Soil Brief *Nigeria 1*

NIGERIA

Sandy reference soils of the moist lowlands near Ibadan (Oyo state)

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ISRIC

International Soil Reference and Information Centre

Reference citation

Fagbami, A.A. and Shogunle, E.A.A., 1995. *Nigeria: Sandy Reference Soils of the moist lowlands near Ibadan.* Soil Brief *Nigeria 1*. University of Ibadan, Ibadan, and International Soil Reference and Information Centre, Wageningen. pp 19.

ISSN: 1381-6950

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ISRIC Soil Monoliths:

Number	*FAO-Unesco*	*Soil Taxonomy*
NG 17	Ferralic Arenosol	Typic Ustipsamment
NG 18	Haplic Lixisol	Udic Kanhaplustalf

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September 1995

Issued in the framework of the National Soil Reference Collections and Databases project (NASREC).
Sponsored by the Directorate General of International Cooperation of the Government of the Netherlands.

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ABSTRACT

Two soil profiles representative for soils from the Basement Complex of southwestern Nigeria were studied as part of the soil reference collection for Nigerian NASREC collaborative work between the University of Ibadan, Nigeria and the International Soil Reference and Information Centre (ISRIC) Wageningen, the Netherlands.

An overview of the Nigerian environment was given as a background to the soil formation environment and soil monolith collection in Nigeria. Southwestern Nigeria is predominantly underlain by crystalline Basement Complex with a relief dominated by the east-west watershed that controls the flow of rivers to the River Niger and the Bay of Benin. The climate is dominated by the moisture-loaden Intertropical Discontinuity (ITD) that moves from the south to the north in the rainy season and to the south in the dry season with a corresponding lowering of the total annual rainfall. There are two peaks of rainfall and a marked dry season in August when moisture sensitive crops like maize may come under stress. The vegetation is forest in the high rainfall areas, and savanna in the sub-humid zone, and sahel in the semi-arid zone.

The two soils are located in the dry rainforest and are located on a typical toposequence called the Egbeda Association which formed on fine-grained biotite-gneiss and schist. The topography is gently undulating.

The NG17 soil is located on the lower slope of the toposequence, it is deep but because of the high sand contents, available water capacity is very low. NG18 is developed on sedentary materials with sandy loam textures in the topsoil and clay-loam to clay in the subsoil. NG17 is classified as a Ferralic Arenosol (FAO-Unesco) and Typic Ustipsamment (USDA Soil Taxonomy); NG18 is classifiied as a Haplic Lixisol (FAO-Unesco) and Udic Kanhaplustalf (USDA Soil Taxonomy).

NG17 and NG18 are used for rainfed maize yam and cassava. NG18 is one of the best cocoa soils of southwestern Nigeria because of its favourable moisture-holding capacity.

FOREWORD

The objective of a Soil Brief is to provide the description of a reference soil in its ecological setting. The Soil Brief is composed of a text part and data annexes. The text part consists of description and discussion of the major characteristics of the soil with figures and diagrams and includes classification and evaluation of the soil and land qualities. Attention is given to special topics such as erosion, soil formation etc. In the annexes the soil and environmental data available from the field, laboratory and office work are given.

The Soil Brief is written for soil specialists and non-soil specialist. For the latter group some of the details given in the annexes require further explication in the text. For the soil scientist the text can serve as reference information of soil and land qualities, soil management and soil formation. Additional information from research and discussions which cannot be stored in the computerized database, are also given.

In 1992, the Departments of Geography and Agronomy of the University of Ibadan in collaboration with the International Soil Reference and Information Centre (ISRIC) described and sampled 15 reference soils for the University of Ibadan Soil Reference Collection and Database (UISREC). The reference soils were selected from 3 major ecological regions in southern Nigeria. Reference soils NG 17 and NG 18 described in this paper, are representative of hill-wash slope and sedentary upper-slope soils respectively on the igneous-metamorphic rocks of the sub-humid tropical rain forest region of southwestern Nigeria.

This Soil Brief has been compiled in cooperation with Mr A.O. Ogunkunle, Mr S.A. Adebulujo (laboratory), Mr A. Gbadegesin, Mr Mokam and Mr G.A. Akinbola (fieldwork) of the University of Ibadan. The final result has been made possible with contributions from ISRIC's soil laboratory and Ms M.-B.B.J. Clabaut (text processing), Mr A.B. Bos, Mr J.H. Kauffman (fieldwork), Dr T. de Meester and Mr A.W. Vogel. Useful comments on the draft of this Soil Brief were obtained from Mr A.E. Hartemink.

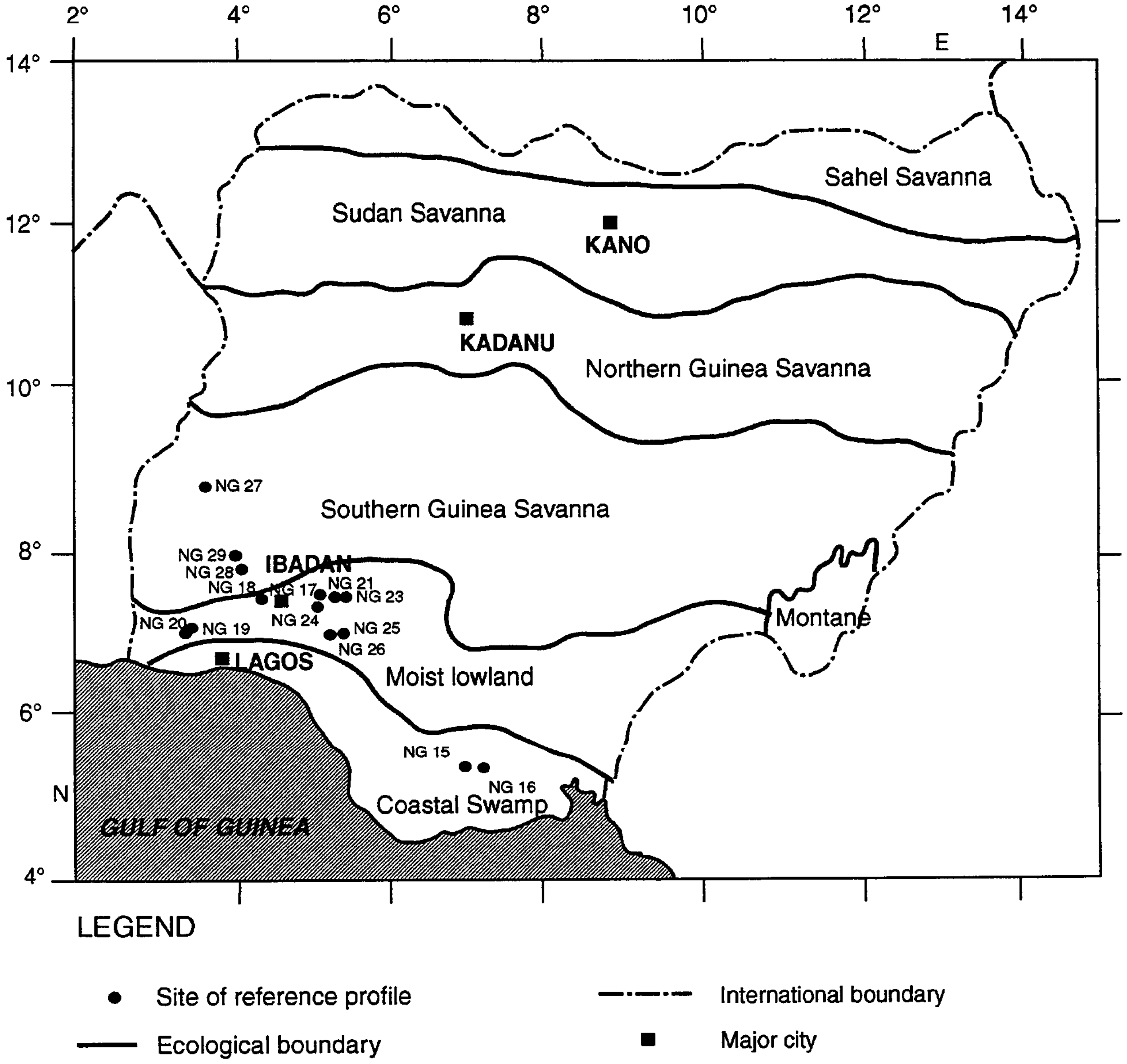


Figure 1 Geographical location of the reference sites.

1 THE MAJOR ECOLOGICAL REGIONS OF NIGERIA

Nigeria can be divided into the 7 major ecological regions (Fig. 1):

(1) The Coastal Swamp Region which includes the coastal forest and mangroves as well as the deltaic swamp forest
(2) The Moist Lowland Region
(3) The Southern Guineas Savanna Region
(4) The Montane Region
(5) The Northern Guinea Savanna Region
(6) The Sudan Savanna Region
(7) The Sahel Savanna Region

The location and extent of most of the regions coincide with the vegetation zones of the country as described by Keay (1953), Areola (1978) and Areola *et al.* (1982). The 12 reference soils (NG 15 to NG 29) are located in the southern part of the country in the following ecological regions: (i) Coastal Swamp, (ii) the Moist Lowland, and (iii) the Southern Guineas Savanna regions. The 3 regions are briefly discussed below.

The *Coastal Swamp Region* includes creeks, lagoons, the Niger delta and the coastal plain. The mean altitude of the creeks and lagoons area is around 40 m a.s.l. while along the coastal plain the elevation is around 160 m a.s.l. In this region, the total annual precipitation ranges from 429 mm at Bonny in the east to 1755 mm at Lagos in the west. The length of the rainy season is about 10 months. The soils are mainly hydromorphic and derived from marine and lacustrine parent materials. The vegetation consist of coastal forest, mangroves and deltaic swamp forest. The mangrove forest is dominated by varieties of red mangrove (*Rhizophera racemosa*), the swamp forest consist solely of slender trees. Reference Soils NG 19 and NG 20 are found in this region and described in Soil Brief *Nigeria 2*.

The *Moist Lowland Region* is underlain by rocks of the Basement Complex. The landscape is undulating and marked by numerous domed or sugar-loaf hills and by occasional flat-topped ridges. The summits of the hills ranges between 300 and 600 m a.s.l. Temperature is high throughout the year with an annual average between 28°C and 32°C. The rainy season lasts for 8 months and total annual rainfall is higher than 1100 mm. The region is covered with lowland forest consisting of evergreen hydrophytic plants with a large diversity. The forest is characteristically stratified. At the forest margins or in areas disturbed by man, woody lianas form an almost impenetrable tangle. The original or high forest is no longer as extensive as it used to be and restricted to a few forest reserves in Ondo, Benin and in the Cross River Basin along the border with Cameroon. The following Reference Soils were studied in this region: NG 17, NG 18 (this Soil Brief) and NG 21 to NG 26. The reference soils are described in Soil Brief *Nigeria 3, 4, 5* and *6*.

The *Southern Guinea Savanna Region* is also underlain by rocks of the Basement Complex. The landscape consists of inselbergs which are interspersed by numerous domed hills. The inselbergs are prominent along the Oyo-Iseyin-Saki axis where Reference Soils NG 27, NG 28, and NG 29 were studied (Soil Brief *Nigeria 7 and 8*). The rainy and dry season are well marked. The rainy season lasts for at least 7 months with a mean annual rainfall between 1000 mm and 1500 mm. The soils are ferruginous tropical soils with kaolinite as the dominant clay mineral. The Southern Guinea Savanna Region can be sub-divided into three types based on nature and proportion of woody species. These are (i) the savanna woodland where trees and shrubs form a fairly close canopy, (ii) the tree savanna where the trees and shrubs are scattered and, (iii) the shrub savanna where trees are absent.

2 THE IBADAN AREA

2.1 Geology and Physiography

The Ibadan area is part of the Niger-Guinea coast watershed. It is dominated by landforms which are closely related to geological structures. The geology comprises igneous and metamorphic rocks of the Precambrian Basement Complex which forms part of the African crystalline shield. It consists predominantly of migmatite, gneiss, schists, quartzite, granite and few basic materials. The quartzite form the most prominent residuals in the Ibadan area. The two highest residuals are quartzite ridges, the Oke-Elefin ("Smoky" hill) stands about 160 m a.s.l and the Aremo ridge at 285 m a.s.l.
The occurrence of rock outcrops depends on resistance to weathering and in general more acid, homogeneous and massive rocks are more resistant. The exposed rocks include older granite such as granite-gneiss and pegmatite, and the gneiss complex such as quartz-schist, while the quartzite residuals are usually covered with dense forest vegetation. The granite masses and, in some cases, the gneiss and migmatite form a rugged topography with inselbergs rising several hundred meters above the surrounding pediments. The landform development in the Ibadan area is closely related to differential responses to weathering and erosion. Rock composition and joints play an important role in deep weathering and evolution of the landscape. The weaker banded gneiss are more deeply weathered, more eroded and, hence, form more subdued features than the more resistant quartzite and gneiss.

2.2 Soils

The complex geology of the area resulted in a variety of soils. There is a close relationship between soil morphology and the nature of the underlying rocks. Of the 8 Soil Associations identified on the basement complex of central western Nigeria by Smyth and Montgomery (1962), 5 are present in the Ibadan area:

- *Iwo* Association: well drained, coarse textured soils, overlying weathered rock material; derived from coarse-grained granitic rocks and gneiss.
- *Egbeda* Association: well drained fine texture soils, overlying reddish brown, yellowish brown and white mottled clay; derived from fine-grained biotite gneiss and schist.
- *Okemessi* Association: well drained coarse textured, very gravelly soils; derived from quartz schists and massive quartzite.
- *Mamu* Association: well drained medium textured, soils; derived from sericite schists.
- *Jago* Association: valley bottom soils with impeded drainage; derived from alluvial and colluvial deposits.

Each soil association is sub-divided into soil series based on soil formation and parent material. In terms of USDA Soil Taxonomy (1975), dominant units are Oxic Tropudalfs, Typic Tropaquepts and Typic Ustipsamments.

2.3 Climate

The Ibadan area has a sub-humid climate in which the rainfall distribution is characterised by two peaks separated by a drought in August. The dry season starts in November and lasts till March, while the rainy season lasts from April to October. The driest month is January with less than 10 mm rain while June and September are the wettest months with rain over 170 mm. March and April have the highest rainfall. These rains, referred, to as "line squalls" always signify the beginning of the rainy season.
Monthly evapotranspiration is higher than 100 mm except in July and August. Between April and October there is a humid period in which rainfall exceeds evapotranspiration (Fig. 2). In November, evapotranspiration exceeds rainfall and this marks the beginning of soil moisture depletion which ends in March. With an annual evapotranspiration of 1421 mm there is a net annual moisture deficit of about 192 mm.

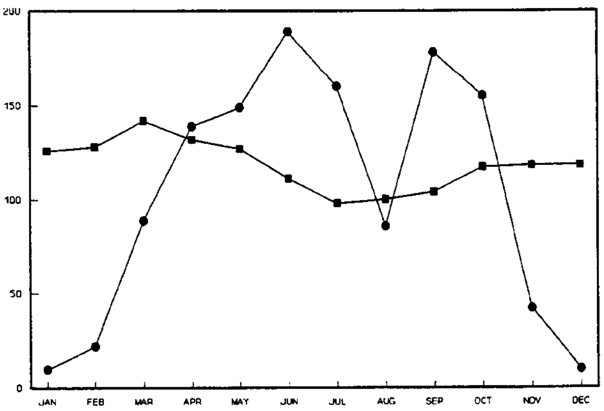


Figure 2 Precipitation (●) and evapotranspiration (■) in mm at Ibadan.

Temperatures at Ibadan are high throughout the year and the annual mean is 26°C (Fig. 3). February, March and April are the hottest months with mean temperatures of about 28°C. The coldest months are June to October, although the minimum temperatures are recorded in the peak of the harmattan months in December. Relative humidity is high throughout the year with an annual average of 84%. The highest relative humidity percentages are recorded during the rainy season: 89 and 88% in July and September respectively. There is a constant cloud cover in the rainy season and as a result, the lowest amount of average daily sunshine hours is recorded during this period.

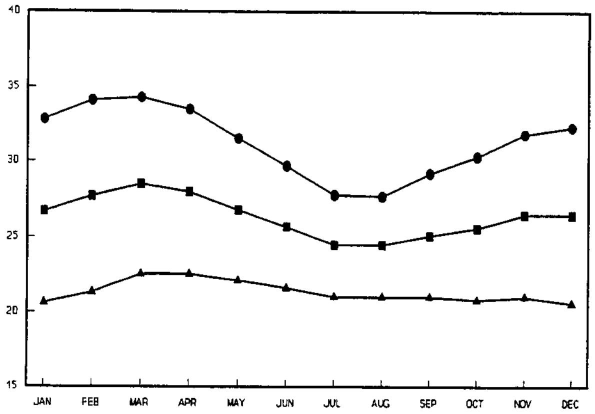


Figure 3 Maximum (●), average (■) and minimum (▲) temperature in °C at Ibadan.

3 THE REFERENCE SOILS

3.1 Location

Reference soils NG 17 and NG 18 are located within the premises of International Institute of Tropical Agriculture (IITA), which is located 7 km North of University of Ibadan in Oyo State. The two soils, locally referred to as *Apomu* and *Egbeda* series respectively, are among the prominent soils on the Basement Complex formation and more specifically, are part of a topographical sequence of soil series of the *Egbeda* association described in section 2.2. According to the survey of Smyth and Montgomery (1962) NG 17-soil occupies 9.6% and NG 18-soil 7.4% of central western Nigeria.

Reference soil NG 17 is located at the lower slope while NG 18 is at middle/upper slope of the gently undulating terrain. The low hill on which the soils are located has closely related soils which are encountered at short intervals along the toposequence.

3.2 Landscape

The landscape consists of a low altitude plain with gently undulating and somewhat short slopes and rounded smooth crests. A diagrammatic illustration of the landscape on which the two soils are found is shown in Fig. 4. The reference soils are derived from intermediate crystalline rocks comprising fine-grained biotite gneiss. The rocks are characteristically strongly foliated with a mosaic of plagioclase feldspar, quartz and biotite mica. The minerals are relatively easily weathered, and may give rise to some of the deepest sedentary soils found on the Basement Complex.

The soils have been subjected to the repetitive pattern of distinct wet and dry seasons and a complex pattern of vegetation. The differences in the soils are mainly due to differences in modes of formation of the parent materials. The parent material of NG 17 is derived from rocks and materials which have been transported from high topographical positions under the influence of erosion process and gravity and have accumulated in the lower slopes. NG 18 is a sedentary soil (in situ) as its parent material directly overlies the solid rock.

3.3 Land use

The soils are under tropical forest species with many climbers and twiners. Areas of cleared land are haphazardly cultivated or are being used for field trials and research studies. On the location where soil NG 17 was studied, the land was under natural fallow and partly under experimental cultivation of improved crop varieties. Contrary to what peasant farms in the Ibadan area practise, cultivation in the IITA farm is done with medium to high technology (fertilizers and agro-chemicals). The soil is rarely exposed for a long period to the rainfall as there is continuous vegetal cover throughout the year and burning of vegetative material is also not practised at the IITA premises.

3.4 Soil characterisation

3.4.1 The soil catena

The relative position of the two reference soils as part of a toposequence has a strong influence on their morphologies. Soil NG 18 is situated on the middle slope with 3% gradient, while soil NG 17 is at the lower slope, close to the poorly drained soils of the valley bottom. The relationship is reflected in the colour and texture.

Soil NG 18 is dark reddish brown in the topsoil and becomes redder with depth. However, down the slope, the red soil gives way to light reddish brown, brown and finally pale greyish brown soils. Soil NG 17 located at the lower slope has a dark brown colour at the surface and is brown to strong brown in the subsoil. In other words, when going towards the valley bottom the soil colour becomes lighter.

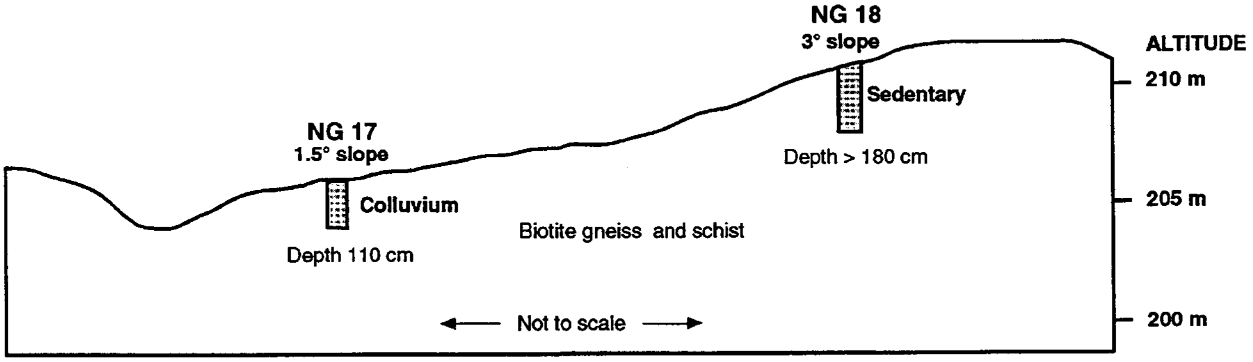


Figure 4 Cross section of profiles NG 17 and NG 18.

Soil NG 18 derived from fine grained parent rock, has finer soil particles and the sandy loam surface soil is underlain by clay at 40 cm soil depth. At the lower slope the soils are sandier: soil NG 17 is sandy to a depth of 73 cm, and its morphology has no relation to the underlying rocks.

3.4.2 Brief field description

Reference soil NG 17 is a deep, moderately well drained soil. It is extremely sandy in texture to a depth of 73 cm, the colour varies from dark brown at the surface to strong brown at the subsoil. It is weakly to moderately structured. There are fine fresh quartz fragments almost throughout the profile, while medium sized Fe and Mn concretions are found at 113 cm depth.

Reference soil NG 18 is a very deep, well drained soil. The sandy loam surface soil is underlain by a clayey to clay-loamy, moderately to strongly structured reddish subsoil. There are fine quartz fragments between 15 and 100 cm, and faint to clear sharp mottles between 40 and 130 cm depth. Below 130 cm depth there are some decomposing gneiss fragments.

Detailed description of the 2 reference soils following the FAO Guidelines for Soil Profile Description (FAO, 1988) is given in Annex 1A (NG 17) and 1B (NG 18).

3.4.3 Brief analytical characterisation

The soil samples were analyzed at ISRIC's soil laboratory according to procedures described by Van Reeuwijk (1993). Some important soil data were selected for presentation in a graphical way using SOLGRAPH (Brunt & Kauffman, 1995).

The particle size distribution of the reference soils is presented in Fig. 6 and 7. Fig. 6 shows that the clay content of profile NG 17 is fairly constant. The silt fraction increases but the sand content decrease below 113 cm soil depth. In soil NG 18, there is sharp clay increase within the upper 70 cm and a corresponding decrease in sand fraction (Fig. 7). This indicates clay accumulation in the subsoil and the increase is sufficient for the classification of an argic horizon.

The distribution of chemical soil properties with depth for the two reference soils is presented in Fig. 8 and 9: organic C, sum of exchangeable bases (Ca, Mg, K and Na), Cation Exchange Capacity (CEC), and pH-H_2O. In NG 17, the sum of bases and CEC have similar distribution patterns down the soil profile and increase in the subsoil. In NG 18, the distribution patterns of CEC and the sum of bases differ in the subsoil and decrease sharply immediately beneath the topsoil. However, the CEC rises sharply again with soil depth. The sharp increase in CEC with depth and the drastic decrease in organic C content, should be attributed to the exchangeable sites of the clay fraction which increases with depth in NG 18. Organic C is higher in the topsoil and decreases down the profile as the influence of vegetation reduces. In the topsoil, Ca accounts for 75 and 65% of the sum of bases in soil NG 17 and soil NG 18 respectively. This is probably a result of liming. Reference soil NG 18 is slightly more acid than NG 17 and its acidity increases with soil depth while there is not such trend in NG 17. pH-H_2O is higher than pH-KCl in all horizons but the differences between the two values increases with soil depth in profile NG 17.

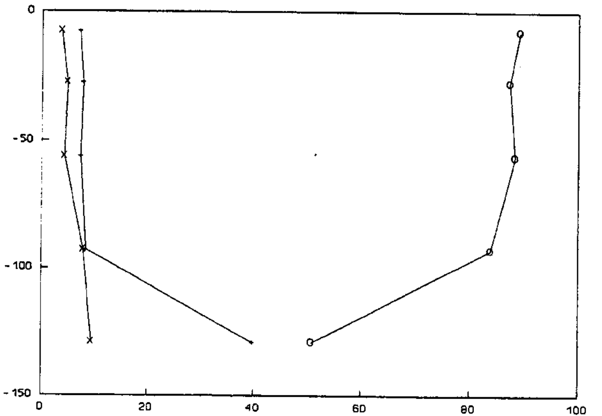


Figure 6 Percentages clay (x), silt (+) and sand (o) versus depth (cm) in profile NG 17.

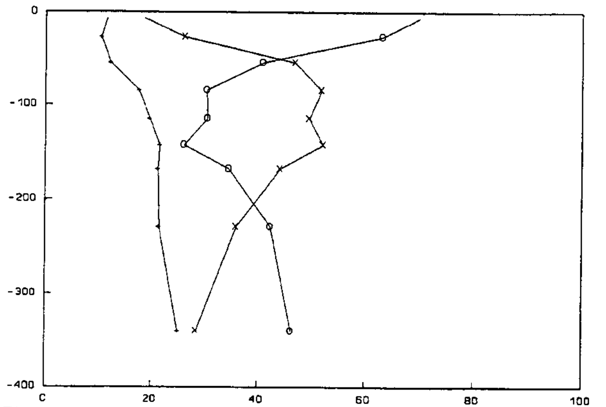


Figure 7 Percentages clay (x), silt (+) and sand (o) versus depth (cm) in profile NG 17.

Fig. 10 and 11 present the moisture retention curves. The intersection point with the X-axis, gives the water content of the soils under saturated conditions and equals total pore-volume. The quantity of soil moisture between pF 0 and pF 2 is expressed by the air capacity which is a measure the aeration conditions. The available soil moisture (ASM) is the quantity of moisture between pF 2 (field capacity) and pF 4.2 (permanent wilting point). The available moisture stored in both soils is low and shows only little changes with depth. The sandy soil texture is responsible for the low available soil moisture. The air capacity of soil NG 17 decreases slightly in the subsoil but is very high due to the sandy texture. For soil NG 18, the decrease is more distinct due to bad drainage conditions in the subsoil, which has also resulted in mottles.

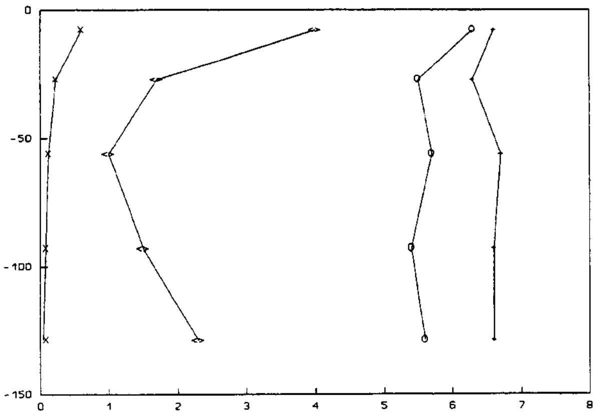


Figure 8 Sum of bases (cmol$_c$ kg^{-1} soil) (<>), pH-H_2O (+), pH-KCl (o) and organic carbon (x) versus depth (cm) in profile NG 17.

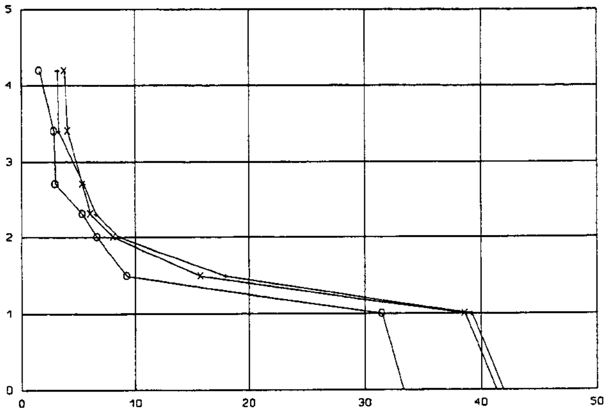


Figure 10 pF or moisture retention curves (water content in vol % versus suction) at depth 0-15 cm (x), 15-39 cm (+), 39-75 cm (o) in profile NG 17.

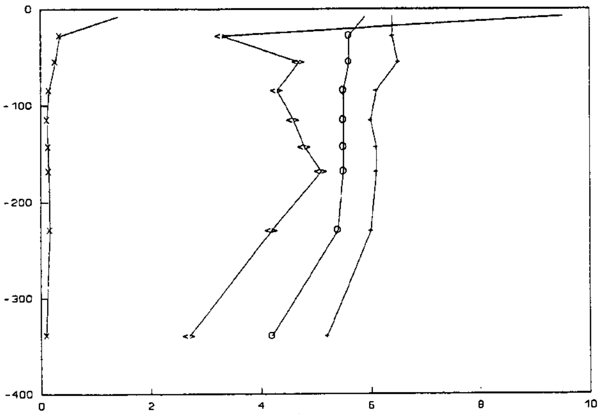


Figure 9 Sum of bases (cmol$_c$ kg^{-1} soil) (<>), pH-H_2O (+), pH-KCl (o) and organic carbon (x) versus depth (cm) in profile NG 18.

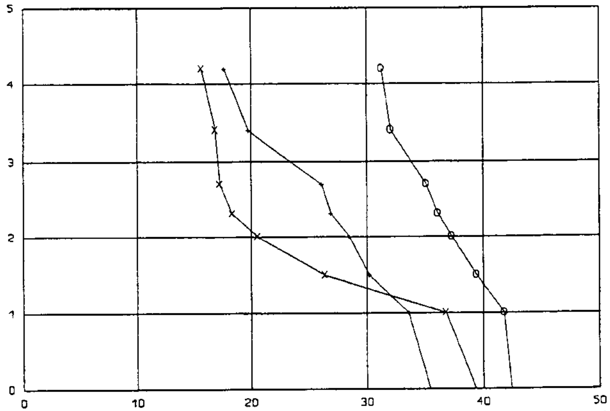


Figure 11 pF or moisture retention curves (water content in vol % versus suction) at depth 0-15 cm (x), 15-40 cm (+), 70-100 cm (o) in profile NG 18.

3.5 Soil classification

Soil classification of NG 17

FAO-Unesco (1988)

NG 17 is coarser than sandy loam to a depth of at least 100 cm from the surface and has no other diagnostic horizon than an ochric A horizon. It keys out as an Arenosol. The CEC$_{clay}$ in the B horizon is lower than 16 cmol$_c$ kg^{-1} and the silt/clay ration is lower than 0.2. The B horizon is therefore ferralic and the full classification becomes ferralic Arenosol.

USDA Soil Taxonomy (1992)

The soil is an Entisol and as it is very sandy, a Psamment. With the ustic soil moisture regime it is fully classified as a Typic Ustipsamment.

In the Nigeria classification system NG 17 belongs to the *Apomu* Series because it has no stones, gravels or concretions in the upper 50 cm.

Soil classification of NG 18

FAO-Unesco (1988)

The soil classifies as a Haplic Lixisol as the soil has an ochric A horizon and an argic B horizon with a CEC of < 24 cmol$_c$ kg^{-1} clay and a base saturation higher than 50%. Despite the nitic properties the soil shows a clear boundary between the A and B horizon and therefore does not key out as a Nitisol.

USDA Soil Taxonomy (1992)

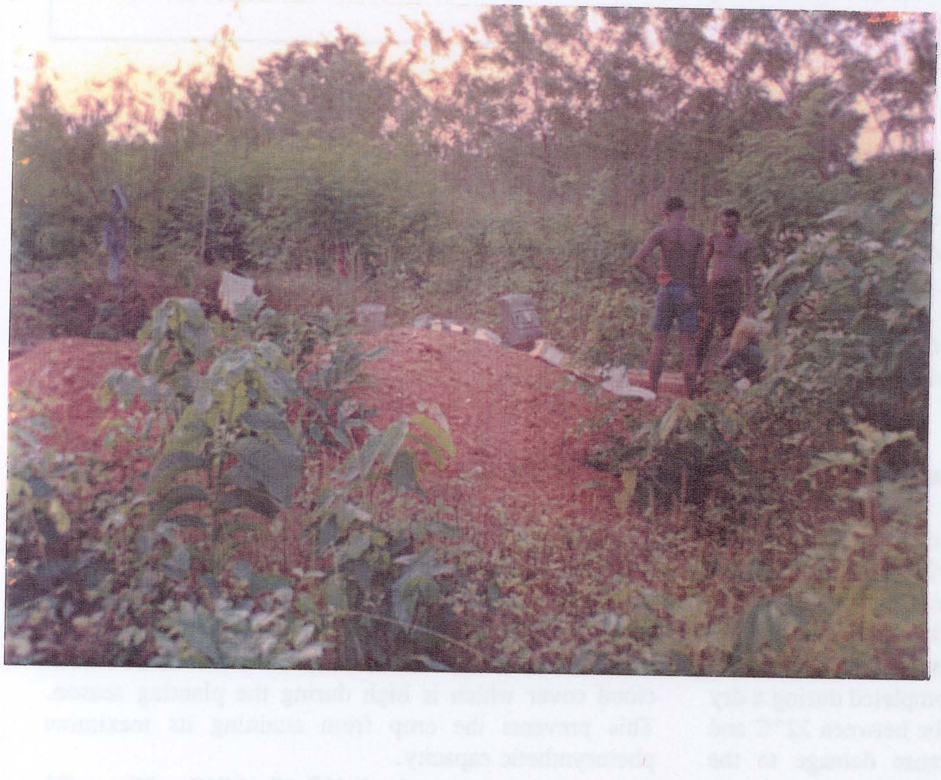
The soil classifies as an Udic Kanhaplustalf. It has an ochric epipedon, an argillic horizon and a kandic horizon. The soil moisture regime is ustic, but the moisture control section is in 6 or more out of 10 years dry in some or all parts for less than 120 cumulative days per year.

In the Nigerian classification system NG 18 belongs to the *Egbeda* Series.

3.6 Soil suitability

In one of the earliest attempts to assess the soil quality of central western Nigerian for their agricultural potential, Smyth and Montgomery (1962) classified the *Apomu* series (soil NG 17) as unsuitable for cocoa, coffee, kola and citrus production, while the *Egbeda* soil series (NG 18) was considered as one of the best soils in the region for the production of these perennial crops. The prevailing land utilization type of the reference soils is arable cultivation with medium input level and

Landscape of NG 18 IITA



Soil pit of NG 18 IITA

Table 1 Key properties of soils NG 17 and NG 18

Texture	Soil NG 17 is very sandy, only in the deep subsoil the texture changes to loam. Soil NG 18 has a sandy loam topsoil and a clayey subsoil. The characteristic gravel layer of *Egbeda* soil series is present between 15 and 40 cm depth and the gravel content is 35%
Organic C	Low in NG 17 (0.6% in upper 15 cm); medium in NG 18 (1.4% in upper 15 cm)
pH	Neutral (pH-H_2O 6.6 and 6.4 in NG 17 and NG 18 respectively)
Sum of bases	Topsoil medium (4.0 $cmol_c\ kg^{-1}$ soil) and subsoil very low (1.7 $cmol_c\ kg^{-1}$ soil) in NG 17; topsoil medium and subsoil low (9.5 and 3.3 $cmol_c\ kg^{-1}$ soil respectively) in NG 18
CEC	Topsoil very low (3.9 $cmol_c\ kg^{-1}$ soil) in NG 17; topsoil low (8.2 $cmol_c\ kg^{-1}$ soil) in NG 18
Clay mineralogy	Kaolinite is dominant
Bulk density	Increases with soil depth in both reference soils from medium (1.4 kg/dm^3) to high (> 1.5 kg/dm^3)
Air capacity	Very high (33%0 throughout the profile of NG 17. High (18%) in the topsoil of NG 18 to low (6%) in the subsoil
Av. soil moisture	Low (6%) all throughout the profile of NG 17. Low (5%) in the topsoil to medium (11%) in the subsoil of NG 18

technology. Therefore, the soils were evaluated for maize production in accordance with the Framework for Land Evaluation (FAO, 1983). The land requirements of maize were taken from Bunting (1981), ILACO (1981), Landon (1991) and Sys *et al.* (1993) and a summary is given in the next paragraph. The maize requirements were matched with the land qualities of the two soils and the results are presented in a list of soil characteristics and land qualities in Annex 2.

3.6.1 Climatic and Soil Requirements of Maize

An optimal water supply for maize (*Zea mays*) can be secured in regions that receive 1000-1500 mm/year or 500-1200 mm in the growing cycle. Rainfall during the growing period should be well distributed along the vegetative cycle and not decrease below 200 mm. Ripening and harvesting must be completed during a dry period. Daily temperatures should be between 22°C and 27°C and higher temperatures cause damage to the pollen. The optimum temperature for germination is 18-21°C. Below 13°C it is greatly reduced and germination fails below 10°C. Maize has a very low tolerance to frost and hail can cause severe damage to the crop.

Maize is a deep rooting (90 cm), nutrient demanding crop (especially nitrogen; optimum pH 6.6- 7.2). Erosion hazard may be high due to the limited protection it offers to the soil surface. The soil, preferably of medium to fine texture and sufficient organic matter content, should be well drained and well structured. Sites with impeded drainage and mottling within 1.0 m from the surface, are not suitable for maize. Tolerance to periods with water saturation of the soil is very low, especially in the first 5 weeks after sowing. On soils with a low moisture retention capacity, or in areas of low rainfall, a low plant density should be used.

3.6.2 Evaluation of NG 17 and NG 18

The length of the growing period is adequate and average annual temperature and annual rainfall are sufficient for maize, although temperatures are a strictly speaking too high for optimum germination. The most severe limitation is radiation because of the characteristic thick cloud cover which is high during the planting season. This prevents the crop from attaining its maximum photosynthetic capacity.

The storage capacity of soil NG 17 (AWC= 37 mm/73 cm soil) is low as a result of the sandy texture of the soil. It is moderate (AWC= 80 mm/100 cm soil) for soil NG 18. Regarding the mottling and increase in clay content with depth, it appears that the permeability of the subsoil is inadequate. Therefore, the land quality "oxygen availability" is somewhat limited for NG 18.

The two soils do not have a satisfactory nutrient retention capacity which is expressed by the very low CEC figures. The nutrient availability is moderately limited, despite the fair organic C contents. Overall the soils have a very low fertility.

The water erosion hazard is weak in NG 17 and moderate in NG 18 because of steeper slope and the lower soil stability. NG 17 is more susceptible to flooding although floods occur rarely.

In order to sustain production on the reference soils, attention should be given to soil fertility, soil water retention, initial land preparation and soil drainage. The soil fertility requires improvement with fertilizer applications. The very low levels of nitrogen and potassium should be particularly supplemented by fertilizers. The severity of the effects of moisture stress varies according to the development stage of the crop. Maize is particularly sensitive during the flowering period.

In terms of land preparation, care should be taken not to destroy the delicate low aggregate stability in NG 17. In this context, the low superficial organic matter content should be improved in order to have formation of more stable aggregates, to improve the soil structure and the chemical fertility.

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Annex 1A ISIS Data Sheet NG17

ISIS 4.0 data sheet of reference soil NG 17 Country : NIGERIA Print date (dd/mm/yy) : 25/04/95

FAO/UNESCO (1988) : Ferralic Arenosol)
USDA/SCS SOIL TAXONOMY (1992) : coarse-loamy, kaolinitic, isohyperthermic (1975 : Typic Ustipsamment)
LOCAL CLASSIFICATION : Apomu Series

DIAGNOSTIC CRITERIA USDA/SCS (1992) : Soil moisture regime : ustic
FAO (1974) & USDA (1975) : Soil moisture regime : ustic

(CLASSIFICATIONS ARE FIELD CLASSIFICATIONS)

LOCATION : NW of IITA, Ibadan, Oyo State
Latitude : 7°30′ 0′′ N Longitude : 3°54′ 0′′ E Altitude : 207 m a.s.l.
AUTHOR(S) : Gbadegesin, A., Mokam Date (mm/yy) : 12/90

GENERAL LANDFORM : plain Topography : flat or almost flat
PHYSIOGRAPHIC UNIT : middle slope
SLOPE Gradient : 3% Aspect : Form : convex
POSITION OF SITE : middle slope
MICRO RELIEF Kind :
SURFACE CHAR. Rock outcrop : nil Stoniness : nil
Cracking : nil Slaking/crusting : nil
Salt : nil Alkali : nil
SLOPE PROCESSES Soil erosion : no
Slope stability : stable

PARENT MATERIAL 1 : colluvium derived from : metamorphic rock
Texture : loamy
Weathering degree : high Resistance :
Remarks :

EFFECTIVE SOIL DEPTH : 113 cm

WATER TABLE Depth : Kind : no watertable observed
DRAINAGE : moderately well
PERMEABILITY : No slowly permeable layer(s) cm
FLOODING Frequency : nil
MOISTURE CONDITIONS PROFILE : 000 - 145 cm dry

LAND USE : fallow
VEGETATION Type : semi deciduous forest Status : secondary

ADDITIONAL REMARKS :

BRIEF CHARACTERIZATION OF THE SOIL:
Deep moderately well drained brown sand derived from metamorphic rocks, with shallow topsoil and many hard magniferous concretions in the subsoil. Under thick secondary forest.

CLIMATE : Köppen: Aw
Station: IBADAN 7 26 N/ 3 54 E 228 m a.s.l 7 km S of site Relevance: good

	No. years of record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
EP Penman mm		126	128	142	132	127	111	98	100	104	117	118	118	1421
precipitation mm	46	10	22	89	139	149	189	160	86	178	155	42	10	1229
tot.glob.rad. MJ m^{-2}		17.4	19.1	19.2	18.7	0.0	16.8	14.2	13.7	14.7	17.3	18.0	17.4	17.0
T mean °C		26.7	27.7	28.5	28.0	26.8	25.7	24.5	24.5	25.1	25.6	26.5	26.5	26.3
T max °C		32.8	34.1	34.3	33.5	31.5	29.7	27.8	27.7	29.2	30.3	31.8	32.3	31.3
T min °C		20.6	21.3	22.5	22.5	22.1	21.6	21.0	21.0	21.0	20.8	21.0	20.6	21.3
windspeed(at 2m) m s^{-1}		1.2	1.2	1.0	0.8	0.8	0.5	0.8	0.8	0.8	0.8	1.0	1.0	0.9
vapour pressure mbar		22.8	23.3	26.0	25.8	25.6	25.1	24.2	24.2	24.2	24.0	24.2	23.3	24.4
bright sunshine %		56	59	53	49	49	41	24	19	25	45	58	59	44

PROFILE DESCRIPTION :

Ap	0 - 15 cm	very dark grayish brown (10YR 3.0/2.0, dry) sandy loam; very weak medium subangular blocky non sticky, non plastic, very friable, loose; many medium discontinuous exped and inped interstitial pores; many very fine to coarse roots throughout and many medium roots between peds; few very fine strongly weathered quartz fragments; clear smooth boundary to
AB1	15 - 39 cm	dark brown (10YR 3.0/3.0, dry) loamy sand; very weak medium subangular blocky non sticky, non plastic, very friable, loose; many fine discontinuous exped and inped interstitial pores; common fine roots throughout; frequent very fine strongly weathered quartz fragments; clear smooth boundary to
AB2	39 - 75 cm	yellowish brown (10YR 5.0/4.0, dry); moderate medium subangular blocky, loose; few fine continuous exped and inped interstitial pores; few fine roots between peds; very frequent very fine strongly weathered quartz fragments; clear wavy boundary to
B2	73 - 113 cm	strong brown (7.5YR 5.0/6.0, dry) loamy sand; moderate medium crumb, slightly hard; few fine discontinuous exped interstitial pores; few fine roots between peds; clear wavy boundary to
BC	113 - 145 cm	strong brown (7.5YR 5.0/8.0, dry) sandy loam; very strong coarse subangular blocky, very hard; few fine discontinuous exped interstitial pores;; frequent medium hard manganiferous concretions;

ANALYTICAL DATA:

Hor. no.	Top - Bot	>2 mm	2000 1000	1000 500	500 250	250 100	100 50	TOT SAND	50 20	20 2	TOT SILT	<2 µm	DISP	BULK DENS	pF- 0.0	--- 1.0	--- 1.5	--- 2.0	--- 2.3	--- 2.7	--- 3.4	--- 4.2
1	0 - 15	0	9	30	29	17	5	89	3	4	7	4	0.9	1.39	41	39	16	8	6	5	4	4
2	15 - 39	0	9	27	27	19	6	87	4	4	8	5	2.3	1.41	42	39	18	9	7	6	3	3
3	39 - 73	0	8	22	30	22	7	88	4	4	7	4	2.4	1.56	33	32	9	7	5	3	3	2
4	73 - 113	0	9	19	27	22	7	84	4	5	8	8	5.8	-	-	-	-	-	-	-	-	-
5	113 - 145	0	9	17	14	8	3	51	36	4	40	9	7.9	-	-	-	-	-	-	-	-	-

Hor. no.	pH- H2O	--¦ KCl	CaCO3 %	ORG- C %	MAT. N %	EXCH CAT. Ca	---- Mg	---- K	---- Na	---¦ sum	EXCH AC.¦ H+Al	Al	CEC soil	---- clay	---- OrgC	---¦ ECEC	BASE SAT %	Al SAT %	EC 2.5 mS cm^{-1}
						¦---	----	----	----	--	$\text{cmol}_c\ \text{kg}^{-1}$	--	----	----	----	---¦			
1	6.6	6.3	-	0.60	0.06	3.0	0.7	0.0	0.3	4.0	0.0	0.0	3.9	105	2.1	4.0	103	0	0.16
2	6.3	5.5	-	0.23	0.03	1.2	0.3	0.0	0.2	1.7	0.0	0.0	1.9	40	0.8	1.7	89	0	0.03
3	6.7	5.7	-	0.12	0.01	0.6	0.3	0.0	0.1	1.0	0.0	0.0	1.2	28	0.4	1.0	83	0	0.02
4	6.6	5.4	-	0.08	0.01	1.0	0.3	0.0	0.2	1.5	0.0	0.0	1.6	21	0.3	1.5	94	0	0.02
5	6.6	5.6	-	0.04	0.01	1.8	0.3	0.0	0.2	2.3	0.0	0.0	2.6	28	0.1	2.3	88	0	0.02

ELEMENTAL COMPOSITION OF TOTAL SOIL (in weight %) AND MOLAR RATIOS

Hor. no.	SiO2	Al2O3	Fe2O3	CaO	MgO	K2O	Na2O	TiO2	MnO2	P2O5	IGN. LOSS	SiO2/ Al2O3	SiO2/ Fe2O3	SiO2/ R2O3	Al2O3/ Fe2O3
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

CLAY MINERALOGY (1 very weak,.., 8 very strong) / EXTRACTABLE Fe Al Si Mn (by AMM. OXALATE(o), Na DITHIONITE(d) & PYROPHO(p)

Hor. no.	MI	VE	CH	SM	KA	HA	ML	QU	FE	GI	GO	HE	Fe(o)	Al(o)	Si(o)	Fe(d)	Al(d)	Fe(p)	Al(p)	Pret	pHNaF
1	3	-	-	3	5	-	2	3	-	-	2	-	0.02	0.00	-	0.37	0.03	-	-	-	-
2	3	-	-	3	6	-	2	3	-	-	2	-	0.05	0.00	-	0.32	0.03	-	-	-	-
3	3	-	-	3	6	-	2	4	-	-	2	-	0.02	0.00	-	0.29	0.03	-	-	-	-
4	3	-	-	3	7	-	3	3	-	-	2	-	0.02	0.00	-	0.47	0.03	-	-	-	-
5	3	-	-	2	8	-	4	3	-	-	3	-	0.14	0.00	-	2.79	0.19	-	-	-	-

Annex 1B ISIS Data Sheet NG18

ISIS 4.0 data sheet of reference soil NG 18 Country : NIGERIA Print date (dd/mm/yy) : 25/04/95

FAO/UNESCO (1988) : Haplic Lixisol (1974 : Ferric Luvisol)
USDA/SCS SOIL TAXONOMY (1992) : sandy over clayey, kaolinitic, isohyperthermic (1975 : Udic Kanhaplustalf)
LOCAL CLASSIFICATION : Egbeda Series

DIAGNOSTIC CRITERIA USDA/SCS (1992) : Soil moisture regime : ustic
FAO (1974) & USDA (1975) : Diagnostic horizons : argillic
: Soil moisture regime : ustic

LOCATION : NW of IITA, Ibadan, Oyo State
Latitude : 7°30' 0'' N Longitude : 3°54' 0'' E Altitude : 210 m a.s.l.
AUTHOR(S) : Fagbami, Akinbola Date (mm/yy) : 12/90

GENERAL LANDFORM : low hill Topography : undulating
PHYSIOGRAPHIC UNIT : gentle slope
SLOPE Gradient : 5% Aspect : Form : convex
POSITION OF SITE : middle slope
MICRO RELIEF Kind :
SURFACE CHAR. Rock outcrop : nil Stoniness : nil
Cracking : nil Slaking/crusting : nil
Salt : nil Alkali : nil
SLOPE PROCESSES Soil erosion : no
Slope stability : stable

PARENT MATERIAL 1 : residual material derived from : gneiss
Texture : clayey
Weathering degree : high Resistance :
Depth lithological boundary (cm): 180
Remarks : intermediate gneiss

EFFECTIVE SOIL DEPTH : 130 cm

WATER TABLE Depth : Kind : no watertable observed
DRAINAGE : well
PERMEABILITY : No slowly permeable layer(s) cm
FLOODING Frequency : nil
MOISTURE CONDITIONS PROFILE : 070 - 180 cm dry 000 - 070 cm moist

LAND USE : medium level arable farming; no irrigation
VEGETATION Type : semi deciduous woodland Status : secondary

ADDITIONAL REMARKS :

BRIEF CHARACTERIZATION OF THE SOIL:
Deep, well drained, reddish clay, derived from gneiss, with weak mottling, quartz fragments and white termites in the subsoil. Land use is alley cropping. Plenty fibrous roots.

CLIMATE : Köppen: Aw
Station: IBADAN 7 26 N/ 3 54 E 228 m a.s.l 7 km S of site Relevance: good

	No. years of record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
EP Penman mm		126	128	142	132	127	111	98	100	104	117	118	118	1421
precipitation mm	46	10	22	89	139	149	189	160	86	178	155	42	10	1229
tot.glob.rad. MJ m^{-2}		17.4	19.1	19.2	18.7	0.0	16.8	14.2	13.7	14.7	17.3	18.0	17.4	17.0
T mean °C		26.7	27.7	28.5	28.0	26.8	25.7	24.5	24.5	25.1	25.6	26.5	26.5	26.3
T max °C		32.8	34.1	34.3	33.5	31.5	29.7	27.8	27.7	29.2	30.3	31.8	32.3	31.3
T min °C		20.6	21.3	22.5	22.5	22.1	21.6	21.0	21.0	21.0	20.8	21.0	20.6	21.3
windspeed(at 2m) m s^{-1}		1.2	1.2	1.0	0.8	0.8	0.5	0.8	0.8	0.8	0.8	1.0	1.0	0.9
vapour pressure mbar		22.8	23.3	26.0	25.8	25.6	25.1	24.2	24.2	24.2	24.0	24.2	23.3	24.4
bright sunshine %		56	59	53	49	49	41	24	19	25	45	58	59	44

PROFILE DESCRIPTION :

Ap 0 - 15 cm 5.0YR 3.0/2.0, moist sandy loam; moderate medium subangular blocky non sticky, slightly plastic, friable; many medium discontinuous exped and inped tubular pores; many very fine to coarse roots throughout and many medium roots between peds; clear wavy boundary to

AB 15 - 40 cm 5.0YR 4.0/3.0, moist gravelly sandy clay loam; moderate medium subangular blocky slightly sticky, slightly plastic, friable; many medium discontinuous exped and inped tubular pores; many coarse roots between peds; very frequent fine strongly weathered quartz fragments; clear smooth boundary to

Bt1	40 - 70 cm	5.0YR 4.0/6.0, moist sandy clay; moderate medium subangular blocky slightly sticky, slightly plastic, firm; few fine faint clear mottles (7.5YR 5.0/6.0); many medium discontinuous exped and inped tubular pores; few medium roots between peds; few fine strongly weathered quartz fragments; gradual irregular boundary to
Bt2	70 - 100 cm	dark red (2.5YR 3.0/6.0, dry) sandy clay; strong medium angular blocky slightly sticky, slightly plastic, very firm, very hard; few fine faint sharp mottles (10YR 5.0/8.0); many fine discontinuous exped tubular pores;; very frequent fine weathered quartz fragments; diffuse broken boundary to
Bt3	100 - 130 cm	dark red (2.5YR 3.0/6.0, dry) sandy clay; strong medium angular blocky slightly sticky, slightly plastic, very firm, very hard; few fine faint clear mottles (10YR 5.0/8.0); patchy thin clay cutans on pedfaces; many fine continuous exped tubular pores;; gradual smooth boundary to
Bt4	130 - 180 cm	dark red (2.5YR 3.0/6.0, dry) clay; strong medium angular blocky slightly sticky, slightly plastic, very firm; patchy thin clay cutans on pedfaces; many fine continuous exped tubular pores; frequent coarse weathered gneiss fragments;

ANALYTICAL DATA:

Hor. no.	Top - Bot	>2 mm	2000 1000	1000 500	500 250	250 100	100 50	TOT SAND	50 20	20 2	TOT SILT	<2 µm	DISP	BULK DENS	pF- 0.0	1.0	1.5	2.0	2.3	2.7	3.4	4.2
1	0 - 15	0	12	22	18	13	5	70	2	9	12	19	15.3	1.42	39	37	26	21	18	17	17	16
2	15 - 40	35	15	22	13	9	5	63	5	6	11	26	25.8	1.52	35	34	30	29	27	26	20	18
3	40 - 70	0	10	14	8	6	3	41	4	8	12	47	17.2	-	-	-	-	-	-	-	-	-
4	70 - 100	0	7	10	6	5	3	31	6	12	18	52	5.5	1.42	42	42	39	37	36	35	32	31
5	100 - 130	0	6	11	6	5	3	31	5	14	20	50	2.5	-	-	-	-	-	-	-	-	-
6	130 - 155	0	4	8	6	5	4	26	12	9	22	52	2.4	-	-	-	-	-	-	-	-	-
7	155 - 180	0	5	10	8	8	4	35	6	16	21	44	3.1	-	-	-	-	-	-	-	-	-
8	180 - 280	0	7	12	9	10	5	42	4	18	22	36	4.5	-	-	-	-	-	-	-	-	-
9	280 - 400	0	4	12	10	12	7	46	4	21	25	29	2.9	-	-	-	-	-	-	-	-	-

Hor. no.	pH- H2O	KCl	CaCO3 %	ORG-C %	MAT. N %	EXCH CAT. Ca	Mg	K	Na	sum	EXCH AC. H+Al	Al	CEC soil	clay	OrgC	ECEC	BASE SAT %	Al SAT %	EC 2.5 mS/cm
						cmol$_c$ kg^{-1}													
1	6.4	5.9	-	1.42	0.16	6.5	1.7	0.0	1.3	9.5	0.0	0.0	8.2	44	5.0	9.5	116	0	0.22
2	6.4	5.6	-	0.35	0.05	2.0	1.0	0.0	0.3	3.3	0.0	0.0	3.9	15	1.2	3.3	85	0	0.04
3	6.5	5.6	-	0.27	0.04	2.9	1.3	0.1	0.4	4.7	0.0	0.0	5.3	11	0.9	4.7	89	0	0.05
4	6.1	5.5	-	0.16	0.02	2.7	1.0	0.0	0.6	4.3	0.0	0.0	6.5	13	0.6	4.3	66	0	0.04
5	6.0	5.5	-	0.12	0.02	2.7	1.4	0.0	0.5	4.6	0.0	0.0	7.2	14	0.4	4.6	64	0	0.04
6	6.1	5.5	-	0.14	0.02	2.6	1.7	0.0	0.5	4.8	0.0	0.0	7.8	15	0.5	4.8	62	0	0.05
7	6.1	5.5	-	0.15	0.02	2.5	2.1	0.0	0.5	5.1	0.0	0.0	9.2	21	0.5	5.1	55	0	0.06
8	6.0	5.4	-	0.17	0.03	1.8	2.0	0.0	0.4	4.2	0.0	0.0	0.0	0	0.6	4.2	-	-	0.05
9	5.2	4.2	-	0.09	0.01	0.4	2.0	0.0	0.3	2.7	0.8	0.7	4.4	15	0.3	3.5	61	16	0.04

ELEMENTAL COMPOSITION OF TOTAL SOIL (in weight %) AND MOLAR RATIOS

Hor. no.	SiO2	Al2O3	Fe2O3	CaO	MgO	K2O	Na2O	TiO2	MnO2	P2O5	IGN. LOSS	SiO2/ Al2O3	SiO2/ Fe2O3	SiO2/ R2O3	Al2O3/ Fe2O3
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

CLAY MINERALOGY (1 very weak,.., 8 very strong) / EXTRACTABLE Fe Al Si Mn (by AMM. OXALATE(o), Na DITHIONITE(d) & PYROPHO(p)

Hor. no.	MI	VE	CH	SM	KA	HA	ML	QU	FE	GI	GO	HE	MX	Fe(o)	Al(o)	Si(o)	Fe(d)	Al(d)	Fe(p)	Al(p)	Pret	pHNaF
1	4	-	-	-	8	-	3	-	-	-	4	-	2	0.08	0.03	0.00	1.54	0.15	-	-	-	-
2	4	-	-	-	8	-	3	-	-	-	4	-	2	0.07	0.25	0.00	2.63	0.21	-	-	-	-
3	3	-	-	-	8	-	3	-	-	-	4	-	2	0.07	0.05	0.00	4.41	0.39	-	-	-	-
4	3	-	-	-	8	-	2	-	-	-	4	-	1	0.08	0.03	0.00	6.00	0.44	-	-	-	-
5	3	-	-	-	8	-	2	-	-	-	4	-	1	0.07	0.05	0.00	6.33	0.38	-	-	-	-
6	3	-	-	-	8	-	2	-	-	-	4	-	1	0.07	0.02	0.00	5.86	0.37	-	-	-	-
7	3	-	-	-	8	-	2	-	-	-	4	-	1	0.10	0.05	0.00	5.90	0.33	-	-	-	-
8	3	-	-	-	8	-	2	-	-	-	4	-	1	0.08	0.03	0.00	3.68	0.20	-	-	-	-
9	3	-	-	-	8	-	2	-	-	-	4	-	1	0.04	0.05	0.00	2.78	0.21	-	-	-	-

remarks (hor. 1 - 9): MINX= TALC

Annex 2 Evaluation of Soil/Land Qualities

LAND QUALITY Availability (1) | vh | h | m | l | vl |

vh = very high h = high m = moderate l = low
vl = very low

Hazard/Limitation (2) | n | w | m | s | vs |

n = not present w = weak m = moderate s = serious
vs = very serious

			NG 17					NG 18				
CLIMATE												
Radiation regime	- total radiation	1					▨					▨
	- day length	1			▨					▨		
Temperature regime		1		▨					▨			
Climatic hazards (hailstorm, wind, frost)		2	▨					▨				
Conditions for ripening		1		▨					▨			
Length growing season		1	▨					▨				
Drought hazard during growing season		2					▨			▨		
SOIL												
Potential total soil moisture		1				▨				▨		
Oxygen availability		1	▨							▨		
Nutrient availability		1					▨					▨
Nutrient retention capacity		1				▨					▨	
Rooting conditions		1	▨					▨				
Conditions affecting germination		1	▨					▨				
Excess of salts	- salinity	2	▨					▨				
	- sodicity	2	▨					▨				
Soil toxicities (e.g. high Al sat.)		2	▨					▨				
LAND MANAGEMENT												
Initial land preparation		2					▨		▨			
Workability		1	▨						▨			
Potential for mechanization		1		▨						▨		
Accessibility	- existing	1	▨					▨				
	- potential	1										
Erosion hazard	- wind	2			▨					▨		
	- water	2		▨						▨		
Flood hazard		2			▨			▨				
Pests and diseases		2				▨					▨	

COMMENTS

Annex 3 Methods of Soil Analysis

Preparation	Each sample is air-dried, cleaned, crushed (not ground), passed through 2 mm sieve, homogenized. Moisture content is determined at 105^0 C.
pH H_2O	(1:2.5): 20 g of soil is shaken with 50 ml of deionised water for 2 hours, electrode in upper part of suspension.
pH-KCl	likewise but shaken with 1 *M* KCl.
EC	(1:2.5): Conductivity of pH-H_2O suspension.
Particle-size distribution	Soil is treated with 15% hydrogen peroxide overnight in the cold, then on waterbath at about 80°C. Then boiled on hot plate for 1 hour. Washings until dispersion. Dispersing agent is added (20 ml solution of 4% Na-hexametaphosphate and 1% soda) and suspension shaken overnight. Suspension sieved through 50 μm sieve. Sand fraction remaining on sieve dried and weighed. Clay and silt determined by pipetting from sedimentation cylinder.
Exchangeable bases and CEC	Percolation with 1*M* ammonium acetate pH7 using automatic extractor. (If EC>0.5mS pre-leaching with ethanol 80%). Cations are determined in the leachate by AAS. CEC: saturation with sodium acetate 1*M* pH7; washed with ethanol 80% and then leached with ammonium acetate 1*M* pH7. Na determined by FES.
Exchangeable acidity and Aluminium	The sample is extracted with *1 M* KCl solution and the exchange acidity (H+Al) titrated with NaOH. Al is measured by AAS.
Carbonate	Piper's procedure. Sample is treated with dilute acidand the residual acid is titrated.
Organic carbon	Walkley-Black procedure. The sample is treated with a mixture of potassium dichromate and sulphuric acid at about 125°C. The residual dichromate is titrated with ferrous sulphate. The result expressed in % carbon (because of incomplete oxidation a correction factor of 1.3 is applied).
Total nitrogen	Micro-Kjeldahl. Digested in H_2SO_4 with Se as catalyst. Then ammonia is distilled, trapped in boric acid and titrated with standard acid.
Extractable Iron, Aluminium, Manganese and Silicon	All determinations by AAS. 1 "Free" (Fe, Al, Mn): Holmgren Shaken with sodium citrate (17%) + sodium dithionite (1.7%) solution for 16 hours. 2 "Active" (Fe, Al, Si): Shaken with acid ammonium acetate 0.2 *M* pH 3 for 4 hours in the dark. 3 "Organically bound" (Fe, Al): Shaken with sodium pyrophosphate 0.1 *M* for 16 hours.
Clay mineralogy	Clay is separated as indicated for particle-size analysis. about 10-20 mg of clay is brought on porous ceramic tile by suction and analyzed using a Philips diffractometer.
Soluble salts	Measuring pH, EC, cations and anions in water extracts. 1 1:5 extract. Shaking 30 g of fine earth + 150 ml of water for 2 hours. 2 saturation extract. Adding to 200-1000 g fine earth just enough water to saturate the sample. Standing overnight. After filtration Ca, Mg, Na, K are measured by AAS. Cl with the Chlorocounter and SO_4 turbidimetrically.
Gypsum	To 10 g of fine earth 100 ml of water is added, shaken overnight and centrifuged. Precipitation by adding acetone. Precipitate redissolved in water and determination of Ca by AAS.
Elemental composition	The fine earth is dried, ignited and fused with lithium tetraborate. The formed bead is analyzed by X-ray fluorescence spectroscopy.
Moisture retention	Moisture determinations on undisturbed core samples in silt box (pF1.0;1.5;2.0) and kaolinite box (pF2.3;2.7) respectivily and on disturbed samples in high pressure pan (pF3.4;4.2). Bulk density obtained from dry weight of core sample.

Annex 4 Units, Glossary, Classes and Acronyms

UNITS

$\text{cmol}_c\ \text{kg}^{-1}$	centimol charge per kilogram (formerly meq/100 g; 1 meq/100 g = 1 $\text{cmol}_c\ \text{kg}^{-1}$)
μm	micro-metre: 1/1000th of a millimetre.
mg kg^{-1}	milligram per kilogram (formerly parts per million (ppm))
mS cm^{-1}	milliSiemens per cm at 25°C (formerly mmho cm^{-1})
MJ	Megajoules (formerly kcal; 1 MJ = 4186.8 kcal)

GLOSSARY

Air capacity	Amount of pore space filled with air 2 or 3 days after soil has been wetted. It is calculated from the difference between amount of water under almost saturated conditions (pF 0.0) and moisture retained at "field capacity" (pF 2.0), and expressed as volume percentage.
Al saturation	Ratio of exchangeable aluminium to the CEC, expressed as percentage.
Available soil moisture	Amount of moisture retained between "field capacity" (pF 2.0) and "wilting point" (pF 4.2), expressed as volume percentage (also called "available water capacity"). It is indicative of the amount of moisture available for plant growth.
Base saturation	Ratio of the sum of bases to the CEC, expressed as percentage.
Bulk density	Weight of an undisturbed soil sample divided by its volume.
CEC	Cation exchange capacity, indicative of the potential nutrient retention capacity of the soil.
Clay mineralogy	Type of clay-sized (< 2μm) particles.
kaolinite	Clay mineral with a low nutrient retention capacity, common in soils from (sub)tropical regions.
smectite	Silica-rich clay mineral with a high nutrient retention capacity and the ability to absorb water, resulting in swelling of the clay particles.
illite	Potassium-rich clay mineral with a moderately high nutrient retention capacity, common in soils from temperate regions and in alluvial soils.
vermiculite	Clay mineral with a high nutrient retention capacity and strong potassium-fixation.
chlorite	Aluminium-rich clay mineral with a moderately high nutrient retention capacity, occurring in variable quantities in soils rich in aluminium.
halloysite	Clay mineral with a moderately high nutrient retention capacity, common in soils derived from volcanic ashes.
quartz	Residual silica, resistant to weathering.
feldspar	Residual primary mineral, unstable in soil environments and, if present, indicative of a slight to moderate degree of weathering.
hematite	Reddish coloured iron oxide, common in well drained soils of tropical regions.
goethite	Yellowish coloured hydrated iron oxide, common in soils of temperate regions.
gibbsite	Aluminium hydroxide, indicative of a high degree of weathering.
Consistence	Refers to the degree and kind of cohesion and adhesion of the soil material, or to the resistance to deformation or rupture.
ECEC	Effective cation exchange capacity. It is calculated by addition of the sum of bases and exchangeable acidity, and reflects the actual nutrient retention capacity of the soil.
ESP	Exchangeable sodium percentage, ratio of exchangeable sodium to the CEC, expressed as percentage.
Exchangeable acidity	Sum of exchangeable hydrogen and aluminium.
Fine earth fraction	Part of the soil material with a particle-size of 2 mm or less (nearly all analyses are carried out on this soil fraction).
Horizon	Layer of soil or soil material approximately parallel to the earth's surface.
Land characteristic	Measurable property of land (e.g. texture).
Land quality	Set of interacting land characteristics which has a distinct influence on land suitability for a specified use (e.g. erosion hazard, which is a.o. influenced by slope, rainfall intensity, soil cover, infiltration rate, soil surface characteristics, texture).
Leaching	Downward or lateral movement of soil materials in solution or suspension.
Mottle	Spot or blotch differing in colour from its surroundings, usually indicative of poor soil drainage.
Organic carbon	Content of organic carbon as determined in the laboratory (% org. C x 1.72 = % org. matter)
Parent material	The unconsolidated mineral or organic material from which the soil is presumed to have been developed by pedogenetic processes.
pF value	Measure for soil moisture tension.
SAR	Sodium adsorption ratio of the soil solution, indicative of sodication hazard.
Soil reaction (pH)	Expression of the degree of acidity or alkalinity of the soil.
Soil structure	Aggregates of primary soil particles (sand, silt, clay) called peds, described according to grade, size and type.

Sum of bases	Total of exchangeable calcium (Ca^{++}), magnesium (Mg^{++}), potassium (K^{+}) and sodium (Na^{+}).
Texture	Refers to the particle-size distribution in a soil mass. The field description gives an estimate of the textural class (e.g. sandy loam, silty clay loam, clay); the analytical data represent the percentages sand, silt and clay measured in the laboratory.
Water soluble salts	Salts more soluble in water than gypsum.

CLASSES OF SOME ANALYTICAL SOIL PROPERTIES

Organic Carbon - C (%)

< 0.3	very low
0.3 - 1.0	low
1.0 - 2.0	medium
2.0 - 5.0	high
> 5.0	very high

Acidity pH-H$_2$O

< 4.0	extremely acid
4.0 - 5.0	strongly acid
5.0 - 5.5	acid
5.5 - 6.0	slightly acid
6.0 - 7.5	neutral
7.5 - 8.0	slightly alkaline
8.0 - 9.0	alkaline
> 9.0	strongly alkaline

Available phosphorus (mg kg^{-1})	**Olsen**	**Bray**
low	< 5	< 15
medium	5 - 15	15 - 50
high	> 15	> 50

CEC [pH7] (cmol$_c$ kg^{-1} soil)

< 4	very low
04 - 10	low
10 - 20	medium
20 - 40	high
> 40	very high

Sum of bases (cmol$_c$ kg^{-1} soil)

< 1	very low
1 - 4	low
4 - 8	medium
08 - 16	high
> 16	very high

Base saturation - BS [CEC pH7] (%)

< 10	very low
10 - 20	low
20 - 50	medium
50 - 80	high
> 80	very high

Aluminium saturation (%)

< 5	very low
05 - 30	low
30 - 60	moderate
60 - 85	high
> 85	very high

Exchangeable sodium percentage - ESP (%)

Soil structure		*Crops*
< 5	very low	< 2
05 - 10	low	02 - 20
10 - 15	medium	20 - 40
15 - 25	high	40 - 60
> 25	very high	> 60

Bulk density (kg dm^{-3})

< 0.9	very low
0.9 - 1.1	low
1.1 - 1.5	medium
1.5 - 1.7	high
> 1.7	very high

ACRONYMS

FAO	Food and Agriculture Organization of the United Nations
ISIS	ISRIC Soil Information System
ISRIC	International Soil Reference and Information Centre
SCS	Soil Conservation Service
UNESCO	United Nations Educational, Scientific and Cultural Organization
USDA	United States Department of Agriculture

Soil Briefs of Nigeria

(ISSN: 1381-6950)

No.	Title	No. of soils*
Nigeria 1	Sandy reference soils of the moist lowlands near Ibadan (Oyo state)	2
Nigeria 2	Reference soils of the coastal swamps near Ikorodu (Lagos state)	2
Nigeria 3	Reference soils of the moist lowlands near Ife (Oshun state)	1
Nigeria 4	Reference soils of the moist lowlands near Ilesa (Oshun state)	2
Nigeria 5	Reference soils of the moist lowlands near Itagunmodi (Oshun state)	1
Nigeria 6	Reference siols of the moist lwlands near Ondo (Ondo state)	2
Nigeria 7	Reference soils of the Southern Guinea Savanna of south western Nigeria (Oyo state)	1
Nigeria 8	Reference soils of the Southern Guinea Savanna of central-western Nigeria (Oyo state)	2

Country Reports

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No.	Country	No. of soils*
1	Cuba	22
2	P.R. of China	51
3	Turkey	15
4	Côte d'Ivoire	7
5	Thailand	13
6	Colombia	18
7	Indonesia	48
8	Ecuador	in prep.
9	Brazil	28
10	Peru	21
11	Nicaragua	11
12	Costa Rica	12
13	Zambia	11
14	Uruguay	10

No.	Country	No. of soils*
15	Gabon	6
16	Ghana	in prep.
17	Philippines	6
18	Zimbabwe	13
19	Spain	20
20	Italy	17
21	Greece	in prep.
22	India	in prep.
23	Kenya	in prep.
24	Mali	in prep.
25	Nigeria	in prep.
26	Mozambique	in prep.
27	Botswana	in prep.

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* State of reference collections as of January 1995