geology of this plateau was described by Clayton (1957) as Gondwana surface developed at 4 000 to 5 000 ft and estimated at about end-Cretaceous Age. Much of the Gondwana surface was later buried under lava flows and a later local surface was developed upon the lava. This plateau is bounded by belts of dissected country or escarpments which consist of metamorphic rocks of the Basement Complex, and intrusive younger granites of the Jurassic Period. The lava that covered the Basement Complex included also the stanniferous alluvium contained on them. Remnants of these older basalt flows, capped with thick layers of ironstone, stand out as flat topped hills. A series of other lava flows occurred later.

There are three important soil units on this plateau, namely:

i. the Ferruginous Tropical Soils on Crystalline acid rocks,

ii. the Groundwater Laterite and

iii. the Eutrophic Brown Soils of the Tropics.

Rocks of the Basement Complex may produce either Ferruginous Tropical Soil or Groundwater Laterite depending upon the drainage conditions. Basaltic rocks may also develop under varied drainage conditions as Eutrophic Brown Soils or Groundwater Laterite. Well drained Ferruginous Tropical Soils (Eutric Cambisols) occur on relatively small areas only. The depth of the soil from the surface to the upper boundary of the indurated plinthite is very variable and this is one of the criteria used in classifying soil depth. The other type of Ferruginous Tropical Soils developed under poor drainage and known as Groundwater Laterite (Plinthic Luvisols) are more widely distributed on this plateau than any of the other types of soils (soil report No. 7 and P71) and in these soils the plinthite is soft and depths are more often more than 60 in. The Eutropic Brown Soils (Eutric Cambisols or Haplic Phaeozem) were developed from volcanic rocks or the Newer Basalt under good drainage. Under poorly drained conditions they produce Groundwater Laterite (P66). Many areas of this type of soil unit have boulders and cannot be cultivated. The well drained Eutropic Brown Soils have good soil structure and are free from inclusions (P70) and their distribution is not extensive as they are confined only to areas covered by volcanic lava. Soils developed from basalt rocks are more productive than those developed from the Basement Complex. The C.E.C. of soils from Basalt parent material ranges from 14 to 16 mEq/100 g soil for the A horizon and from 15 to 18 mEq/100 g soil for the B horizon, whilst soils developed from the Basement Complex range from 5 to 8 mEq/100 g soil for the A horizon and from 6 to 14 mEq/100 g soil for the B horizon (soil report 7, P66 and P70). Soils developed from basalt usually have a 2:1 lattice type clay and the exchange complex is generally well saturated with bases and the carbon: nitrogen ratio is approximately 10:1.

Miango F.R. is one of the experimental sites for the Bauchi Plateau Zone. Various experiments on growth of exotic species such as pines and eucalypts have been initiated here. The climatic conditions on the plateau appear favourable for the growth of pines and being located on not too well drained soils, some species of eucalypts are suited to this condition. The water table in this particular reserve was below 25 ft in July, 1970 and then rose to 4.5 ft in September, 1970. This fluctuation of water table may be one of the factors that led to the development of red mottles in the profile (report No.10).

2.5 SOIL CONSERVATION PRACTICES NECESSARY IN THE ECOLOGICAL ZONES

The physical and chemical limitations of most soils in the area under study are very common for all the ecological zones. In the northern area of Nigeria (Sudan and Sub-Sudan Zones) the soils are generally sandy and the rainfall very low for forest establishment. Towards the southern parts of the country, rainfall increases but the soils which were derived from rocks of the Basement Complex are either shallow due to the presence of an indurated ironpan or are deep but with some degree of drainage problem. Only small areas have deep and well drained soils. While most of the soils derived from sandstones are deep, very sandy and very low in fertility, others are also limited in depth due to the presence of ironpan in some part of the profile. The following are the conservation practices for each of the ecological zones:

2.5.1 Sudan and Sub-Sudan Zones

These zones have low rainfall (20 to 40 in a year) and the suitability of any soil in these zones for forest plantations is an economic problem. The soils in most forest reserves located in the Sudan Zone are mainly Aeolian Drift sand (Regosols) and interspersed with fine textured alluvium (Vertisols and Solonchaks), while those in the Sub-Sudan were developed either from Aeolian sands also or from rocks of the Basement Complex. For forestry purposes, the soils in these two zones are classified as marginally plantable. The climate (rainfall) is more of a limiting factor than the soils. But trees on a short rotation like those intended for charcoal, fuel and for posts may be grown. Neem trees have shown some adaptability to the soils and climate but as to how long the trees can survive under these conditions is still the subject of study. The low organic matter content of the soils requires special attention. At the Maiduguri F.R. (P 60) it was shown that the organic matter content of the soil can be raised from less than 1 percent to as high as 4 percent by simply allowing the fallen neem leaves to decay in the ground. For newly established plantations, it may be necessary to establish windbreaks in order to control soil moisture evaporation and cut down transpiration from the young seedlings.

In the case of Solonchaks, the elimination of the salts by flushing with water may not be practical in view of the scarcity of water. In the case of the Vertisols, proper timing in land preparation to attain the maximum friability of the soil should be followed. In both cases, however, the selection of suitable species of trees should be the right approach for the soils in these zones.

2.5.2 Northern Guinea Zone

This zone has an annual rainfall from 40 to 50 in. Natural vegetation is more luxuriant than in the Sudan Zone. The soils in this zone are Ferruginous Tropical Soils on Sandy Parent Material (Eutric Cambisols, Plinthic Luvisols and Lithosols). For the first soil, soil depth and erosion are the important problems. It has been found that the roots of some indigenous and exotic species cannot penentrate the indurated plinthite layer whereas some other species have that ability. The plinthite layer may be more than 36 in in thickness and can be very hard. The use of a subsoiler to break this hardened layer may be a temporary remedy and at the same time prove also very expensive. Species of trees whose roots can penetrate the hardened plinthite should be selected. So far, the roots of eucalypts only have shown to possess this ability to penetrate indurated plinthite.

Soil erosion presents some problem specially during the early period of the establishment of the plantation. Observations have shown that soon after the trees are fully established and their canopies closed, soil erosion becomes stabilized and controlled. In lands with steep slopes, it will be necessary to prepare the land in alternate strips along the general contour. This system will reduce the length of the downward slopes and prevent rapid runoff. All land operations, like cultivation, should be done along the general contour.

In the case of the Luvisols in this zone, in relatively small areas only is soil drainage a very critical factor for tree growth. These areas are usually lower bottom lands along courses of streams. This type of land is not very suitable for forestry but if it becomes necessary to plant on it, selected species of trees proved to be tolerant to wet soils should be planted. Draining

the land can be done, but owing to the relatively low rainfall in this zone, it will be better to let the rain water percolate into the soil and be stored for future use rather than to let the water flow out into the streams.

The Lithosols are under capability class V and this soil unit is not recommended for any kind of cultivation and it is classified as Unplantable.

2.5.3 Southern Guinea Zone

This zone has a higher annual rainfall than the Northern Guinea Zone and it is also characterized by a more luxuriant vegetation including the presence of Riparian forest. The three principal soil units in this zone are the Ferruginous Tropical Soils on Crystalline acid rocks (Eutric Cambisols, Plinthic Luvisols) and Red Ferrallitic Soils on Loose Sandy Sediments (Rhodic Feralsols). The important soil problems of the Ferruginous Tropical Soils are also similar to those found in the Northern Guinea Zone, namely soil depth and drainage conditions. The treatments necessary for their correction will also be the same as those mentioned for the Northern Guinea Zone. In the case of the Ferrallitic Soils which are common in many forest reserves in this zone, the problem lies in soil profile deficiency. These Ferrallitic Soils developed from sandstone are sandy and generally acidic and have very low reserves of weatherable minerals. Being sandy, permeability is rapid and leaching of plant nutrients is excessive. To correct these deficiencies, it will be necessary to increase both the moisture and fertility holding capacities of the soil by increasing the organic matter content through green manuring. The low fertility of the soils is shown in a fertilizer experiment conducted in the Mokwa Forest Reserve (Takumah loamy sand) which gave significant results with the application of nitrogen and phosphorus upon the growth of Gmelina (Jackson 1970). Much greater effect could have been obtained if the organic matter content in the soil was increased. So far, the effect of organic matter upon the growth of trees has been tried only in the Sudan Zone in the Yambawa fine sand. Jackson (1970) found significant results on the growth of neem.

Large areas of class IV and class V lands are found in many forest reserves in this Southern Guinea Zone. While class IV lands are classified as marginally plantable, they should be considered as last in priority for forest plantations. The class V lands should be set aside for wildlife.

2.5.4 Derived Savanna Zone

This vegetative zone located in the southern scarpment of Jos Plateau has much higher rainfall (50 to 70 in a year) than the same vegetation zone located south of the Benue River. The important soil units found in the area near the Jos Plateau are Ferruginous Tropical Soils on Crystalline Acid rocks (Eutric Cambisols and Plinthic Luvisols), Eutrophic Brown Soils (Eutric Cambisols or Haplic Phaeozems) and Lithosols. Soil depth and soil drainage are the important problems of the Ferruginous Tropical Soils and the Lithosols. Some forest reserves (Sanga River) have wide areas of shallow soils (Daji sandy loam). Like other similar soils of very limited effective depth, the selection of appropriate species of trees whose roots can penetrate the indurated plinthite is recommended rather than breaking it with the use of a subsoiler. Subsoiling has, in many cases, promoted the development and hardening of the plinthite. Alexander and Cady (1962) claimed that deforestation causes hardening of the plinthite. Hardened plinthite were noted under Riparian forest in both the Sanga River and Nimbia Forest Reserves.

Soil erosion and drainage are the important soil problems confronting the Eutrophic Brown Soils. Soil erosion becomes a problem only during the early period of growth of the trees but as soon as the canopies of the trees close, soil erosion becomes stabilized and controlled. In the case of soils with poor drainage, the selection of suitable species of trees should be followed.

The area classified also as Derived Savanna located south of the Benue River has lower rainfall (46 to 56 in a year) than the similar vegetation zone located south of the Jos escarpment. The soil units in this area were developed from Cretaceous sandstones and classified as Red Ferrallitic Soils (Rhodic Feralsols). The soils in most profiles are sandy with very low water holding capacity, generally acidic, low in organic matter content and low in general fertility. Trial plantings with teak, Gmelina, pines and Eucalyptus made in the Western Okura Forest Reserve (soil report No.9) on very deep, well drained and red sandy soil are generally very poor compared with similar trees planted in the Derived Savanna Zone also located south of the Jos escarpment in Eutropic Brown Soils. The deficiencies of these Ferrallitic soils are moisture, organic matter and the low reserve of weatherable minerals. Soil conservation practices needed to correct these deficiencies are to increase the organic matter content of the soil by green manuring and by application of fertilizers. So far, no fertilizer experiments have been conducted in this soil unit in this particular vegetation zone.

Lithosols are also found in this soil developed from sandstone. The treatments necessary for this soil deficiency will be similar to those already mentioned for other Lithosols - selection of suitable tree species whose roots can penetrate the indurated plinthite.

2.5.5 Bauchi Plateau Zone

Located at 3 000 to 4 000 ft altitude, temperature assumes an important climatic factor. For this reason, pines seem to be well adapted in this zone. Two important soils in this zone are the Eutrophic Brown Soils developed from basaltic lava flows and the Ferruginous Tropical Soils on acid Crystalline rocks developed from the Basement Complex. The latter soils are generally poorly drained (Plinthic Luvisols) and most forest reserves located in this soil unit are planted to various species of Eucalyptus. Unlike the Ferruginous Tropical Soils, the Eutrophic Brown Soils have higher C.E.C., higher inorganic matter and the soils have good structure to promote better root development. The soils are slightly susceptible to soil erosion which can easily be controlled. In the case of erosion in pine plantations, mechanical means of control should be resorted to in as much as pine trees provide very little ground cover and the rate of growth of pine trees is rather slow. Selection of suitable species of trees should be made for the poorly drained soils on this plateau. Rainfall in this zone ranges from 45 to 57 in per annum so that it becomes more important to make this rain percolate into the soil rather than to drain it out into the streams. Some species of Eucalyptus are known to be tolerant to wet soils.

Most of the soils mapped in the northern States of Nigeria, with the exception of the Eutrophic Brown Soils of the Tropics and some of the Fluvisols are low in fertility. Jackson (1970) has reported many fertilizer experiments conducted on important soils including the Eutrophic Brown Soils. The results from phosphate application have shown significant response on

growth of some species of Pinus, Gmelina, teak and Eucalyptus. In many cases, better results were obtained when nitrogen was added. Potash, however, has failed to give any response to any species so far tried. The experiments also showed that different soil types and different species of trees require different amounts and kinds of fertilizers.

Field observations also have shown that ash from burned savanna trees has a profound effect on the growth of some exotic species of trees. Also, trees grown on old sites of termite mounds are much bigger than those from surrounding areas. These observations suggest that much improvement in the growth of trees can still be obtained through increasing the organic matter content of the soil and the application of different combinations of various fertilizer elements.

3. RECOMMENDATIONS

It is recommended that semidetailed soil surveys of further forest reserves should continue, as large areas of suitable plantable land are and will be required for plantation development. To continue the classification of the soils in the remaining forest reserves in the northern States of Nigeria, a full time counterpart in the soil survey section should be appointed and trained. The section should also have a well trained draftsman with experience in map making.

It is suggested that a simple system of classifying savanna soils according to suitability for plantation development as initiated in the present studies should be developed as opportunity offers. In the longer term, following further development, such a simple classification might provide the basis for a more complex forestry site quality classification system. The depth from the soil surface to the horizon of the indurated plinthite and the soil drainage conditions are the two most important criteria in classifying soil units in relation to forest plantation development.

As the present soil survey section of the Savanna Forestry Research Station is inadequately staffed to continue large scale soil surveys, the Federal Department of Forestry will require to consider how much essential work will be required in the future, and whether such work under certain circumstances should be the responsibility of a centralized agency or should be the responsibility of the several State Forestry Departments. The need for uniformity of survey methods and correlation of results hardly requires stressing.

The need for detailed soil surveys of areas of silvicultural development is a matter of some priority to provide data to determine the correlation between the growth of forestry plantation species and the site factors, particularly soil characteristics.

As in soil surveying, the measurement of depths of water tables and detailed investigation of their fluctuation in some of the selected forest reserves should also be continued.

The soils in most forest reserves in the Sudan Zone are marginally plantable due to soil factor and climatic limitations. These forest reserves should be devoted mainly for trees intended for fuel, charcoal and for posts. Some of the soils in this zone have alkalinity problems and species trial planting experiment should be tried in this soil unit. The cultivation of Vertisols should be done when the soil reaches its maximum friability.

Fertilizer experiments caused harmful effects on neem trees planted on the Sandy Regosols in this Sudan Zone. It is therefore recommended that organic matter should be added with the fertilizers to act as a buffer.

The Ferruginous Tropical Soils in the Northern Guinea Zone are beset by problems either of shallowness (depth to the indurated plinthite) or poor drainage. For these soil deficiencies, it is better to select suitable species of trees either for poor drainage condition or for shallow soils rather than to correct the soil deficiencies either by drainage ditches or by the use of a subsoiler to break the indurated ironpan.

The important soil units in the Southern Guinea Zone whose limitations are similar to those found in the Northern Guinea Zone should also be treated similarly. Another important soil unit in this zone is the sandy soil developed from sandstone. This soil will require some conservation practices to improve both water and fertility holding capacities by the addition of organic matter. Selection of suitable species of trees for this Ferrallitic Soil should be done in conjunction with the fertility tests.

The soils in the Derived Savanna Zone are also Ferruginous Tropical Soils and Ferrallitic Soils on Loose Sandy Sediments like those in the Southern Guinea Zone, with the exception of some soils developed from the Newer Basalt (Eutropic Brown Soils of the Tropics). These soils found in some forest reserves are very limited in area and are almost reforested. The development of the soils in this zone should be concentrated in the Ferruginous Tropical Soils and in the Red Ferrallitic Soils. Some of the Ferruginous Tropical Soils are deep and well drained and are plantable without restrictions while others are shallow and some are poorly drained. The recommendations given for these soil deficiencies, as mentioned in the other zones, are also applicable. In the case of the Red Ferrallitic Soils which are very sandy, the addition of organic matter and application of fertilizers are recommended. It should be noted, however, that the Derived Savanna Zone near Jos receives greater rainfall than on the south of Benue River of the same zone. This may account for the poor growth of Teak and Gmelina in the latter area.

The climatic conditions in the Bauchi Plateau are different from the other vegetation zones described due to its high altitude. Preliminary growth trials of pines at the Miango Forest Reserve showed good adaptability. But large areas of soils on this plateau belong to the Luvisols group which are poorly drained. The suitability of pines in this soil unit is still under study in a trial planting located at the Mongu forest reserve. More trial plantings of pines should be done on deep and well drained soils similar to those at the Ta Hos forest reserve.

The plantable soils in all the forest reserves so far studied are generally low both in organic matter and in essential elements. Fertilizer experiments together with organic matter should be tried. This kind of combination is important in cases of sandy soils (Red Ferrallitic Soils).

Lands under capability class IV are marginally plantable. These lands should be set aside for future development or for wildlife purposes.

Appendix 1

CLIMATIC DATA IN THE SUDAN ZONE[1/]

Month	Sokoto[2/]					Kano[3/]					Maiduguri[4/]				
	Rainfall	Temperature °F		Relative humidity %		Rainfall	Temperature °F		Relative humidity %		Rainfall	Temperature °F		Relative humidity %	
	In	Max.	Min.	0600 G.M.T.	1200 G.M.T.	In	Max.	Min.	0600 G.M.T.	1200 G.M.T.	In	Max.	Min.	0600 G.M.T.	1200 G.M.T.
January	0.0	91.6	59.6	28	12	0.0	85.6	56.1	37	13	0.0	88.9	54.7	48	17
February	0.0	95.5	62.9	31	16	0.0	89.9	59.5	33	12	0.0	92.9	58.0	41	13
March	0.0	100.7	70.2	23	10	0.1	95.7	65.9	31	12	0.0	98.2	64.9	34	11
April	0.4	104.9	76.2	33	17	0.4	100.8	72.4	42	19	0.3	104.1	71.1	32	12
May	2.0	102.8	78.6	56	29	2.5	99.3	74.6	63	32	1.6	102.1	75.4	53	25
June	3.5	97.6	76.4	71	41	4.4	94.5	73.9	74	46	2.7	97.4	74.8	73	40
July	5.8	90.7	72.5	81	55	8.0	87.2	71.1	88	60	6.9	89.4	72.7	87	60
August	9.3	86.3	72.1	90	68	12.4	85.1	69.6	94	71	8.8	85.6	71.2	94	69
September	5.7	89.4	71.6	90	63	5.0	88.0	69.4	92	61	4.1	89.4	70.9	93	59
October	0.5	96.1	70.5	82	41	0.5	93.5	68.1	80	36	0.8	95.3	68.5	83	37
November	0.0	97.7	64.3	47	16	0.0	92.5	61.6	48	15	0.0	95.1	59.6	60	18
December	0.0	92.6	59.8	38	17	0.0	87.1	56.9	43	12	0.0	90.3	55.4	56	20

1/ Data from Land and People in Nigeria by Buchanan and Pugh.
Temperature and relative humidity from 1943 to 1947

2/ Rainfall mean of 35 years

3/ Rainfall mean of 46 years

4/ Mean of 34 years.

Appendix 2

CLIMATIC DATA IN THE SUB-SUDAN ZONE[1/]

Month	Bauchi[2/]					Yola[3/]					Yelwa[4/]				
	Rainfall	Temperature °F		Relative humidity %		Rainfall	Temperature °F		Relative humidity %		Rainfall	Temperature °F		Relative humidity %	
	In	Max.	Min.	0600 G.M.T.	1200 G.M.T.	In	Max.	Min.	0600 G.M.T.	1200 G.M.T.	In	Max.	Min.	0600 G.M.T.	1200 G.M.T.
January	0.0	87.8	59.0	28	10	0.0	95.1	65.2	35	16	0.0	94.8	58.7	55	14
February	0.0	91.1	62.7	25	9	0.0	98.4	69.4	33	15	0.0	99.0	65.6	47	18
March	0.2	95.5	68.4	27	10	0.3	102.0	75.5	34	17	0.1	102.0	72.6	50	22
April	1.4	98.1	72.7	47	18	1.9	103.0	78.8	55	26	1.0	102.6	77.7	61	33
May	3.5	94.8	72.0	72	34	4.9	96.9	76.1	76	39	4.0	97.1	77.0	76	48
June	5.9	89.6	69.4	84	50	6.2	90.5	73.4	87	61	4.7	90.7	73.2	88	62
July	9.1	84.5	67.9	90	62	6.8	87.4	72.4	90	66	6.0	87.3	72.5	91	68
August	14.5	82.1	67.5	94	69	7.7	86.2	72.5	92	68	10.4	84.2	71.9	95	77
September	7.1	84.3	67.3	93	64	7.8	87.2	71.5	93	69	8.7	87.0	71.1	96	72
October	1.5	88.9	67.5	86	45	3.2	91.1	71.9	91	60	3.2	91.2	70.7	95	63
November	0.0	91.2	63.0	54	17	0.2	96.9	67.5	71	29	0.0	96.4	62.4	91	34
December	0.0	89.2	59.7	38	13	0.0	96.0	65.1	47	19	0.0	95.9	56.8	78	21

1/ Data from Land and People in Nigeria by Buchanan and Pugh
Temperature and relative humidity from 1943 to 1947 inclusive

2/ Rainfall mean of 33 years

3/ Rainfall mean of 35 years

4/ Mean of 13 years.

Appendix 3

CLIMATIC DATA IN THE NORTHERN GUINEA ZONE

Month	Samaru[1]					Kaduna[2]				
	Rainfall	Temperature °F		Relative humidity %		Rainfall	Temperature °F		Relative humidity %	
	In	Max.	Min.	0600 G.M.T.	1200 G.M.T.	In	Max.	Min.	0600 G.M.T.	1200 G.M.T.
January	0.0	87.7	57.3	24	19	0.0	88.8	58.9	36	15
February	0.0	90.8	60.5	22	16	0.1	91.0	62.8	35	17
March	0.1	95.6	67.0	30	17	0.5	93.7	67.2	45	20
April	3.9	96.5	71.0	53	30	2.7	95.7	71.2	61	30
May	9.9	91.8	70.1	62	44	5.8	91.5	71.2	81	50
June	13.4	87.4	67.8	75	59	7.0	86.0	68.1	91	64
July	16.2	83.2	67.1	80	68	8.6	81.7	67.4	94	72
August	20.4	81.7	66.9	82	71	12.3	79.9	67.9	95	77
September	17.1	84.7	66.4	77	65	11.0	83.6	66.7	95	68
October	4.4	88.7	63.4	61	45	3.0	87.9	66.1	92	53
November	0.6	89.5	60.4	35	25	0.2	90.5	59.5	71	23
December	0.0	87.3	57.3	27	21	0.0	89.4	57.1	51	17

1/ Annual Report, 1966/67 Institute for Agricultural Research.
Data mean from 1928–66

2/ Data from Land and People of Nigeria by Buchanan and Pugh.
Rainfall mean of 35 years; and other data from 1943 to 1947.

Appendix 4

CLIMATIC DATA IN THE SOUTHERN GUINEA ZONE[1/]

Month	Makurdi[2/]					Bida[3/]					Minna[4/]				
	Rainfall	Temperature °F		Relative humidity %		Rainfall	Temperature °F		Relative Humidity Mean	0900 h	Rainfall	Temperature °F		Relative humidity %	
	In	Max.	Min.	0600 G.M.T.	1200 G.M.T.	In	Max.	Min.			In	Max.	Min.	0600 G.M.T.	1200 G.M.T.
January	0.11	94.0	65.1	81	29	0.02	94	69		30	0.0	94.9	66.6	40	24
February	0.27	96.7	69.9	77	30	0.24	97	72		43	0.2	96.8	71.5	44	29
March	1.59	96.5	75.5	84	42	1.22	99	76		62	0.7	97.8	73.6	53	33
April	2.91	93.6	75.5	88	53	2.17	98	76		67	2.4	97.7	75.4	73	44
May	6.27	89.9	73.5	92	62	5.26	91	74		74	5.9	92.6	73.4	84	56
June	6.45	87.1	72.0	94	67	6.66	88	72		80	7.4	86.9	71.1	91	68
July	9.14	85.5	71.9	94	68	7.29	86	72		83	7.9	83.9	70.4	93	73
August	9.93	85.0	72.0	94	71	7.14	85	72		81	11.0	82.3	70.5	94	77
Sept.	11.69	86.1	71.5	95	68	8.48	86	72		84	11.9	84.7	69.6	94	72
October	5.31	87.7	71.2	95	65	3.98	89	71		78	5.7	88.1	69.6	93	65
November	0.42	90.1	69.4	94	50	0.29	92	68		70	0.2	93.2	66.5	77	40
December	0.16	92.2	62.7	90	35	0.00	93	67		48	0.0	94.6	65.5	53	28

1/ Data for Bida and Minna from Land and People in Nigeria by Buchanan and Pugh. Temperature and relative humidity are mean from 1943 to 1947

2/ Climate Investigation Centre, Lagos. Record mean 1951-60.

Appendix 5

CLIMATIC DATA IN THE DERIVED SAVANNA ZONE

Month	Lokoja[1/]					Enugu[2/]					Nimbia[3/] (1967 - 70)				
	Rainfall	Temperature °F		Relative humidity %		Rainfall	Temperature °F		Relative humidity %		Rainfall	Temperature °F		Relative humidity %	
	In	Max.	Min.	0600 G.M.T.	1200 G.M.T.	In	Max.	Min.	0600 G.M.T.	1200 G.M.T.	In	Max.	Min.	0600 G.M.T.	1200 G.M.T.
January	0.1	90.0	71.0	70		0.7	89.7	72.2	82	46	0.0	92	63	63	36
February	0.2	93.0	74.0	67		1.1	92.1	73.3	80	46	0.0	96	67	61	31
March	2.3	95.0	77.0	70		2.6	92.7	75.0	86	54	0.9	96	70	78	45
April	4.4	95.0	77.0	70		5.9	91.1	74.8	88	62	5.5	93	74	86	54
May	5.5	90.0	74.0	75		10.4	88.1	72.9	91	69	9.1	87	74	89	65
June	8.1	88.0	73.0	77		11.4	85.1	71.6	92	73	7.8	84	70	89	68
July	7.3	85.0	72.0	78		7.6	82.9	71.5	92	75	15.5	83	66	91	71
August	7.8	85.0	72.0	73		6.7	83.0	71.1	91	73	16.3	81	66	89	72
Sept.	9.7	87.0	71.0	79		12.8	84.5	70.8	93	73	10.7	84	65	93	69
October	5.1	87.0	72.0	78		9.8	86.5	71.0	93	70	3.4	87	66	93	65
November	0.5	90.0	71.0	73		2.1	89.2	72.6	91	58	0.9	92	62	89	36
December	0.5	90.0	66.0	75		0.5	89.3	72.1	83	50	0.0	90	58	75	29

1/ Data based from weather station at Lokoja. Mean of 51 years

2/ Data from Land and People in Nigeria by Buchanan and Pugh. Temperature and relative humidity are means from 1943 - 47

3/ Savanna Forestry Research Station record.

Appendix 6

CLIMATIC DATA IN THE BAUCHI PLATEAU ZONE[1/]

Month	Jos				
	Rainfall	Temperature °F		Relative humidity %	
	In	Max.	Min.	0600 G.M.T.	1200 G.M.T.
January	0.1	82.1	57.0	33	14
February	0.1	85.6	59.3	40	17
March	1.0	87.2	64.1	45	18
April	3.5	88.5	66.3	66	24
May	7.9	85.0	65.4	83	46
June	9.1	80.9	63.4	92	62
July	12.9	76.4	62.7	95	71
August	11.6	74.9	62.3	97	76
September	8.4	78.6	62.2	96	63
October	1.6	82.2	62.2	86	45
November	0.1	83.4	60.3	51	21
December	0.1	82.4	57.2	40	17

1/ Data from Land and People in Nigeria by Buchanan and Pugh. Rainfall is mean of 29 years and other data mean from 1943 to 1947.

Appendix 7

LIST OF SOIL SURVEY REPORTS

1. A semidetailed soil survey of the Afaka Forest Reserve, North Central State;

2. A semidetailed soil survey of the Nimbia Forest Reserve, North Central State;

3. A semidetailed soil survey of the Sanga River Forest Reserve, North Central State;

4. A semidetailed soil survey of the Yambawa Forest Reserve;

5. A semidetailed soil survey of Mokwa Forest Reserve;

6. A semidetailed soil survey of the Osara Forest Reserve;

7. A semidetailed soil survey of Rafin-Bauna, Mongu and Gindiri-Langai Forest Reserves Benue Plateau State;

8. A reconnaissance soil survey of Doma Forest Reserve, Benue Plateau State;

9. A reconnaissance soil survey of Dekina, Okura-Iyale and Western Okura Forest Reserves, Kwara State;

10. A report on the fluctuation of water tables in some forest reserves in the Northern Region of Nigeria.

Appendix 8

LIST OF INDIVIDUAL PROFILES EXAMINED

P6	-	Katsina City Hall Plantation, Katsina
P16	-	Gusau Rural Plantation, Sokoto
P42	-	Anara Forest Reserve, Zaria
P44	-	" " " Zaria
P55	-	Hadejia Town Plantation, Hadejia
P56	-	" " " Hadejia
P57	-	Malam Maduri Plantation
P58	-	Gabasawa Forest Reserve, Gumel
P59	-	Gumel Forest Reserve, Gumel
P59-A	-	" " " Gumel
P60	-	Maiduguri Fuel Plantation, Maiduguri
P61	-	Balori Ridge Forest Reserve, Maiduguri
P62	-	Fuchu Forest Reserve
P62-A	-	" " "
P63	-	Pompomari Forest Reserve, Maiduguri
P64	-	Danfisa Forest Reserve, Azare
P65	-	Kurmin-Biri Forest Reserve, Katchia, Kaduna
P66	-	Miango Forest Reserve, Jos Plateau
P67	-	Cece Forest Reserve, Lapai, Minna
P68	-	Vom Plantation, Vom, Jos Plateau
P69	-	Chanje Forest Reserve, Kafanchan
P70	-	Ta-Hoss Forest Reserve, Jos Plateau
P71	-	Barakin-Ladi Forest Reserve, Jos Plateau
P72	-	Jere Forest Reserve, Jos Plateau
P73	-	Maje Abuchi Forest Reserve, Abuja
P74	-	Minna Fuel Plantation, Minna
P76	-	Idu Forest Reserve, Abuja
P78	-	Agaie Fuel Plantation, Bida
P90	-	Guga Forest Reserve, Zaria
P92	-	" " " Zaria
P93	-	" " " Zaria
P94	-	Kainji Dam Site
P95	-	" "

Appendix 9

A SUMMARY OF THE EXTENT, RAINFALL AND GEOLOGICAL FORMATION OF THE SOIL UNITS IN THE FOREST RESERVES OF THE SAVANNA AREAS OF NIGERIA

Forest reserve	Area (ac)	Vegetation Zone	Annual rainfall (in)	Geological Formation	Soil Units	Area (ac)
Afaka	26 982	Northern Guinea	43	Basement Complex	Ferruginous Tropical Soil on Sandy Material (Eutric Cambisols)	19 070
					Groundwater laterite (Plinthic Luvisols)	2 520
				Alluvium	Hydromorphic	1 942
					Unclassified	3 450
Nimbia	5 440	Derived Savanna	67	Newer Basalt	Eutrophic Brown soil (Eutric Cambisols)	1 975
					Groundwater laterite (Plinthic Luvisols)	138
					Ferruginous Tropical soil " " (Eutric Cambisols)	918
						1 235
				Basement Complex	Hydromorphic (Eutric Fluvisols)	127
					Unclassified	1 047
Sanga River	70 054	Derived Savanna at northern part	66	Newer Basalt	Eutrophic Brown soil (Eutric Cambisols)	7 330
				Basement Complex	Lithosol over Ferruginous crust	25 690
					Ferruginous Tropical soil (Eutric Cambisols)	22 179
		Southern Guinea at the southern part			Hydromorphic	694
				Alluvium	Juvenile soil on Riverian (Eutric Fluvisols)	2 952
					Groundwater laterite (Plinthic Luvisols)	11 039
						170
Yambawa	385	Sudan	33	Aeolian Drift Sand	Juvenile soil (Dystric Regosols)	380
					Hydromorphic (Eutric Cambisols)	5

Appendix 9 (Cont'd)

Forest reserve	Area (ac)	Vegetation	Annual rainfall (in)	Geological Formation	Soil units	Area (ac)
Mokwa	15 123	Southern Guinea	44	Sandstone	Red, Weakly Ferralitic soil on loose sandy sediment (Rhodic Ferralsols)	13 700
					Transitional Ferruginous Tropical soil (Eutric Cambisols)	935
					Lithosol on Ferruginous crust	400
					Unclassified	88
Osara	119 040	Southern Guinea	52	Basement Complex		
					Ferruginous Tropical soil on acid crystalline rocks (Eutric Cambisols)	46 091
				Alluvium	Groundwater laterite	291
					Plinthic Luvisols	2 058
					Juvenile soil on Riverian (Eutric Fluvisols)	441
					Unclassified	70 159
Dekina	26 611	Derived Savanna	56	Cretaceous Sandstone	Red Ferralitic (Rhodic Ferralsols)	13 040
					Lithosol Raw mineral soils	1 596
Western Okura	23 469	Derived Savanna	56	Cretaceous	Red Ferrallitic (Rhodic Ferralsols)	
					Ferruginous Tropical Soil (Eutric Cambisols)	2 112
					Raw Mineral Soils	1 175
Okura-Iyale	48 920	Derived Savanna	56	Cretaceous Sandstone	Red Ferrallitic (Rhodic Ferralsols)	43 691
					Lithosols Raw mineral soils	2 729
						2 508

Appendix 9 (Cont'd)

Forest reserve	Area (ac)	Vegetation	Annual rainfall (in)	Geological Formation	Soil units	Area (ac)
Doma	247 298	Southern Guinea	55	Cretaceous Sandstone	Red Ferrallitic (Rhodic Ferralsols)	37 492
					Ferruginous Tropical (Eutric Cambisols)	158 293
				Alluvium	Juvenile soil on Riverian (Dystric Fluvisols)	
					Unclassified	42 040
					Ferruginous Tropical soil on acid crystalline rocks (Eutric Cambisols)	46 091
				Alluvium	Groundwater laterite (Plinthic Luvisols)	291
					Hydromorphic soils (Eutric Fluvisols)	2 058
					Juvenile soil on Riverian (Eutric Fluvisols)	
					Unclassified	70 159
Rafin-Bauna	2 477	Bauchi-Plateau	56	Basement Complex	Ferruginous Tropical Soils (Eutric Cambisols)	15
				Alluvium	Eutric Fluvisol	5
					Unclassified	2 457
Gindiri-Langai	3 271	Bauchi-Plateau	56	Basement Complex	Eutric Cambisols	1 531
					Vertic Cambisols	239
					Unclassified	1 501
Mongu	1 331	Bauchi-Plateau	56	Basement Complex	Eutric Cambisols	304
					Raw mineral soil	767
				Alluvium	Vertric Cambisols	160

Appendix 10

SOME CHARACTERISTICS OF THE SOIL UNITS

Soil Unit	Drainage	Colour	Solum Depth (In)	Clay Mineral	C.E.C. mEq/100 g soil	Friability	Mineral Reserve	Fertility
Ferruginous Tropical Soil (Eutric Cambisols)	Good	Yellowish brown to Yellowish red	20 to 60	Kaolinite and some Montmo-rillonite	6 to 12	Friable moist, hard dry	Appreci-able	Fair to low
Groundwater Laterite (Gleyic Luvisols)	Poor	Light brown Red mottles	20 to 60	do	6 to 12	do	do	do
Hydromorphic (Eutric Fluvisols)	Very Poor	Dark gray	over 60	Mainly Montmorillonite	———	Depends on soil texture	Usually high	———
Eutrophic Brown Soil (Haplic Phaeozems)	Well Drained	Reddish brown	over 60	do	30 to 30	Friable moist or dry	High	High
Lithosol	Well drained	Brown to brownish Gray	12 or Less	———	———	Friable moist, hard dry	Fair	Fair
Juvenile Soil on Riverian (Dystric Fluvisols)	Well drained	Light gray to brown	Over 60	———	2 to 5	Usually sand and very loose	Very low	Very low
Red Weakly Ferrallitic (Rhodic Ferralsols)	A little excessive	Yellowish red	Over 60	Kaolinite	2 to 10	Very friable	Very low	Very low
Vertisol	Moderate-ly well	Dark gray to black	36 to 60	Montmorillonite	30 to 50	Hard dry, plastic wet	High	High
Juvenile Soil on Aeolian (Dystric Regosols)	Excessive	Yellowish brown	Over 60	———	2 to 5	Very loose wet or dry	Very low	Very low

Appendix 11

DESCRIPTION OF INDIVIDUAL PROFILES

I Information on the Site:

a. Profile No: 58

b. Soil name: Yambawa series

c. Higher category classification: Weakly Developed Soils within Juvenile Soils on Aeolian Sand, or Quartzipsamments

d. Date of examination: 21 September 1967

e. Author: A. Barrera and S. Amujo

f. Location: Gabasawa F.R.; 30 miles from Kano. Latitude 12° 10' N, longitude 9° 0' E

g. Elevation: 1 300 ft

h. Land form:

i. physiographic position: Plain
ii. surrounding land form: Plain
iii. microtopography: Flat

i. Slope on which profile is sited: About 2 percent down to the south

j. Land-use: Cleared and planted to neem trees

k. Climate: Under Sudan Savanna where the annual rainfall averages 33.9 in with 7 months of less than 1 in of rain. The mean annual temperature is 81°F. The annual maximum is 101 °F and the annual minimum is 67 °F. The relative humidity at 1 530 hrs ranges from 11 percent in March to 68 percent in August.

II General Information on the Soil

a. Parent material: Aeolian sand drift belonging to the Chad Formation consisting mainly of quartz sand. This was deposited during the Quarternary

b. Drainage: Somewhat excessive, Class 5

c. Moisture conditions in profile: Moist

d. Depth of groundwater table: During time of survey was 43 in

e. Presence of surface stones, rock outcrops: Nil

f. Evidence of erosion: Nil

g. Presence of salt or alkali: Nil

h. Human influence: Nil

III Brief Description of the Profile: A very deep sandy deposit carried by wind. The sand is very loose and structureless (single grained); greysh brown, brown to brownish yellow. The colour diminishes with depth. Mottles may be present especially at the lower parts of the profile. There is very little to no profile development and there are very few distinguishing characteristics among the horizons.

IV Profile Description

AC_p	0	-	5	in	Brown (10 YR 5/3) moist, fine sand; structureless;
	0	-	13	cm	loose and very friable moist or dry; few fine roots; boundary is smooth and diffuse; pH 5.6;
	5	-	12	in	Light yellowish brown (10 YR 6/4) moist, fine
	13	-	30	cm	sand; structureless (single grain); very slightly compact, generally loose and friable; few fine roots boundary is smooth diffuse; pH 5.6;
	12	-	24	in	This layer is very similar to above layer only
	30		61	cm	very slightly different in colour. pH 5.6;
	24	-	40	in	Very pale brown (10 YR 7/4) moist, very fine sand;
	61	-	102	cm	structureless (single grain); very loose and friable; free of any inclusion; boundary is smooth and diffuse; pH 5.6;
	40	-	+	in	Very pale brown (10 YR 7/4) moist; fine sand;
	102	-	+	cm	structureless (single grain); loose and friable; with few faint yellowish red (5 YR 5/6) mottles; few fine iron concretions; pH 5.2

Note: At this depth (43 in) the water table appeared and it was not possible to dig further down.

V Interpreted Characteristics of the Soil

Being sandy, the soil is loose and has very rapid permeability. It is very easy to cultivate even with the use of farm machinery but the difficulty lies in the choice of plants to suit both the soil and the climatic conditions of this area. To improve this soil, organic matter must be added to increase its water holding capacity and at the same time prevent rapid leaching of the plant nutrients. Some difficulty will be encountered in irrigation due to the rapid permeability but an overhead system of irrigation is suggested.

So far neem trees have shown good adaptability to both soil and climate of this area but how long a plantation of neem can survive still remains to be seen. However, it has already been found that if the wood desired is only for posts or for fuel, neem trees are well adapted.

The classification of this soil into Weakly Developed and Juvenile Soil on Aeolian Sand was based on the work of R.A. Pullan from a previous classification made on this same type of soil. The profile characteristics especially of the texture, structure and colour confirm the above classification. The chemical analysis showed very low C.E.C. and the mechanical analysis showed this soil to consists mainly of quartz sand which accounts for the low cation exchange capacity.

VI Chemical and Mechanical Analysis of the Samples

Profile No. 58

Depth Inches Centimetres	0 - 5 0 - 13	5 - 12 13 - 30	12 - 24 30 - 61	24 - 40 61 - 102	40 - 60 102 - 152
Soil reaction (pH)	6.3	5.1	5.0	6.1	7.0
C.E.C. (mEq/100 g soil)	1.1	0.5	0.4	0.4	0.3
Extractable cations:					
K (ppm)	16	16	8	20	4
Na					
Ca (ppm)	150	120	90	60	90
Mg (ppm)	58	49	73	53	48
Total	224	185	171	133	142
Sol. phoshopus (ppm)	-	2.0	-	1.4	-
Organic matter (percent)	0.39	0.34	0.17	0.21	0.10
Total nitrogen (percent)	0.029	-	-	-	-
Soil fractions (percent)					
Coarse sand					
Fine sand					
Silt					
Clay					

Note: Soil reaction was determined with 1:2.5 soil to water ratio.
Organic carbon by the method of Walkley Black
Exchangeable bases using N-Ammonium Acetate.
Soluble phosphorus was extracted by a 0.2N H_2SO_4 solution using 1 to 20 soil:acid ratio.
Mechanical analysis with the method of Bouyoucos using "Calgon" for dispersion.

DESCRIPTION OF INDIVIDUAL PROFILE

I Information on the Site:

a. Profile No: 62

b. Soil name: Birmin Series of the Gadao Association

c. Higher category classification: Weakly Developed Soils on loose sediments or a Eutric Regosols or a Psamment

d. Date of examination: 13 October 1967

e. Author: A. Barrera and S. Amujo

f. Location: Fuchu F.R.; 31 mi northeast of Maiduguri along Maiduguri - Dikwa road. Latitude 11° 50' N, longitude 13° 30' E

g. Elevation: Approximately 1 000 ft

h. Land form:

i. physiographic position: Plain
ii. surrounding land form: Plain
iii. microtopography: Flat

i. Slope on which profile is sited: Flat 0-1%

j. Land-use: Planted to forest tree seedlings consisting of Acacia spp mostly

k. Climate: Located in the Sudan Zone type of vegetation where annual rainfall ranges from 15 to 35 in falling between June to September. Temperature has a maximum of 106°F in April and a minimum of 55.6°F in February. The wind is NE from December to February and SW from May to June.

II General Information on the Soil

a. Parent material: Sandy materials over the Chad Sediments

b. Drainage: Excessive

c. Moisture conditions in profile: Moist at 245 in below surface

d. Depth of groundwater table: 184 ft

e. Presence of surface stones, rock outcrops: None

f. Evidence of erosion: None

g. Presence of salt or alkali: None

h. Human influence: Land cleared for planting

III. Brief Description of the Profile

The profile is poorly developed, consisting of very deep, excessively drained light yellowish brown fine sand on top, followed by a series of reddish yellow structureless fine sand layers.

IV. Profile Description

0	-	5	in	Brown (10 YR 5/3) wet to light yellowish brown (10 YR 6/4) dry, fine sand; single grain, very loose dry, friable moist; few fine pores, many fine roots; clean and smooth boundary; pH 5.4;
5	-	14	in	Dark brown (7.5 YR 4/4) wet to light yellowish brown (10 YR 6/4) dry, fine sand; structureless; very slightly compact, friable moist, few fine and medium pores, abundant fine and coarse roots; boundary is clear and smooth; pH 5.3;
14	-	24	in	Strong brown (7.5 YR 5/6) wet to reddish (7.5 YR 6/6) dry, fine sand; structureless, loose and friable moist or dry, very slightly compact; few fine roots, smooth and diffuse boundary; pH 5.3;
24	-	48	in	Reddish yellow (7.5 YR 6/8) wet to reddish yellow (7.5 YR 7/6) dry, fine sand; structureless; very loose and friable moist; few fine roots; smooth and diffuse boundary; pH 5.0;
48	-	86	in	Reddish yellow (7.5 YR 6/6) wet to reddish yellow (7.5 YR 7/6) dry, fine sand; structureless; very loose and friable moist, boundary smooth and clear; pH 5.0;
86	-	102	in	Very pale brown (10 YR 7/4) moist to yellow (10 YR 7/6) dry, fine sand; structureless, very loose moist; pH 6.2.

V. Interpreted Characteristics of the Soil

This soil is very sandy and under a climate with low rainfall and warm temperature. The soil has rapid permeability and is low in fertility. The choice of plants to suit these conditions is very limited. Only a few adaptable species can grow. In this reserve, trial plantings have been started with some species of Eucalyptus and others. Under similar soils and climate, neem trees have shown good growth for posts and fuel wood. The suitability of this site for timber purposes still has to be proved.

The addition of organic matter to this soil will increase its water-holding capacity as well as retain much of the fertility. Fertilization with complete elements of nitrogen, phosphorus and potassium will help plants to a good start. An overhead irrigation system is suggested in view of the rapid permeability of the soil which makes it impossible to conduct water through ditches.

The classification of this soil as Weakly Developed Soils and Juvenile Soils on Aeolian Sand was based on the morphological characteristics of the profile as shown by its texture, colour and structure. This was also classified by R.A. Pullan in 1962 in his survey of this area. The chemical analysis showed very low C.E.C. as the soil mineral is mainly made of quartz.

VI Chemical and Mechanical Analysis of the Samples

Profile No. 62

Depth Inches Centimetres	0 - 5 0 - 13	5 - 14 13 - 36	14 - 24 36 - 61	24 - 48 61 -122	48 - 86 122 -218	86-102 218-259
Soil reaction (pH)	5.4	5.3	5.3	5.0	5.0	6.2
C.E.C. (mEq/100 g soil)	2.8	5.0	6.1	6.4	5.4	4.1
Extractable cations:						
K (ppm)	16	8	8	16	24	40
Na (ppm)	-	-	-	-	-	-
Ca (ppm)	210	200	300	220	160	300
Mg (ppm)	100	112	126	151	112	102
Total	326	320	434	387	296	442
Sol. phosphorus (ppm)		3.6		7.0		8.0
Organic matter (percent)	0.41	0.25	0.17	-	0.14	-
Total nitrogen (percent)	-	-	-	-	-	-
Soil fractions (percent)						
Coarse sand						
Fine sand						
Silt						
Clay						

Note: Soil reaction was determined with 1:2.5 soil to water ratio.
Organic carbon by the method of Walkley Black.
Exchangeable bases using N-Ammonium Acetate.
Soluble phosphorus was extracted by a 0.2N H_2SO_4 solution using 1 to 20 soil: acid ratio
Mechanical analysis with the method of Bouyoucos using "Calgon" for dispersion.

DESCRIPTION OF INDIVIDUAL PROFILE

I Information on the Site:

a. Profile No: 62-A

b. Soil name:

c. Higher category classification: A cracking clay or Vertisol

d. Date of examination: 13th October, 1967

e. Author: A. Barrera and S. Amujo

f. Location: Fuchu F.R., 31 miles along Maiduguri - Dikwa road. Latitude 11° 50' N, longitude 13° 30'E

g. Elevation: Approximately 1 000 ft

h. Land form:

i. physiographic position: Plain
ii. surrounding land form: Plain
iii. microtopography: Flat

i. Slope on which profile is sited: Flat (0-1%)

j. Land-use: Under cover of grass and low trees

k. Climate: Located in the Sudan Zone type of vegetation where the annual rainfall is from 15 to 35 in falling between June to September. Temperature has a maximum of 106°F in April and a minimum of 55.6°F in February. The wind is NE from December to February and SW from May to June.

II General Information on the Soil

a. Parent material: Alluvial deposits

b. Drainage: Slow, Class 3

c. Moisture conditions in profile: Moist at 13 in from surface

d. Depth of groundwater table: 184 ft

e. Presence of surface stones, rock outcrops : None

f. Evidence of erosion: None

g. Presence of salt or alkali: Alkaline below 13 in depth

h. Human influence: None

III Brief Description of the Profile

The black upper layer is clay that cracks on drying and is hard when dry to plastic and sticky when wet. The lower layers are also clay which is dark grey to dark greyish brown clay, and are alkaline. The lowest layer is pale yellow to white sandy loam and is calcareous.

IV Description of Profile

0 - 3 in Dark grey (10 YR 4/1) moist to grey (10 YR 5/1) dry, clay; massive structure; very hard dry, sticky and plastic wet, very few fine pores; many fine roots; boundary is smooth and diffuse; pH 5.4;

3 - 13 in Dark grey (10 YR 4/1) moist or dry, clay; massive structure; very hard dry; plastic and sticky wet; many fine roots; smooth and diffuse boundary; pH 6.2;

13 - 38 in Dark greyish brown (10 YR 4/2) wet or dry, clay; massive structure; compact and hard dry; plastic and sticky wet; slight reaction with HC1; clear and smooth boundary; pH 8.0;

38 - 66 in White (10 YR 8/2) dry to very pale brown (10 YR 7/3) wet, sandy loam structureless; hard dry and slightly sticky and slightly plastic wet; no reaction with HC1; boundary smooth and clear; pH 7.9;

66 - 89 in Pale yellow (2.5 Y 5.4) wet to white (2.5 Y 8/0) dry clay; massive structure, very hard dry, plastic and sticky wet, strongly calcareous, medium size modules of $CaCO_3$; pH 8.5.

V Interpreted Characteristics of the Soil

This soil is the so-called cracking clay type and is very difficult to work either when wet or dry. When dry it is hard and when wet it is plastic and sticky. The analysis shows it has only 0.81 percent organic matter on the A horizon so that large additions of this material will help to make the soil more friable. Trees or other plants may be damaged especially during the dry season due to breaking up at their roots caused by the cracking of the soil. The addition of organic material may reduce this cracking. There is little danger of erosion or wind blowing from this soil type. However, there are some indications of this soil becoming alkaline as shown by the high pH values both in the third and last horizons. These two layers are also calcareous. Any irrigation done in this soil should be well controlled so as to prevent salts rising to the surface. Adequate drainage is also essential.

The classification of this soil as Vertisol was based on its physical conditions and texture of the upper 38 in. The characteristic cracking seen at the time of sampling further confirms this classification.

I Chemical and Mechanical Analysis of the Samples

Profile No. 62 - A

Depth Inches Centimetres	0 - 3 0 - 8	3 - 13 8 - 36	13 - 38 36 - 97	38 - 66 97 - 168	66 - 81 168 - 231
Soil reaction (pH)	5.4	6.2	8.0	7.9	8.5
C.E.C. (mEq/100 g soil)	16.3	14.7	27.6	14.1	18.0
Extractable cations:					
K (ppm)	128	88	120	64	72
Na	-	-	-	-	-
Ca (ppm)	320	480	580	300	560
Mg (ppm)	671	707	593	328	318
Total	1 119	1 275	1 293	692	950
Sol. phosphorus (ppm)		3.6		7.0	
Organic matter (percent)	0.81	0.41	0.36	-	-
Total nitrogen (percent)	0.066	0.031	-	-	-
Soil fractions (percent)					
Coarse sand					
Fine sand					
Silt					
Clay					

Note: Soil reaction was determined with 1:2.5 soil to water ratio.
Organic carbon by the method of Walkley Black.
Exchangeable bases using N-Ammonium Acetate.
Soluble phosphorus was extracted by a 0.2N H_2SO_4 solution using 1 to 20 soil: acid ratio
Mechanical analysis with the method of Bouyoucos using "Calgon" for dispersion.

DESCRIPTION OF INDIVIDUAL PROFILE

I Information on the Site:

a. Profile No: 64

b. Soil name: Very similar to Inkeb series described by Pullan (1962)

c. Higher category classification: May be placed under Halomorphic (Tomlinson, 1965) or as Gleyic Solonchak (Soil Map of the World)

d. Date of examination: 14 October 1967

e. Author: A. Barrera and S. Amujo

f. Location: At Danfisa F.R. located between Azare and Misau. Latitude 11° 18' N, longitude 10° 23' E. In a cassia plantation

g. Elevation: 1 600 ft

h. Land form:

i. physiographic position: Plain
ii. surrounding land form: Undulating plain (2 to 8% slope)
iii. microtopography: Plain

i. Slope on which profile is sited: 2 to 3% down towards the NE

j. Land-use: Planted to Cassia siamea

k. Climate: Seven months dry (mid October to end of April). Rain starts in May with its peak in August with an annual mean of 30.6 in. The mean monthly temperature (maximum) is 102°F in April to 85°F in August. The mean minimum is 76°F in May to 52°F in December.

II General Information on the Soil

a. Parent material: Alluvium on inter-dune depressions

b. Drainage: Moderately well drained, Class 3

c. Moisture conditions in profile: Dry on upper 17 in and moist below

d. Depth of groundwater table: No record

e. Presence of surface stones, rock outcrops: None

f. Evidence of erosion: Slightly eroded along paths

g. Presence of salt or alkali: alkali below 17 in from surface

h. Human influence: Field has been under cultivation for sometime.

III Brief Description of the Profile

Fairly deep, fine-textured soils from 4 to 56 in depth and with clime concretions throughout this depth. Red mottles are clearly visible within the light-coloured (pale brown to white) soil matrix. High pH values (pH 8.2 to pH 9.9) may indicate presence of soluble sodium salt.

IV Description of the Profile

0	-	4	in	Dark brown (10 YR 4/3) wet to pale brown (10 YR 6/3) dry,
0	-	10	cm	sandy loam; medium weak granular structure; hard dry, friable moist; few fine quartzite grains, many fine roots; boundary is smooth and clear; pH 7.0;
4	-	9	in	Yellowish brown (10 YR 5/4) wet to brown (10 YR 5/3)
10	-	23	cm	dry, clay; weak medium subangular structure; hard dry, plastic and sticky wet; many fine pores; many medium roots; few to very few small lime concretions; boundary is smooth and diffuse; pH 8.0;
9	-	17	in	Pale brown (10 YR 6/3) moist, clay; weak medium subangular
23	-	43	cm	structure; with few fine and distinct red mottles (10 YR 5/1); hard dry and sticky and plastic wet; few very fine pores; many fine quartzite grains, few lime concretions; soil matrix is calcareous; boundary is smooth and clear; pH 8.2;
17	-	38	in	Pale brown as above; with many medium and distinct
43	-	97	cm	light grey (2.5 Y 7/2) and red (2.5 YR 4/8) mottles; sandy clay; weak medium subangular blocky structure; hard dry, slightly plastic and sticky wet; few lime concretions; boundary is smooth and clear; pH 9.4;
38	-	48	in	Same characteristics as above; except that this horizon
97	-	122	cm	is more compact and reaction is but slightly calcareous; boundary is smooth and clear; pH 9.9;
48	-	56	in	White (2.5 Y 8/2) moist, sandy clay; with red (2.5 YR 4/8)
122	-	142	cm	and pale yellow (2.5 Y 7/4) mottles; weak medium subangular structure; compact and hard dry, slightly plastic and sticky wet; slightly calcareous; pH 9.8.

V Interpreted Characteristics of the Soil

The cultivation of this soil by mechanical means is somewhat doubtful due to the presence of several outcrops of granite in the surrounding areas. In addition, the relief being rolling with 3 to 5 percent of slope may create a problem in soil erosion. If cultivation is to be done, another soil problem to encounter is drainage. Mottles are present 9 in below the surface. Much of this soil moisture comes from lateral seepage. This soil has a problem in alkalinity possibly with concentrations of sodium salts about 17 in from the surface. The soil may be suitable only for either grazing or for trees but only plants suitable or tolerant to alkaline conditions should be tried.

The classification of this soil as Halomorphic or Gleyic Solonchak is based on a previous classification and substantiated from the chemical analysis. The horizons of high pH values put this soil as gleyic.

VI Chemical and Mechanical Analysis of the Samples

Profile No. 64

Depth Inches Centimetres	0 - 4 0 - 10	4 - 9 10 - 23	9 - 17 23 - 43	17 - 38 43 - 97	38 - 48 97 - 122	48 - 56 122 - 142
Soil reaction (pH)	7.0	8.0	8.2	9.4	9.9	9.8
C.E.C. (mEq/100 g soil)	7.8	13.8	13.8	11.9	6.6	10.3
Extractable cations:						
K (ppm)	136	116	112	164	196	120
Na						
Ca (ppm)	1 080	1 950	2 130	1 470	1 080	960
Mg (ppm)	194	253	299	503	389	583
Total	1 410	2 319	2 541	2 137	1 665	2 763
Sol. phosphorus (ppm)		8.8		2.8		3.6
Organic matter (percent)	0.94	0.52	0.37	0.30	0.17	0.18
Total nitrogen (percent)	0.073	0.032				
Soil fractions (percent)						
Coarse sand						
Fine sand						
Silt						
Clay						

Note: Soil reaction was determined with 1:2.5 soil to water ratio.
Organic carbon by the method of Walkley Black.
Exchangeable bases using N-Ammonium Acetate.
Soluble phosphorus was extracted by a 0.2N H_2SO_4 solution using 1 to 20 soil : acid ratio.
Mechanical analysis with the method of Bouyoucos using "Calgon" for dispersion.

DESCRIPTION OF INDIVIDUAL PROFILE

I Information on the Site:

a. Profile No: 67

b. Soil name: Danggappe loamy sand

c. Higher category classification: Red, Weakly Ferrallitic Soils on Loose Sandy Sediment or as a Rhodic Ferralsols

d. Date of examination: 16 June 1968

e. Author: S. Amujo and A. Barrera

f. Location: Cece F.R. Lapai, Abuja. Latitude 9° 4' N, longitude 6° 47' E

g. Elevation: Approximately 800 ft

h. Land form:

i. physiographic position: Upper slope of plain
ii. surrounding land form: Flat
iii. microtopography: Flat

i. Slope on which profile is sited: Less than 1%

j. Land-use: Savanna woodland

k. Climate: This reserve lies within the Southern Guinea Zone type of vegetation where the annual rainfall ranges from 45 to 55 in and a dry season lasting from 1 to 3 months with the peak of rainfall in September. The mean annual minimum temperature ranges from 70° to 72°F and the annual maximum from 90° to 92°F.

II General Information on the Soil

a. Parent material: Cretaceous, soft and coarse grained sandstone

b. Drainage: Somewhat excessively drained, Class 5

c. Moisture conditions in profile: Moist throughout the full depth

d. Depth of groundwater table: 30 ft in June

e. Presence of surface stones, rock outcrops: None

f. Evidence of erosion: Nil

g. Presence of salt or alkali: Nil

h. Human influence: Still under woodland

III Brief Description of the Profile

Very deep, red (2.5 YR or redder) weakly Ferrallitic sandy clays within 25 in from the surface underlying a sandy loam or loamy sand surface horizon, dominated by coarse sand throughout the profile; some B horizon development.

IV Profile Description

A11	0 - 5 in 0 - 13 cm	Dark brown (7.5 YR 3/2) wet to brown (7.5 YR 4/4) dry, loamy sand; structureless; loose and friable wet or dry; few fine roots; smooth and diffuse boundary; pH 6.9;
A12	5 - 12 in 13 - 31 cm	Brown (7.5 YR 4/4) wet to strong brown (7.5 YR 5/6) dry, loamy sand; structureless; loose and friable wet or dry; few fine roots; boundary smooth and diffuse; pH 6.5;
A13	12 - 20 in 31 - 51 cm	Strong brown (7.5 YR 5/6) wet to strong brown (7.5 YR 5/8) dry, loamy sand; structureless; loose and friable wet or dry; few fine and few medium roots; boundary smooth and diffuse; pH 6.3;
B2	20 - 35 in 51 - 89 cm	Dark red (2.5 YR 3/8) wet to red (2.5 YR 4/6) dry sandy clay loam; structureless to almost massive; slightly hard dry, and slightly plastic wet; few medium roots; boundary smooth and diffuse; pH 5.9;
C3	35 - 73 in 89 -186 cm	Dark red (10 R 3/6) wet to red (10 R 4/8) dry, clay; massive structure; slightly hard dry and slightly plastic wet; pH 5.4.

V Interpreted Characteristics of the Soil

The soil is very suitable for mechanical cultivation in that it is loose and friable and rock outcrops are absent. Soil erosion is not likely since the land is almost flat and infiltration is rapid which does not allow any runoff. However, the fertility is very low and would need liberal addition of organic matter and complete fertilizer. For better growth of plants, a constant supply of soil moisture will be needed specially during the dry season.

The classification of this soil as Red Weakly Ferrallitic soil on Loose Sandy Sediment was based on previous classification made by Higgins, et al., as shown by the red colour of the soils in the profile; very deep solum; very low base saturation and very low reserve of weatherable minerals.

VI Chemical and Mechanical Analysis of the Samples

Profile No. 67

Depth Inches Centimetres	0 - 5 0 - 13	5 - 12 13 - 31	12 - 20 31 - 51	20 - 35 51 - 89	35 - 73 89 -186
Soil reaction (pH)	6.9	6.5	6.3	5.9	5.4
C.E.C. (mEq/100 g soil)	3.6	3.2	1.8	2.9	0.6
Extractable cations:					
K (ppm)	32.0	0	0	4.0	0
Na	-	-	-	-	-
Ca (ppm)	360	220	100	180	320
Mg (ppm)	112	71	49	46	68
Total	612	291	149	230	388
Sol. phosphorus (ppm)	-	6.0	-	4.4	
Organic matter (percent)	0.88	0.46	0.07	0.15	0.17
Total nitrogen (percent)	0.057				
Soil fractions (percent)					
Coarse sand					
Fine sand					
Silt					
Clay					

Note: Soil reaction was determined with 1:2.5 soil to water ratio.
Organic carbon by the method of Walkley Black.
Exchangeable bases using N-Ammonium Acetate.
Soluble phosphorus was extracted by a 0.2N H_2SO_4 solution using 1 to 20 soil : acid ratio.
Mechanical analysis with the method of Bouyoucos using "Calgon" for dispersion.

DESCRIPTION OF INDIVIDUAL PROFILE

I Information on the Site

a. Profile No. 69

b. Soil name:

c. Higher category classification: Ferruginous Tropical Soil on Acid Igneous Rock or as Humic Cambisols as defined in soil units for the soil map of the world

d. Date of examination: 22 June 1968

e. Author: S. Amujo and A. Barrera

f. Location: In Change F.R. near Kafanchan. Latitude 9° 30' N, longitude 8° 20' E. On the left side of the road between Jama'a and Kafanchan

g. Elevation: 2 400 ft

h. Land form:

i.	physiographic position:	Escarpment or hillside
ii.	surrounding land form:	Hilly
iii.	microtopography:	Flat but broken by several rock outcrops

i. Slope on which profile is sited: 3 to 4%

j. Land-use: Land was cleared from its original woodland savanna then planted to pine seedlings

k. Climate: Area falls under the Derived Savanna Zone type of vegetation where the annual rainfall ranges from 50 to 70 in with a tendency to a double peak in June and September. Temperature varies with a mean maximum of 95°F and a mean minimum of 60°F.

II General Information on the Soil

a. Parent material: Basement Complex with Hornblende, Migmatite and older granite as the principal rocks

b. Drainage: Well drained, class 4

c. Moisture conditions in profile: Moist

d. Depth of groundwater table: Not determined

e. Presence of surface stones, rock outcrops: Numerous outcrops of Inselbergs (granite)

f. Evidence of erosion: Slight

g. Presence of salt or alkali: Nil

h. Human influence: Land recently ploughed for planting

III Brief Description of the Profile

The soil is deep and well drained with mica present in all horizons. Soil has dark brown A horizon and strong brown to yellowish red lower horizons and iron and manganese concretions found below 65 in. Numerous outcrops of granite are found.

IV Profile Description

Ap	0	- 4	in	Dark brown (10 YR 3/3) moist, clay loam; medium,
	0	- 10	cm	weak granular; friable moist; many fine roots, few fine mica; boundary is smooth and clear; pH 4.9;
A1	14	- 11	in	Dark yellowish brown (10 YR 4/4) moist, clay loam;
	10	- 28	cm	weak medium subangular blocky; friable moist; very slightly plastic or sticky wet; few medium roots and frequent very fine mica; boundary is smooth and diffuse; pH 5.8;
B11	11	- 29	in	Strong brown (7.5 YR 5/6) moist, clay loam; moderate,
	28	- 74	cm	medium subangular blocky; friable moist, slightly plastic or sticky wet; few fine roots, few grains of quartzites and many fine mica; boundary is smooth and diffuse; pH 5.7;
B12	29	- 65	in	Yellowish red (5 YR 4/6) moist, clay; moderate,
	74	- 165	cm	medium subangular blocky; soft wet, friable moist, slightly plastic either wet or dry, non sticky wet; medium size and many mica; boundary smooth diffuse; pH 5.8;
CC	65	- 99	in	Pale yellow (2.5 Y 7/4) moist, clay; moderate and
	165	- 251	cm	medium subangular blocky; non plastic or sticky wet; crumbly moist; very many fine mica; few iron and manganese concretions; pH 5.6.

V Interpreted Characteristics of the Soil

This soil is located in a rolling relief and only patches of small areas can be selected that can be cultivated with safety. In addition, there are several outcrops of Inselbergs which will prevent mechanization. But the soil appears friable and can easily be cultivated and the reserve of weatherable mineral is fair. The nitrogen content of the top layer may be considered as medium to high but nevertheless, fertilizer containing nitrogen and phosphorus will help promote good growth of plants. The soil will be suitable for trees. The relief and presence of rock outcrops are the factors which made this soil under capability class IVe.

The classification of this soil as a Ferruginous Topical Soil under Crystalline Acid rock was based on the origin or parent material, presence of iron concretions in the lower layers, slight development of a B horizon and with an appreciable amount of weatherable mineral. The profile shows that the B horizon is strong brown to yellowish red signifying concentration of iron.

VI Chemical and Mechanical Analysis of the Samples

Profile No. 69

Depth Inches Centimetres	0 - 4 0 - 10	4 - 11 10 - 28	11 - 29 28 - 74	29 - 65 74 - 165
Soil reaction (pH)	4.9	5.8	5.7	5.8
C.E.C. (mEq/100 g soil)	18.2	11.0	7.85	9.20
Extractable cations:				
K (mEq/100 g exch. cat.)	0.13	0.76	0.68	0.70
Na " "	0.20	0.22	0.22	0.22
Ca " "	0.95	2.50	1.10	0.50
Mg " "	1.06	1.96	1.56	1.58
Total	2.34	5.44	3.56	3.00
Sol. phosphorus (ppm)				
Organic matter (percent)	3.61	1.62	1.51	0.69
Total nitrogen (percent)	0.20	0.13	0.14	0.065
Base Saturation (percent)	12.9	49.5	45.4	32.7
Soil fraction (percent)				
Coarse sand				
Fine sand				
Silt				
Clay				

Note: Soil reaction was determined with 1:2.5 soil to water ratio.
Organic carbon by the method of Walkley Black.
Exchangeable bases using N-Ammonium Acetate.
Soluble phosphorus was extracted by a 0.2N H_2SO_4 solution using 1 to 20 soil : acid ratio.
Mechanical analysis with the method of Bouyoucos using "Calgon" for dispersion.

DESCRIPTION OF INDIVIDUAL PROFILE

I Information on the Site:

a. Profile No. 71

b. Soil name:

c. Higher category classification: Ferruginous Tropical Soil on Crystalline Acid Rock or as Plinthic Luvisols

d. Date of examination: 24 June 1968

e. Author: S. Amujo and A. Barrera

f. Location: Barakin Ladi F.R.

g. Elevation: 4 350 ft

h. Land form:

i. physiographic position: Plateau
ii. surrounding land form : Flat
iii. microtopography: Flat

i. Slope on which profile is sited: About 1%

j. Land-use: Planted to Eucalyptus

k. Climate: Located in the Jos Plateau type of vegetation where annual rainfall ranges from 45 to 55 in with its peak in July or August; with a maximum temperature of 82.3° F and a mean minimum of 61.9° F; the mean relative humidity at 1200 hours G.M.T. is 39 percent, low from October to May.

II General Information on the Soil

a. Parent material: Porphyritic Biotite and Biotite-Muscovite Granite, all of the Basement Complex

b. Drainage: Imperfectly drained, class 2

c. Moisture conditions in profile: Wet

d. Depth of groundwater table: Not determined

e. Presence of surface stones, rock outcrops: Nil

f. Evidence of erosion: Nil

g. Presence of salt or alkali: Nil

h. Human influence: Land ploughed previously for planting

III Brief Description of the Profile

This is a shallow, imperfectly drained soil derived from rocks of the Basement Complex. The upper part of solum is brownish yellow clay to a depth of 14 in followed by a hard and massive layer of hard plinthite which is greatly mottled with red.

IV Description of the Profile

Ap	0	-	5	in	Dark yellowish brown (10 YR 4/4) moist, clay;
	0	-	13	cm	weak, fine, granular; friable moist, slightly plastic or sticky wet; few fine pores; many fine roots and many fine quartzite grains; boundary wavy and clear; pH 5.4;
B11	5	-	9	in	Brownish yellow (10 YR 6/6) moist, clay; weak and
	13	-	23	cm	medium subangular blocky; friable moist; slightly plastic or sticky wet; many fine roots and many fine quartzite grains; boundary is wavy and diffuse; pH 5.5 with few red (2.5 YR 5/6) medium and distinct mottles;
B12	9	-	14	in	Brownish yellow (10 YR 6/6) moist clay; same structure
	23	-	36	cm	as above; with common (10 percent) medium and red (2.5 YR 4/6) distinct mottles; non plastic or sticky wet; boundary is wavy and clear; pH 5.4;
C1	14	-	20	in	Red (10 R 4/6) moist, clay; massive structure;
	36	-	51	cm	brittle wet; many (50 percent) coarse and prominent mottles; few fine roots; boundary is wavy and clear; pH 5.6;
C2	20	-	50	in	Same colour as above but with coarse and prominent
	51	-	127	cm	many light yellowish brown (2.5 YR 6/4) mottles; also massive structure; very hard dry; non plastic or sticky wet; with iron concretions and grains of quartzite; pH 6.0. The reddish material is very hard while the yellowish is loose and soft.

V Interpreted Characteristics of the Soil

The principal problem of this soil is drainage. The water table, as shown by the mottles in the profile, rises to 5 or 9 in from the surface during the height of the rainy season. This condition will certainly affect growth of some plants or limit the choice of plants to suit the conditions. So far, only eucalypts have been tried in this reserve and they are still young. But there are some species of Eucalyptus that can thrive in poorly drained soils. Cultivation by mechanical means presents no problem as the land is flat. But some kind of proper disposal of runoff should be provided to prevent possible erosion on this 2 percent slope.

There is a fair amount (1.6 percent) of organic matter in the topsoil and the nitrogen content is also fair. The reserve of weatherable minerals is appreciable (C.E.C. from 28 to 4.0 mEq/100 g soil). Nevertheless it will also prove beneficial to add commercial fertilizers to this soil. The lower horizons show very low values for C.E.C. which may mean they are strongly weathered and leached. Also this horizon (hard iron pan) will prove a hindrance to root development to some species of trees.

The classification of this soil as a Ferruginous Tropical Soil on Crystalline acid rock or as a Plinthic Luvisols is based on the development of a structural B horizon, presence of mottles in the lower horizons and the nature of its parent material.

VI Chemical and Mechanical Analysis of the Samples

Profile No. 71

Depth Inches Centimetres	0 - 5 0 - 13	5 - 9 13 - 23	9 - 14 23 - 36	14 - 20 36 - 51	20 - 50 51 - 127
Soil reaction (pH)	5.4	5.5	5.4	5.6	6.0
C.E.C. (mEq/100 g soil)	10.6	11.5	4.9	14.4	5.0
Extractable cations:					
K (ppm)	153	100	103	108	80
Na					
Ca (ppm)	320	280	300	240	220
Mg					
Total					
Sol. phosphorus (ppm)	9.0	7.0			
Organic matter (percent)	1.89	1.20			
Total nitrogen (percent)	0.10	0.06			
Soil fractions (percent)					
Coarse sand					
Fine sand					
Silt					
Clay					

Note: Soil reaction was determined with 1:2.5 soil to water ratio.
Organic carbon by the method of Walkley Black.
Exchangeable bases using N-Ammonium Acetate.
Soluble phosphorus was extracted by a 0.2N H_2SO_4 solution using 1 to 20 soil : acid ratio.
Mechanical analysis with the method of Bouyoucos using "Calgon" for dispersion.

DESCRIPTION OF INDIVIDUAL PROFILE

I Information on the Site:

a. Profile No: 73

b. Soil name:

c. Higher category classification: Ferruginous Tropical Soil on Acid Crystalline Rocks or as a Eutric Cambisols

d. Date of examination: 21 December 1969

e. Author: A. Barrera

f. Location: Maje Abuchi F.R. near Abuja. Latitude 9° 14' N, longitude 7° 10' E

g. Elevation: 1 200 ft

h. Land form:

i. physiographic position: Upper slope of peneplain
ii. surrounding land form: Hilly
iii. microtopography: Undulating

i. Slope on which profile is sited: About 4 to 5 percent

j. Land-use: At present under tree savanna type of vegetation

k. Climate: Under Southern Guinea type of vegetation with an annual rainfall of 53.3 in with a peak in September and with two months of less than 1 in rain. The mean annual maximum temperature is 91.1°F and the annual minimum 70.3° F, with November to January as a cold period. The annual mean relative humidity at 12.00 G.M.T. is 52 percent, low between November to April.

II General Information on the Soil:

a. Parent material: Gneiss, Migmatite and Older Granite, of the Basement Complex

b. Drainage: Moderately well drained, class 3

c. Moisture conditions in profile: Dry

d. Depth of groundwater table: Not determined

e. Presence of surface stones, rock outcrops: Outcrops of Inselbergs

f. Evidence of erosion: Slight

g. Presence of salt or alkali: Nil

h. Human influence: Seasonal burning of the area

III Brief Description of the Profile

This is a deep, moderately well drained to well drained soil generally gravelly specially below 21 in from the surface. The texture is sandy loam on the top layer followed by gravelly clay loam below. Gravels decrease and the texture becomes clayey at 53 in below the surface. Gravels are generally indurated ironstones.

IV Description of the Profile

A	0	- 6	in	Very dark greyish brown (10 YR 3/2) wet to grey
	0	- 15	cm	(10 YR 5/1) dry, sandy loam; weak fine granular; loose and friable moist, non sticky non plastic wet; common fine pores; few very fine roots; boundary is smooth and clear; pH 5.4;
B11	6	- 21	in	Brownish yellow (10 YR 6/8) wet or moist, clay
	15	- 53	cm	loam with few fine gravels; medium, fine subangular structure; friable moist, slightly sticky and plastic wet; few fine pores; and few fine roots; boundary is wavy and diffuse; pH 5.2;
B12	21	- 31	in	Brownish yellow (10 YR 6/6) dry to brownish yellow
	53	- 79	cm	(10 YR 6/8) wet; gravelly clay loam; medium fine subangular blocky; slightly sticky and plastic wet, friable moist; with few and very faint yellowish red mottles; very few fine roots; boundary is wavy and diffuse; pH 5.2;
B13	31	- 41	in	Yellow (10 YR 7/8) dry to brownish yellow (10 YR 6/8)
	79	- 104	cm	wet, gravelly clay loam; fine, weak subangular blocky; slightly sticky and plastic wet; hard dry, friable moist; very few fine roots; boundary is wavy and diffuse; pH 5.4;
B2	41	- 53	in	Strong brown (7.5 YR 5/6) wet to yellow (10 YR 7/8)
	104	- 135	cm	dry, gravelly clay loam; fine, weak subangular blocky; hard dry, slightly sticky and plastic wet; few gravels of granite and more of indurated ironstones; boundary is wavy and diffuse; few faint yellowish red mottles; pH 5.6;
B3	53	- 60	in	Yellowish brown (10 YR 5/8) wet to pale yellow
	135	- 152	cm	(2.5 Y 7/4) dry, gravelly clay; weak massive structure; hard dry, slightly plastic and sticky wet; very few fine pores; few, medium and faint yellowish red mottles; pH 5.4.

V. Interpreted Characteristics of the Soil

This soil is suitable for planting especially with the use of machinery with due precaution against some outcrops of granite. Also, safeguards against soil erosion should be taken as the 4 to 5 percent slope is likely to create soil washing when the soil is cultivated. The fertility of this soil is only fair as there are appreciable amounts of weatherable minerals, but a liberal application of fertilizers and organic matter will be necessary for good growth. Irrigation may present some problems due to the source of water and the slope of the land.

The classification of this soil as Ferruginous Tropical Soil on Acid Crystalline rock or as Eutric Cambisols is based mainly on the presence of a structural B horizon and a pallid A horizon. In the absence of chemical analysis it can only be assumed that the organic matter content is very low and the base saturation percentage likewise low. This has to be confirmed after the analysis of this soil.

VI Chemical and Mechanical Analysis of the Samples

Profile No. 73

Depth Inches Centimetres	0 - 6 0 - 15	6 - 21 15 - 53	21 - 31 53 - 79	31 - 41 79 - 104	41 - 53 104 -135	53 - 60 135 -152
Soil reaction (pH)	4.9	5.5	4.8	5.1	5.2	5.2
C.E.C. (mEq/100 g soil)	9.0	15.0	31.4	12.4	18.0	20.0
Extractable cations:						
K (mEq/100g exch.cat.)	0.15	0.23	0.20	0.20	0.17	0.16
Na	0.03	0.03	0.40	0.03	0.36	0.16
Ca Mg^{+}	3.0	2.33	2.03	2.41	2.93	2.93
Total	3.18	2.59	2.63	2.64	3.46	3.25
Sol. phosphorus (ppm)						
Organic matter (percent)	1.7	1.0	1.2	0.5	0.2	0.3
Total nitrogen (percent)	0.12	0.11	0.08	0.08	0.07	0.07
Soil fractions (percent)						
Coarse sand						
Fine sand						
Silt						
Clay						

Note: Soil reaction was determined with 1:2.5 soil to water ratio.
Organic carbon by the method of Walkley Black.
Exchangeable bases using N-Ammonium Acetate.
Soluble phosphorus was extracted by a 0.2N H_2SO_4 solution using 1 to 20 soil : acid ratio.
Mechanical analysis with the method of Bouyoucos using "Calgon" for dispersion.

DESCRIPTION OF INDIVIDUAL PROFILE

I Information on the Site:

a. Profile No: 74

b. Soil name:

c. Higher category classification: Plinthic Gleysols

d. Date of examination: 30 November 1969

e. Author: A. Barrera

f. Location: Minna Fuel Plantation (near Minna). Latitude 9° 40' N, longitude 6° 30' E

g. Elevation: 1 000 ft

h. Land-form:

i. physiographic position: Lower slope
ii. surrounding land form: Upland, rolling
iii. microtopography: Undulating with little depressions

i. Slope on which profile is sited: 2 to 3%

j. Land-use: Cultivated and planted to Eucalyptus

k. Climate: Under the Southern Guinea Zone type of vegetation with an annual rainfall from 45 to 55 in with a peak in August or September with 4 to 5 months of less than 1 in of rain. Mean maximum temperature from 94 to 97° F and a minimum of 66 to 71°F, occurring mainly between November to April. The relative humidity at 0600 G.M.T. is low from December to March (40 to 53 percent) and high (84 to 94 percent) for the rest of the year.

II General Information on the Soil

a. Parent material: Gneiss and Migmatite and Older Granite

b. Drainage: Moderately well drained - class 3

c. Moisture conditions in profile: Mostly dry

d. Depth of groundwater table: Not determined

e. Presence of surface stones, rock outcrops: Nil

f. Evidence of erosion: Nil

g. Presence of salt or alkali: Nil

h. Human influence: Top soil ploughed and planted to trees

III Brief Description of the Profile

A moderately deep, moderately well drained grey sandy soil resting over pale yellow to white clay which is prominently mottled with dark brown to strong brown increasing in the intensity of the mottles with depth starting from 26 in from the surface.

IV Description of the Profile

0	-	6	in	Grey (10 YR 6/1) dry to black (10 YR 2/1) wet,
0	-	15	cm	sandy loam; weak, medium subangular to fine granular; loose when dry, friable moist, few fine roots, boundary is clear and wavy; pH 5.6;
6	-	26	in	Reddish yellow (7.5 YR 7/8) dry, sandy loam;
15	-	66	cm	same structure as above; loose and friable dry, very slightly sticky wet; few fine roots; boundary is clear and wavy; pH 5.4;
26	-	41	in	Yellow brown (10 YR 5/6) dry, clay; weak,
66	-	104	cm	medium subangular blocky; friable moist, slightly plastic and sticky wet; few fine granitic gravels; (2 to 5 mm size); boundary is clear and wavy; pH 5.8. Few, medium and faint strong brown mottles present.
41	-	60	in	Pale yellow (2.5 Y 7/4) dry or wet, clay with
104	-	152	cm	dark brown (7.5 YR 4/4) common, medium and distinct mottles; very plastic wet; massive structure; boundary is clear and wavy; pH 5.8;
60	-	72	in	White (2.5 Y 8/2) dry or wet clay; massive
152	-	183	cm	structure; hard dry, very plastic wet; with many, medium and prominent strong brown (7.5 YR 5/8) mottles; pH 5.8.

V Interpreted Characteristics of the Soil

The top soil is friable and loose and can be worked easily with either machinery or hand cultivation, however, being on slopes, this soil is likely to erode especially if saturated with water when runoff will occur. Poor drainage conditions start at below 26 in as the texture becomes clay and with very slow permeability. It is advisable to plant only shallow rooted plants that are not susceptible to water logging or plants that are tolerant to wet soil. From the appearance of the colour of the soil, there is very little organic matter which may also mean low nitrogen and some basic nutrient elements.

The classification of this soil as Plinthic Gleysols was based mainly from the pallid colour of the A horizon and the gleyed condition of the underlying layers.

DESCRIPTION OF INDIVIDUAL PROFILE

I Information on the Site:

a. Profile No: 90

b. Soil name:

c. Higher category classification: Ferruginous Tropical Soils on Sandy Parent Material on Crystalline Acid Rocks or as Eutric Cambisoils

d. Date of examination: 16 September 1969

e. Author: A. Barrera

f. Location: Guga F.R. About 4 miles from Shika. Latitude 11° 13' N, longitude 7° 31' E. Along site trial plots of Eucalyptus

g. Elevation: 2 300 ft

h. Land-form:

i. physiographic position: Crest of peneplain
ii. surrounding land form: Sloping southward
iii. microtopography: Flat

i. Slope on which profile is sited: 2%

j. Land-use: Originally savanna woodland but later cleared and planted to several plots of Eucalyptus

k. Climate: Under Northern Guinea Zone type of vegetation where annual rainfall ranges from 40 to 50 in with 5 months under 1 in of rain. The mean maximum temperature is 88.7°F while the minimum is 64.6°F or an annual mean of 76.8°F. The relative humidity at 0600 G.M.T. ranges from 61% to 95% between April to November and from 35 to 51% for the rest of the year, and at 1200 hours G.M.T., it is from 50 to 77% from May to October and from 15 to 30% from November to April.

II General Information on the Soil

a. Parent material: Aeolian Drift Sand over Ferruginous soils developed from the Basement Complex;

b. Drainage: Moderately well drained, class 3

c. Moisture conditions in profile: Moist

d. Depth of groundwater table: Not determined

e. Presence of surface stones, rock outcrops: Nil

f. Evidence of erosion: Moderate sheet and severe gully erosion

g. Presence of salt or alkali: Nil

h. Human influence: Area was cleared and cultivated.

III Brief Description of the Profile

It is deep moderately well drained sandy loam resting over clay loam and clay for the substratum. The top layer is yellowish brown and becomes reddish brown down to 4 ft after which the soil is yellow to almost white. Red mottles which are frequent increase in intensity with depth down to 6 ft. Micas are also present from 48 in and below. The hard plinthite layer is located between 32 and 61 in.

IV Description of the Profile

Ap	0	- 4	in	Dark yellowish brown (10 YR 4/4) wet to light yellowish
	0	- 10	cm	brown dry, sandy loam; weak fine granular; friable moist, slightly hard dry; many fine roots; few spherical concretions of iron and few fine mica; boundary smooth and clear; pH 6.0;
B1	4	- 15	in	Yellowish red (5 YR 4/6) wet to yellowish red (5 YR 5/8)
	10	- 38	cm	dry, clay loam; weak fine subangular blocky; slightly hard dry, slightly plastic and sticky wet; few fine roots and few spherical iron concretions; boundary smooth and diffuse; pH 5.6;
B2	15	- 32	in	Strong brown (7.5 YR 5/6) wet to light reddish brown
	38	- 81	cm	(10 YR 7/4) dry, clay loam; weak fine subangular blocky; slightly hard dry; slightly plastic and sticky wet; few iron concretions and few fine roots; boundary smooth and clear; pH 6.0;
B3	32	- 48	in	Pink (7.5 YR 7/4) wet to light reddish brown (10 YR 7/4)
	81	- 122	cm	dry, clay loam; weak, medium subangular blocky; hard and compact dry, slightly plastic and sticky wet; few fine mica; this layer is less moist; boundary is wavy and clear; pH 6.1. Medium and common red (2.5 R 4/8) covering about 20 percent;
C1	48	- 61	in	Pale yellow (2.5 Y 7/4) wet to very pale yellow
	122	- 155	cm	(10 YR 7/3) dry, clay; weak medium subangular blocky; slightly hard dry, slightly sticky and plastic wet; few fine mica; many, medium and prominent red (2.5 YR 4/8) mottles (about 40 percent); boundary wavy and clear; pH 5.9;
C2	61	- 120	in	White (2.5 Y 8/2) wet or dry, clay loam; almost massive;
	155	- 305	cm	soft but slightly plastic or sticky wet; coarse and fine mica (about 10 percent) mixed; layer almost dry; with red (2.5 YR 5/8) common, medium and prominent mottles; pH 5.7.

Note: Horizon below is highly weathered granite and gneiss which is purplish in colour but highly micaceous.

V. Interpreted Characteristics of the Soil

This soil is fairly deep on the upper slopes but becomes shallow on the lower slopes mainly due to soil erosion. The land can be mechanically cultivated but some system of erosion control measures should be established. Runoff should be controlled by properly graded channels and possibly diverted from emptying into the headstreams. There is an appreciable amount of weathered minerals as shown by the high values in cation exchange capacity. The exchangeable calcium is high but rather low in potash in the upper horizons and the available phosphorus is also low. The organic matter content as well as the nitrogen content are both low. This soil will need liberal application of complete fertilizer and addition of organic matter.

The classification of this soil as Ferruginous Tropical Soil or as Eutric Cambisols is based on the development of B horizon mottles and the presence of an appreciable amount of weatherable minerals and of a hard and compact layer between 32 and 61 in depth.

VI Chemical and Mechanical Analysis of the Samples

Profile No: 90

Depth Inches Centimetres	0 - 4 0 - 10	4 - 15 10 - 38	15 - 32 38 - 81	32 - 48 81 -122	48 - 61 122 - 155	61-120 155-305
Soil reaction (pH)	6.0	5.6	6.0	6.1	5.9	5.7
C.E.C. (mEq/100 g soil)	8.5	13.2	15.8	16.9	13.2	15.9
Extractable cations:						
K (ppm)	40	48	132	92	68	52
Na						
Ca "	240	420	720	740	780	640
Mg "	139	182	328	338	268	238
Total	419	650	1180	1 170	1110	930
Sol. phosphorus (ppm)	4.8	1.6	2.8	3.2	2.4	1.6
Organic matter (percent)	0.86	0.55	0.27	0.24	0.19	0.14
Total nitrogen (percent)	0.047	0.044	0.032	0.028	0.024	0.027
Soil fractions (percent)						
Coarse sand						
Fine sand						
Silt						
Clay						

Note: Soil reaction was determined with 1:2.5 soil to water ratio.
Organic carbon by the method of Walkley Black.
Exchangeable bases using N-Ammonium Acetate.
Soluble phosphorus was extracted by a 0.2N H_2SO_4 solution using 1 to 20 soil : acid ratio.
Mechanical analysis with the method of Bouyoucos using "Calgon" for dispersion.

DESCRIPTION OF INDIVIDUAL PROFILE

I Information on the Site:

a. Profile No: 92

b. Soil name:

c. Higher category classification: Plinthic Luvisols

d. Date of examination: 19 March 1969

e. Author: A. Barrera

f. Location: Moshe Forest Reserve, Kwara State. Latitude 9°47' N, longitude 4° E

g. Elevation: 1 200 ft

h. Land-form:

i. physiographic position: Valley bottom
ii. surrounding land form: Rolling
iii. microtopography: Flat

i. Slope on which profile is sited: 2% approximately

j. Land-use: Cleared and planted to Teak

k. Climate: Under Northern Guinea Zone type of vegetation. Annual rainfall is 38.1 in with a peak of 10.4 in in August. Relative humidity at 0600 G.M.T. is 47 to 96 percent and at 1200 G.M.T. 14 to 77 percent, in all cases it being high during the rainy season (April to October).

II General Information on the Soil

a. Parent material: Alluvial and colluvial material derived probably from Granite and Gneiss

b. Drainage: Moderately well drained - class 3

c. Moisture conditions in profile: Dry

d. Depth of groundwater table: Not determined

e. Presence of surface stones, rock outcrops: Nil

f. Evidence of erosion: Nil

g. Presence of salt or alkali: Nil

h. Human influence: Cultivated and planted to Teak.

III Brief Description of the Profile

It is a deep, moderately well drained greyish brown silt loam and sandy loam lying over brownish grey, slightly mottled with red clays to about 50 percent. The lower horizon is almost white but also mottled with yellowish brown.

IV Description of the Profile

A_p	0	-	7	in	Very dark greyish brown (10 YR 3/2) wet to greyish brown (10 YR 5/2) dry, silt loam; very fine granular; friable moist, very slightly hard dry; fine to medium pores; many fine roots; boundary smooth and diffuse; pH 6.4;
	0	-	17	cm	
A_1	7	-	13	in	Dark brown (10 YR 4/3) wet to light yellowish brown (10 YR 6/4) dry, sandy loam; fine granular structure; friable dry, soft moist; many fine and medium pores; some fine roots; no other inclusions; boundary clear and smooth; pH 5.2;
	18	-	33	cm	
B_{21}	13	-	38	in	Light brownish grey (10 YR 6/2) wet to light grey (10 YR 7/2) dry, clay; massive structure; with fine common and distinct red (2.5 YR 4/8) dry or wet mottles to about 10 percent of the soil mass; plastic but not sticky wet, slightly hard dry; mottles slightly hard to form concretions; boundary clear and wavy; pH 5.4;
	33	-	96	cm	
B_{22}	38	-	58	in	Same colour as above layer with mottles much bigger (medium size) also clay; massive; and similar other characteristics as above; pH 5.6;
	96	-	147	cm	
B_{23}	58	-	69	in	Same colour as above; also clay; but mottles amounts to about 50 percent of the soil mass; hard dry, plastic and sticky wet; few manageneses and many hard iron concretions; boundary clear and smooth; pH 5.3;
	147	-	175	cm	
C	69	-	132	in	White (10 YR 8/2) with yellowish brown (10 YR 5/8) mottles wet or dry, silty clay; massive structure; very hard dry; plastic and sticky wet; few fine quartzites; mottles to about 25 percent; pH 5.1.
	175	-	335	cm	

V. Interpreted Characteristics of the Soil

This soil is deep and friable silt loam or sandy loam but poorly drained being in the bottom of a valley which serves as drainage. The soil is quite fertile, being rich in organic matter and very high in cation exchange capacity. The base exchange shows medium to very high in calcium but low in phosphorus.

Mechanized cultivation can be done but with some erosion control in addition to installing a drainage system.

The classification of this soil as Plinthic Luvisols is based as its profile characteristics showing development of B horizon with the presence of soft plinthite.

VI. Chemical and Mechanical Analysis of the Samples

Profile No. 92:

Depth Inches Centimetres	0 - 7 0 - 18	7 - 13 18 - 33	13 - 28 33 - 96	28 - 58 96 - 147	58 - 69 147 - 175
Soil reaction (pH)	6.4	5.2	5.4	5.3	5.1
C.E.C. (mEq/100 g soil)	16.2	15.2	12.7	13.5	14.3
Extractable cation:					
K (ppm)	36	20	28	32	32
Na "					
Ca "	680	200	440	360	320
Mg "	250	112	151	165	136
Total					
Sol. phosphorus (ppm)	11	5	5	5	4
Organic matter (percent)	2.6	0.84	0.21	0.13	0.19
Total nitrogen (percent)	0.13	0.57			
Soil fractions (percent)					
Coarse sand					
Fine sand					
Silt					
Clay					

Note: Soil reaction was determined with 1:2.5 soil to water ratio.
Organic carbon by the method of Walkley Black.
Exchangeable bases using N-Ammonium Acetate.
Soluble phosphorus was extracted by a 0.2N H_2SO_4 solution using 1 to 20 soil : acid ratio.
Mechanical analysis with the method of Bouyoucos using "Calgon" for dispersion.

Appendix 12

REFERENCES

Alexander, L.T. and Cady, J.G. Genesis and hardening of laterite soils.
1962 United States Department of Agriculture. Soil Conservation Service. Tech. Bull., 1232.

Annual Report 1968/69, Savanna Forestry Research Station, Samaru
1969 Zaria. Min. of Agric. and Natural Resources.

Annual Report 1969/70, Savanna Forestry Research Station, Samaru,
1970 Zaria. Min. of Agric. and Natural Resources.

Bate, J.A.R. and Baker, T.C.W. Studies on a Nigerian Forest soil.
1960 II. The distribution of phosphorus in the profile and in the various soil fractions. Jour. Soil Science. Oxford Clarendon Press. V. II N.2.

Boughey, A.S. The physiognomic delimitation of West African vegetation
1957 types. Hour. West African Sci. Assoc. 3: No.2.

Buckman, N.O. and Brady, N.C. The nature and properties of soils
1962 McMillan Book Co., N.Y.

Buchanan, K.M. and Pugh, J.C. Land and people in Nigeria. University
1966 of London Press Ltd. England.

Clayton, W.D. A preliminary survey of soil and vegetation in northern
1957 Nigeria. Min. Agric. Northern Nigeria. Not Published.

Clayton, W.D. Derived Savanna in Kabba Province, Nigeria. Samaru
1962 Research Bull. No.15.

D'Hoore, J.L. Soil Map of Africa. Scale 1:5 000 000. Explanatory
1964 Monograph. C.C.T.A. Lagos. 205 pp.

FAO Guidelines for Soils Descriptions. Food and Agriculture
1968 Organization of the United Nations. Rome.

FAO Definitions of Soil Units for the Soil Map of the World. FAO
1968 and unesco of the United Nations.

Higgins, G.M. and Mould, A.W.S. Progress of Soil Survey in Northern
1959 Nigeria. Proc. of the Third Inter-African Soil Conference. Dalaba, 1.

Higgins, G.M. and Okunola, Y.A. Report on the detailed survey of the
1960 Ochanja Area, Kabba Province, Northern Nigeria. Soil Survey Bull. No.30. Institute for Agric. Res. Samaru, Zaria.

Higgins, G.M. 1965 Pedological factors in northern Nigerian soils. Part III. An attempted forecast of response zones. Ins. Agr. Res. Ahmadu Bello University, North Central State.

Higgins, G.M., Ramsay, D.M. and Pullman, R.A. A report on the climate, soils and vegetation of the Niger Trough. Soil Survey Section. Regional Research Station, Ministry of Agriculture. Samaru, Zaria. Bull. No. 10.

Hildebrand F.H. and Velette, J. 1969 A reconnaissance soil survey of the Wase-Ibi Area, Benue Plateau State, Nigeria. Soil Survey Bull. No.39 Institute for Agric. Res. Samaru, Zaria.

Howard, W.J. 1964 A report on vegetation and site type. Afaka Forest Reserve. Zaria Native Authority.

Jackson, J.K. 1970 Some results from fertilizer experiments in plantations. Paper presented at the First Annual Conference of the Forestry Association of Nigeria. Ibadan.

Jungerius, P.D. 1964 The environmental background of land-use in Nigeria. K.N.A.G.

Keay, R.W.J. 1953 An Outline of Nigerian vegetation. 3rd Edition. Federal Government Printer, Lagos.

Keay, R.W.J., Onochie, C.F.A. and Stanfield P.P. 1960 Nigerian Trees. Federal Department of Forest Research. Ibadan. Federal Government Printer. Vol. 1.

Keay, R.W.J. and Onochie, C.F.A. 1964 Nigerian Trees. Department of Forest Research, Ibadan. Nigerian National Press Ltd., Vol. II.

Klimkenberg, K. and Higgins, G.M. 1968 An outline of northern Nigerian soils. Nigerian Jour. Sci. 2:91-111.

Palmer, J.R. 1967 Report on the preliminary site potential survey of Osara Forest Reserve. Igbira Native Authority.

Russ, W. 1957 The geology of parts of Niger, Zaria and Sokoto Provinces. Bull. No.27. Federal Government of Nigeria.

Samie, A.G.A. 1969 Consumptive use of water per foot of soil investigated for different tree covers at Afaka, North Guinea Savanna. Savanna Forestry Research Station, Annual Report 1968/69.

Sivarajasingham, S. 1959 The nature and origin of laterite. M.S. Thesis. Cornell University. Reproduced by the U.S.D.A. Soil Conservation Service.

Tomlinson, P.R. 1957 A preliminary soil report of Afaka Forest Reserve. Reserve Experimental Area. Zaria Province. Northern Nigeria. Regional Research Station. Ministry of Agric. Samaru, Zaria. Bull. No.2.

Tomlinson, P.R. 1965 Soils of northern Nigeria. Institute for Agr. Res. Ahmadu Bello University, Samaru Misc. Paper No. 11.

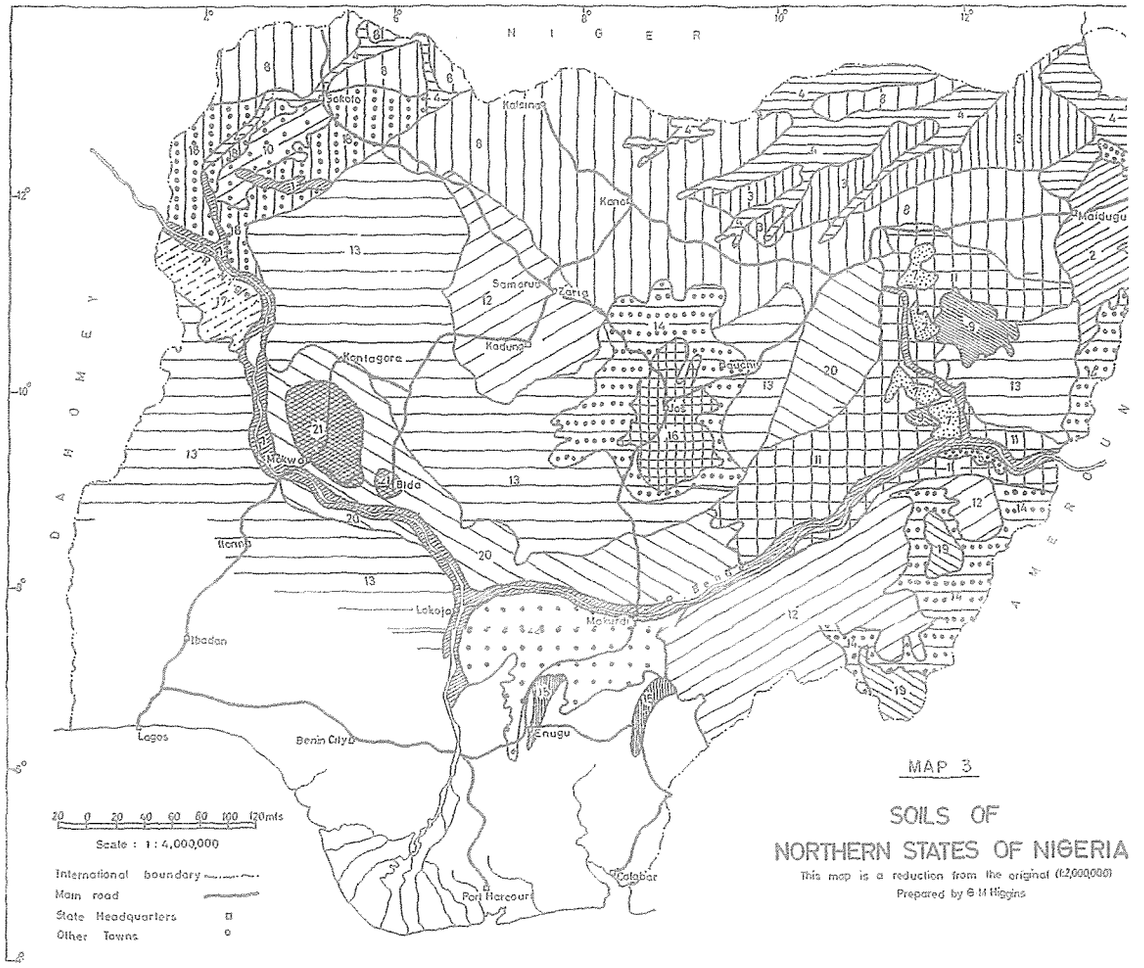
U.S. Dept. of Agri. 1951 Soil Survey Manual. Soil Survey Staff. Handbook No.18.

U.S. Department of Agriculture. Soil Conservation Service. Supplement
1967 to Soil Classification System (7th Approximation) 2nd Printing. 1-107.

Walter, M.W. Length of the rainy season in Nigeria. Institute Agr. Res.
1968 Ahmadu Bello University, Samaru. Res. Bull. No. 103.

Wilde, S.A. Forest soils and forest growth. Chronica Botanica Co.,
1946 U.S.A.

Yager, T.U. A report on the descriptions of soil profiles in some areas
1966 in Northern Nigeria. Savanna Forestry Research Station, Samaru, Zaria. Unpublished.



MAP 3

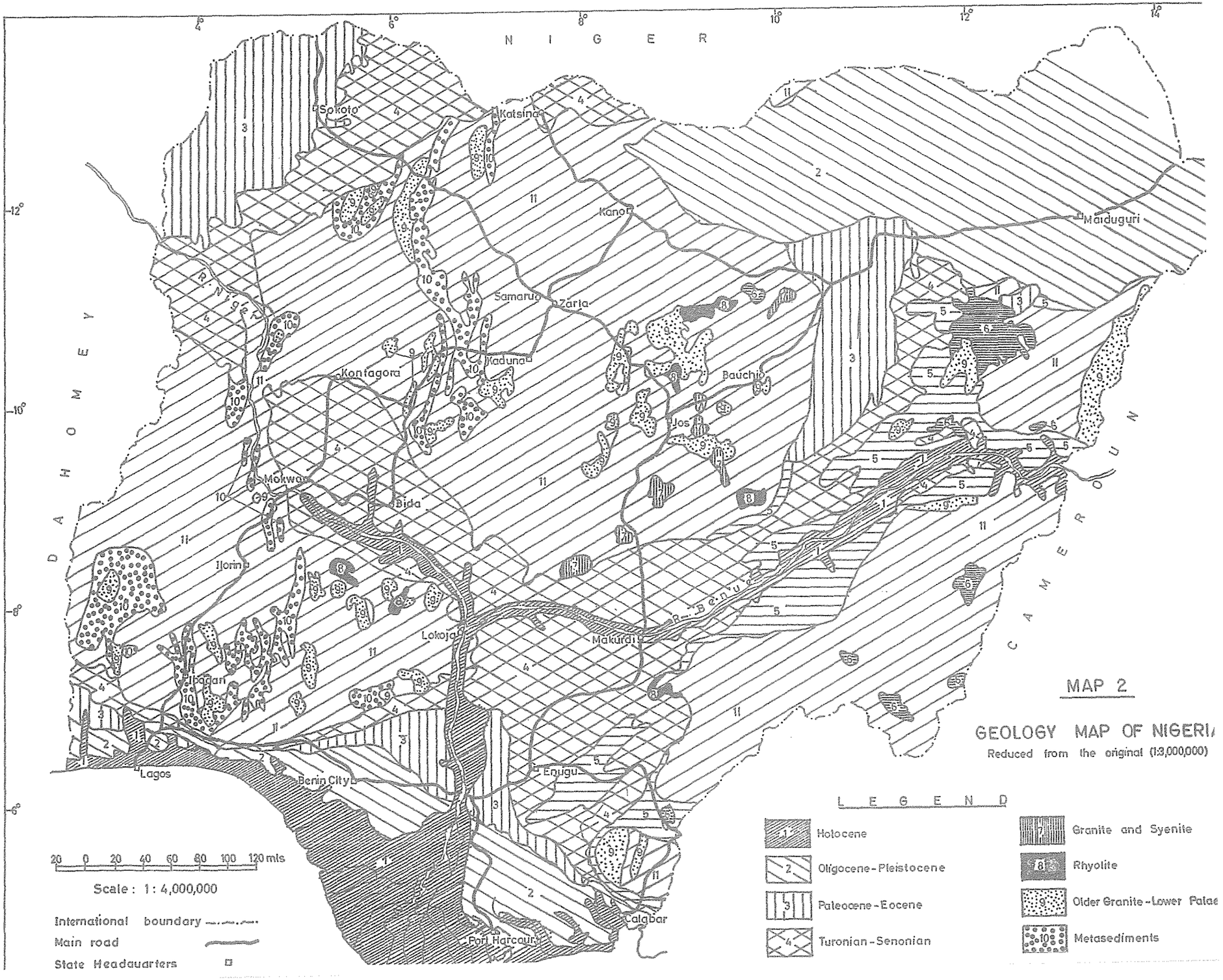
SOILS OF NORTHERN STATES OF NIGERIA

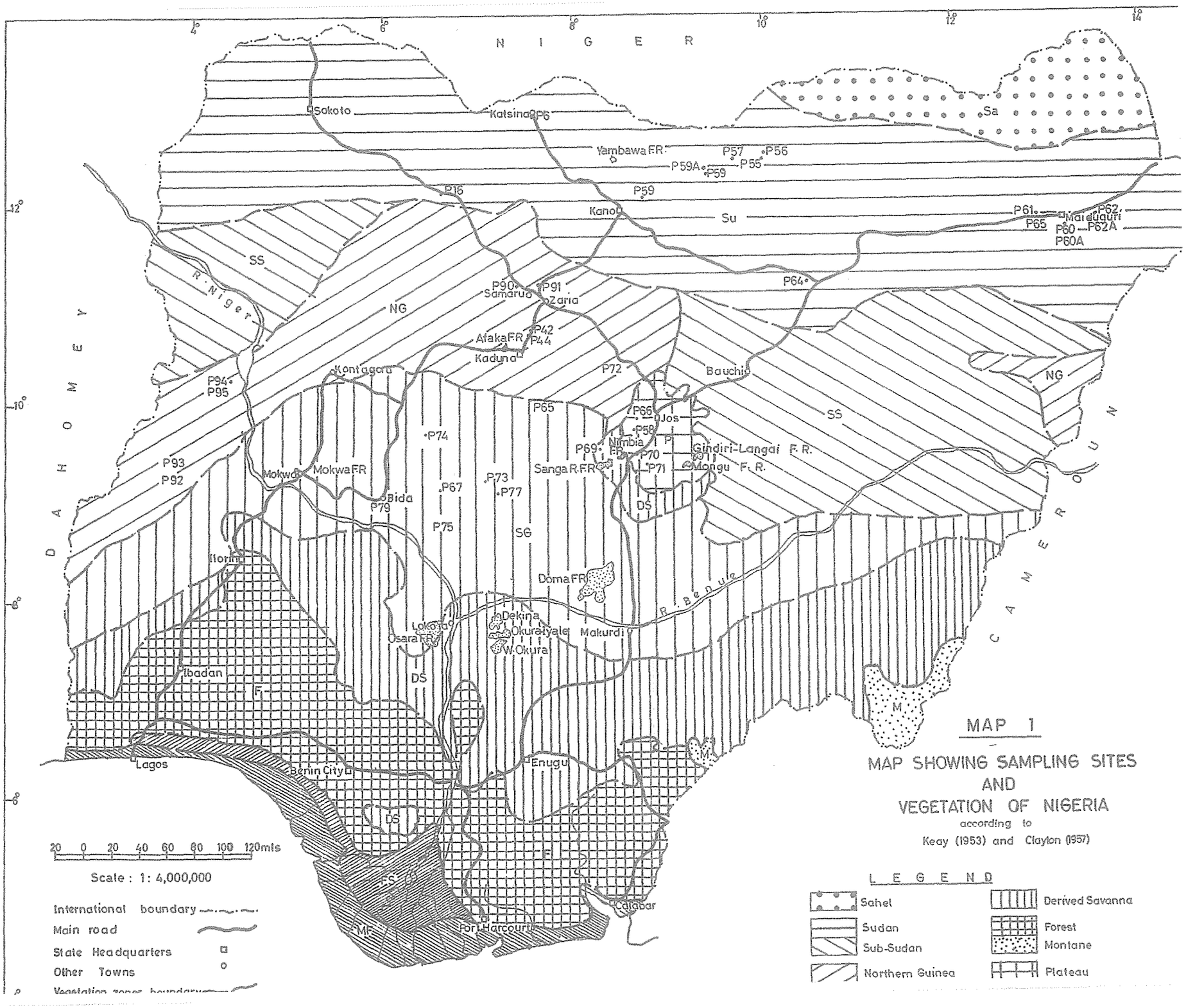
This map is a reduction from the original (1:2,000,000)

Prepared by G M Higgins

LEGEND

1. Juvenile Soils on alluvium and Hydromorphic Soil
2. Juvenile Soils on alluvium, Hydromorphic Soils and Brown Soils
3. Juvenile Soils on aeolian sands
4. Juvenile Soils Hydromorphic Soils and Halomorphic Soils
5. Vertisols of topographic depressions
6. Vertisols of topographic depressions and Brown Soils
7. Vertisols of lithomorphic origin
8. Brown and Reddish brown Soils
9. Eutrophic Brown Soils and Vertisols of lithomorphic origin
10. Ferruginous Tropical Soils on sandy parent material and Lithosols on ferruginous crusts
11. Ferruginous Tropical Soils on sandy parent material and undifferentiated Lithosols
12. Ferruginous Tropical Soils on sandy parent material and on crystalline acid rock
13. Ferruginous Tropical on crystalline acid rocks
14. Ferruginous Tropcil Soils on crystalline acid rocks and Lithosols
15. Ferrallitic Soils red and brown Soils from sandstone
16. Ferruginous Tropical Soils on crystalline acid rocks and undifferentiated Ferrisols
17. Undifferentiated Ferruginous Tropical Soils
18. Undifferentiated Ferruginous Tropical Soils and on sandy
19. Humic Ferrisols and Lithosols
20. Undifferentiated Ferrisols
21. Undifferentiated Ferrisols and Lithosols
22. Ferrallitic Soils, deep porous red Soils from sandy dep


N I G E R
DAHOMEY
CAMEROUN
Sokoto
Katsina
Kano
Maiduguri
Zaria
Samaru
Kaduna
Kontagora
Bauchi
Jos
Mokwa
Bida
Ilorin
Lokoja
Makurdi
Benue R.
Ibadan
Lagos
Benin City
Enugu
Calabar
Port Harcourt
20 0 20 40 60 80 100 120 mls
Scale : 1 : 4,000,000
International boundary
Main road
State Headquarters
MAP 2
GEOLOGY MAP OF NIGERIA
Reduced from the original (1:3,000,000)
L E G E N D
1 Holocene
2 Oligocene - Pleistocene
3 Paleocene - Eocene
4 Turonian - Senonian
7 Granite and Syenite
8 Rhyolite
9 Older Granite - Lower Palae
10 Metasediments


N I G E R
DAHOMEY
CAMEROUN
Sokoto
Katsina
Sa
Yambawa FR.
P57
P56
P59A
P55
P59
P16
Kano
Su
P61
P62
Maiduguri
P65
P60
P62A
P60A
SS
R. Niger
NG
P90
Samaru
P91
Zaria
P64
Afaka FR.
P42
P44
Kaduna
Kontagora
P72
Bauchi
P94
P95
P65
P66
Jos
P58
P74
P69
Nimbia
P70
Gindiri-Langai F. R.
P71
Mongu F. R.
Sanga R.FR
P93
P92
Mokwa
Mokwa FR
P73
P67
P77
Bida
P79
DS
P75
SG
Ilorin
Doma FR
R. Benue
Dekina
Okura-Iyale
W. Okura
Makurdi
Lokoja
Osara FR.
Ibadan
F
DS
M
Lagos
Benin City
Enugu
DS
F
FS
DS
Calabar
MF
Port Harcourt
20 0 20 40 60 80 100 120mls
Scale : 1: 4,000,000
International boundary
Main road
State Headquarters
Other Towns
Vegetation zones boundary
MAP 1
MAP SHOWING SAMPLING SITES AND VEGETATION OF NIGERIA
according to
Keay (1953) and Clayton (1957)
L E G E N D
Sahel
Sudan
Sub-Sudan
Northern Guinea
Derived Savanna
Forest
Montane
Plateau

MR/B8730/8.71/E/1/150