Soil Brief *Nigeria 4*

NIGERIA

Reference soils of the moist lowlands near Ilesa (Oshun state)

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ISRIC

International Soil Reference and Information Centre

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Soil Brief *Nigeria 4*

NIGERIA

Reference soils of the moist lowlands near Ilesa (Oshun state)

ISRIC Soil Monoliths:

Number	*FAO-Unesco*	*Soil Taxonomy*
NG 22	Ferric Acrisol	Typic Kanhaplustult
NG 23	Ferric Acrisol	Udic Kandiustult

A.A. Fagbami
E.A.A. Shogunle

October 1995

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CONTENTS

ABSTRACT

Two soils (NG 22 and NG 23) representing the major soils developed from quartzite of the Basement Complex were studied for the soil reference collection of Nigeria by the University of Ibadan, Nigeria and the International Soil Reference and Information Centre (ISRIC), Wageningen, the Netherlands. Soil description, sampling and analyses were done by teams from the two institutions.

Two dominant factors determine the characteristics of these soils. Firstly, the resistant acid rocks which characteristically forms long ridges called "whale backs" with narrow crests and sleep slopes. Secondly, the porosity of the rock and the climate with abundant rainfall and high temperatures. The combination of these factors produce soils with gravelly layers to a depth of one metre and a distinct clay bulge on the steep slopes (NG 23) and deeper soils with a less distinct clay bulge on the lower slopes (NG 22). The soils are generally deeper than the corresponding soils in the drier zones.

The soils on the steep slopes should preferably be under permanent tree crops (e.g cocoa) but traditionally the slopes are used for arable crops, e.g. yams, cassava and rice. NG 22 has no slope limitation and is suitable for arable crops. In other areas of the southwest, these soils are used for cocoa.

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 specialists. 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 22 and NG 23 described in this paper, are representative for the soils derived from schist in the sub-humid tropical rainforest region of south-western 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, Mr A.B. Bos and Mr J.H. Kauffman (fieldwork), Ms M.B. Clabaut (text processing), Dr T. de Meester and Mr A.W. Vogel (editors).

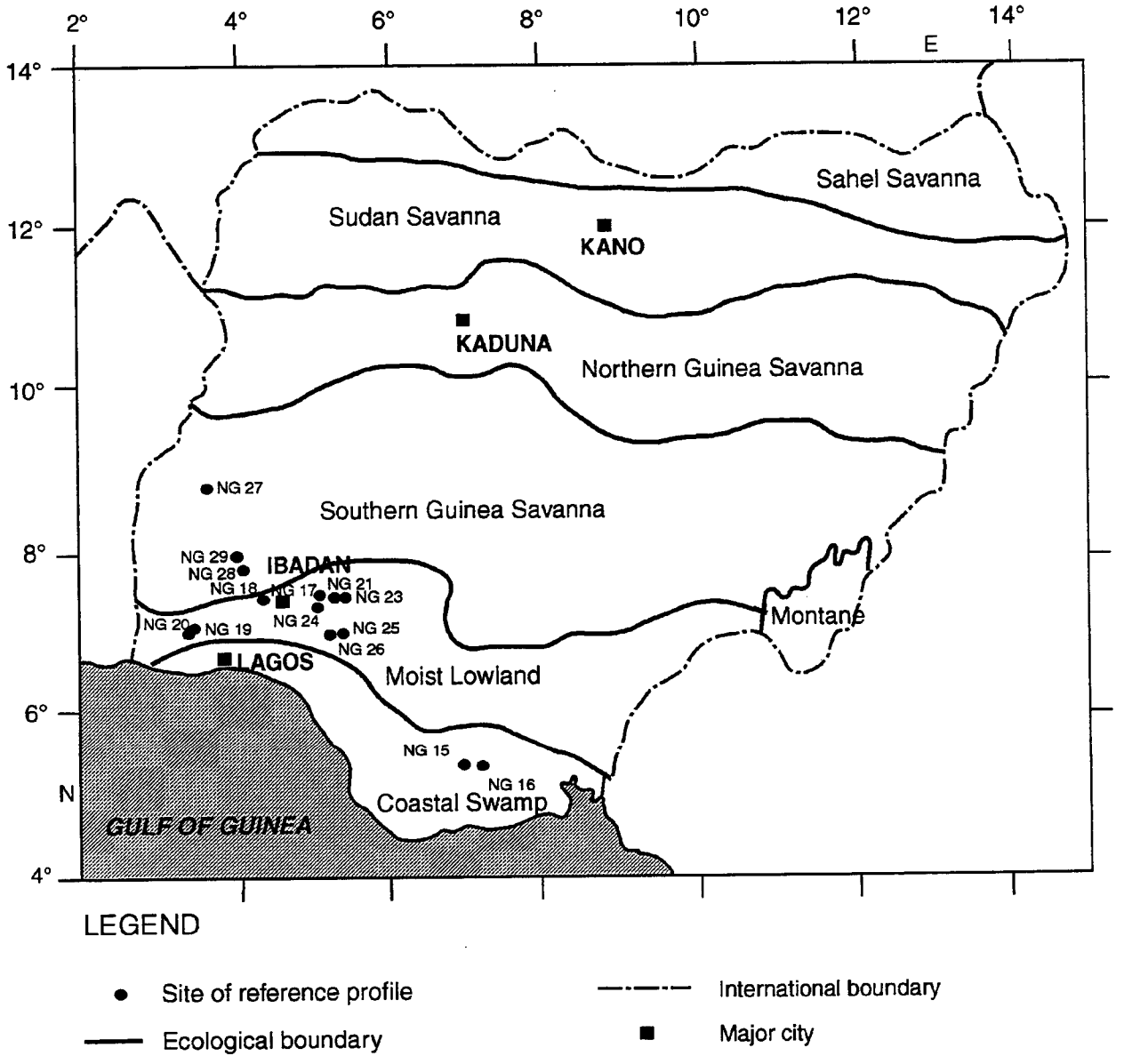

Figure 1 Major ecological regions and geographical location of the reference sites.

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 Guinea 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 Guinea 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 about 40 m a.s.l. while along the coastal plain the elevation is about 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 consists of coastal forest, mangroves and deltaic swamp forest. The mangrove forest is dominated by varieties of red mangrove (*Rhizophera racemosa*), the swamp forest consists 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, and NG 21 to NG 26. The soils are described in Soil Briefs *Nigeria 3, 4* (this Soil Brief), and *Nigeria 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 Briefs *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 closed canopy, (ii) the tree savanna where the trees and shrubs are scattered and, (iii) the shrub savanna where trees are absent.

2 ACID BASEMENT COMPLEX ROCKS

The Basement Complex rocks of southwestern Nigeria are mainly metamorphic. Although there are few basic rocks, the majority ranges from intermediate to acid. General information on the Basement Complex rocks of southwestern Nigeria is given in Smyth & Montgomery (1962). The geomorphology of the area is discussed in Soil Brief *Nigeria 2*.

2.1 Physiography

In the acid Basement Complex rocks quartzite, schists and quartz minerals dominate but also mica is present. The relief of the area is controlled by differential erosion and the topography is characterized by ridges rising abruptly several metres above the surrounding landscape. These resistant elongated quartzite formations are bordered by deeply incised valleys. The rocks are fairly resistant to weathering, and furthermore they are porous which reduces the rate of weathering as surface run-off is decreased (Smyth & Montgomery, 1962).
The relief of three toposequences was studied by Moormann (1981). The relief is hilly with narrow crests, steep slopes and a considerable height difference (100--200 m) between crests and valley bottoms. A common feature in the landform on Basement Complex complex rocks is a stoneline or gravel layer, which is known to be most pronounced in the acid crystalline toposequences where the parent rocks contain quartz which weathers slowly.

2.2 Soils

The soils are derived from rocks consisting mainly of quartz. These rocks are mainly classified as gneiss, schists, quartzite and occasionally metamorphic conglomerates. They are resistant to weathering and give rise to shallow soils with a high proportion of quartz gravels and stones. The *Okemessi* Association of Smyth & Montgomery (1962) is a typical soil derived from acid crystalline rocks. The very coarse sand fraction is a diagnostic feature of these soils. The soils are usually well drained, with colours ranging from greyish brown to brown. However, there is an exception in *Etionni* series (reference soil NG 22), whose brownish red to red colours resemble the soils derived from basic amphibolite material.
Moormann (1981) has shown that climatic zonality is only moderately well expressed in the morphological features of the various profiles on residuum and colluvium of acid Basement Complex rocks. The depth of the solum tends to increase with increasing rainfall for soils with comparable physiographic position.

3 REFERENCE SOILS NG 22 AND NG 23

In this section the two Reference soils are described and discussed; their full descriptions and other data stored in the ISRIC Soil Information System (Van Waveren and Bos, 1988) is given in Annex 1A (NG 22) and 1B (NG 23). The reference soils are described according to the Guidelines for Soil Profile Description (FAO, 1977).

3.1 Location and occurrence

Reference soils NG 22 and NG 23 are located at Effon Alaye about 46 km northwest of Ife, and 42 km southeast of Oshogbo which is the capital of Oshun State. The soils are locally referred to as *Etionni* and *Erinoke* series respectively. NG 22 occupies 0.5% and NG 23 0.6% of central western Nigeria (Smyth & Montgomery, 1962). The soils occur on a toposequence of Okemessi Association. NG 22 is found at the lower slope and NG 23 at the middle slope.

3.2 Climate

The climate at the site is sub-humid with distinct wet and dry seasons. The distribution pattern of the rainfall is bimodal (Fig. 2), characterised by two peaks in June and September separated by a drought in August. There are insufficient climatic data for Effon Alaye. However, at Ado-Ekiti which is 33 km southwest of the site the annual rainfall is 1300 mm, which is higher than in Ibadan (reference soil NG 17 and NG 18) but less than in Ikorodu (NG 19 and NG 20). The dry season extends from November to February and the rainy season from March to October. January is the driest month with average precipitation of 10 mm.
There is little variation in the climate of western Nigeria. The temperature is high throughout the year. Relative humidity is also high, particularly during the rainy season.

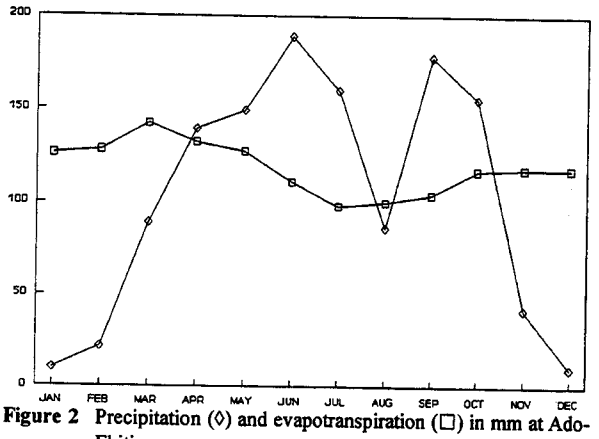

Figure 2 Precipitation (◊) and evapotranspiration (□) in mm at Ado-Ekiti.

3.3 Landscape, geology and soil formation

The topography is undulating with steep sided elongated ridges, narrow crests and deeply incised valleys. The two soils are derived from acid crystalline rocks which are highly resistant to weathering. The schists are fine grained while the quartzites are coarse grained. Pedogenesis differs in the two soils because of a difference in the mode of formation of parent materials and as a result of topographical location. NG 22 located at the lower slope, is formed from hill-wash materials and fine colluvial particles. The parent material of NG 23 is hill-creep material which accumulated at the base of the elongated quartzite ridge; the material is much coarser and contains many large boulders.

3.4 Vegetation and land use

The site of NG 22 has been under fallow for over 25 years and is presently under high forest. The fallow at NG 23 is only 2 years old. The semi-deciduous forest in the vicinity is very thick with an almost closed canopy. The vegetation has contributed in reducing soil erosion on the steep slopes to a tolerable minimum. Some common tree species are *Ceiba pentrandra* (kapok) and *Triplochiton scleroxylon*.

3.5 Soil characterisation

3.5.1 Catenary relationship in morphology between NG 22 and NG 23

Although the two Reference soils are derived from similar parent rocks (quartzite), their relative topographical location has influenced their morphology. NG 22 is located at the lower slope with a 2° gradient while NG 23 is at middle slope with a 8° gradient. At the upper topographical position, the soils have coarser texture because the fine particles have been washed downslope. Hence, NG 23 is gravelly and stony at the surface and it has a high content of coarse sand fraction in the upper 100 cm. The characteristic gravel layer of these soils is very prominent in the first four horizons of profile NG 23, but it is found only in the 5th horizon of NG 22. The upper slope soils are shallower and contain many fragments of weathering minerals. NG 23 has fragments of partially weathered quartz moved downwards from the surface horizon, while weathering mica occurs at 98 cm depth. NG 22 is a deeper soil and has very few weathering minerals in the upper 100 cm. Some quartz fragments are found below 114 cm depth.

3.5.2 Brief field description

Reference soil NG 22 is a deep, sandy clay loam soil over a sandy clay subsoil. Colour varies from dark brown at the surface to reddish brown and red in the subsoil. The soil is weakly to moderately structured. It has few quartz fragments and few small Fe/Mn concretions in the subsoil.
Reference soil NG 23 is sandy loam over sandy clay loam and loam, and is very gravelly. The sand fraction is very coarse. Colours range from dark greyish brown to reddish brown, and dark red at the subsoil. The soil is weakly to moderately structured with frequent quartz and few mica minerals. There are distinct mottles between 90 cm and 175 cm soil depth.
Detailed description on the two soils according to the Guidelines for Soil Profile Description (FAO, 1977) is given in Annexes 1A and 1B.

3.5.3 Brief analytical characterisation

The soil samples were analyzed at the ISRIC's soil laboratory according to the procedures described by Van Reeuwijk (1993). In Table 1 the classification of some key properties is given (ISRIC, in prep.; Landon, 1991). Some important soil data were selected and presented in a graphical way using SOLGRAPH (Brunt & Kauffman, 1995).
The clay content increases with soil depth in both soils, which indicates the presence of an argic horizon. The sand fraction and gravel content decrease with soil depth in NG 23. In NG 22 the sand content is rather constant. Fig. 3 and 4 show the distribution of five chemical soil properties with depth for the two soils. The organic C content, the sum of the exchangeable bases (Ca, Mg, K and Na) and the soil acidity (pH-H_2O and pH-KCl). Organic C decreases gradually down the profile of both soils. The pattern of the sum of bases is similar to that of organic C. Over 60% of the exchangeable bases is accounted for by Ca in the topsoil of the two reference soils. The low base saturation and high exchangeable acidity may indicate the extent of leaching due to the intense high rainfall condition. Exchangeable Al increases in the upper 100 cm and accounts for about half of the ECEC. NG 22 is strongly acid and NG 23 is slightly acid. Within 160 cm depth acidity decreases in NG 22 but slightly increases in NG 23.

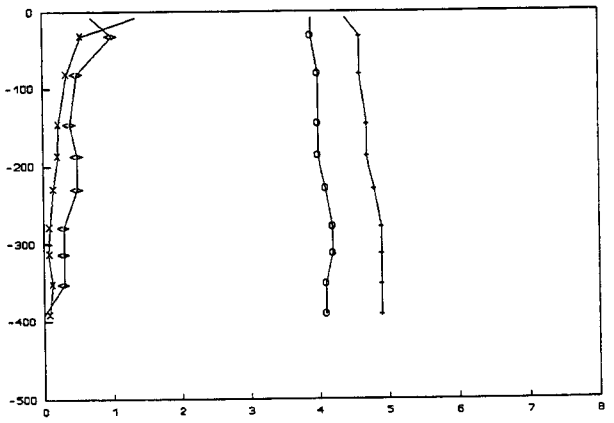

Figure 3 Sum of bases ($cmol_c\ kg^{-1}$ soil) (<>), pH-H_2O (+), pH-KCl (o) and organic carbon (×) versus depth (cm) in profile NG 22.

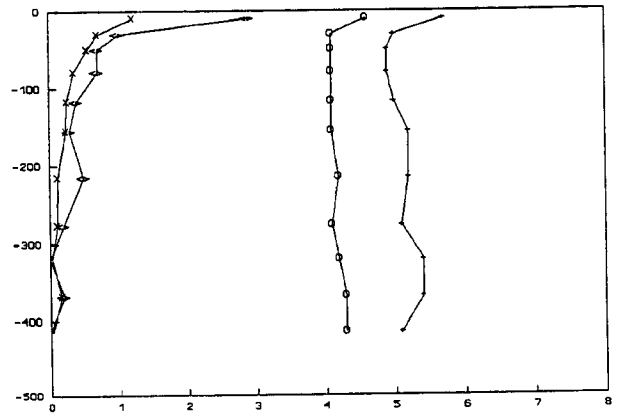

Figure 4 Sum of bases ($cmol_c\ kg^{-1}$ soil) (<>), pH-H_2O (+), pH-KCl (o) and organic carbon (×) versus depth (cm) in profile NG 23.

Table 1 Key properties of soils NG 22 and 23

Texture	NG 22 is sandy clay loam over sandy clay; NG 23 is sandy loam over sandy clay loam. NG 23 is very gravelly, (34% in the upper 100 cm)
Organic C	Medium in NG 22 (1.3% in upper 15 cm); medium in NG 23 (1.2% in upper 20 cm)
pH	Strongly acid in NG 22 (pH-H_2O 4.4); slightly acid in NG 23 (pH-H_2O 5.7)
Sum of bases	Low in the topsoil of NG 22 and NG 23 (1.3 and 2.9 $cmol_c\ kg^{-1}$ soil respectively) and in the subsoil very low (0.8 and 1.0 $cmol_c\ kg^{-1}$ soil)
ECEC	Very low throughout both soils (± 3.5 $cmol_c\ kg^{-1}$ soil)
Exch. aluminium	High in the subsoil of both soils (± 40%)
Clay mineralogy	Kaolinite is dominant in both soils

3.6 Soil classification

3.6.1 Soil classification of NG 22

FAO-Unesco (1988)
The soil is classified as an Ferric Acrisol.

USDA Soil Taxonomy (1992)
In Soil Taxonomy the soil is classified as a Typic Kanhaplustult.

3.6.2 Soil classification of NG 23

FAO-Unesco (1988)
The soil classifies as a Ferric Acrisol, because the soil has an argic B horizon with a CEC of < 24 $cmol_c$ kg^{-1} clay and a base saturation of $< 50\%$. The A horizon is not thick enough to be classified as a mollic one, in spite of its dark colour, and base saturation of $> 50\%$. The structure of the B horizon is subangular and therefore does not match with the characteristics of nitic properties. The silt-clay ratio is too high to classify the B horizon as ferralic. The soil is not strongly humic and is lacking ferric and gleyic properties and plinthite.

USDA Soil Taxonomy (1992)
The soil has an argillic and kandic horizon. The silt-clay ratio is higher than 0.2, so the B horizon is not oxic. The soil moisture regime is ustic with certain characteristics of an udic soil moisture regime. The soil keys out as an Udic Kandiustult.

3.7 Soil suitability

The land is currently under natural fallow and low input arable production is commonly practised in the area. NG 22 and NG 23 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). The requirements were matched with the land qualities of the two soils and the results are presented in Annex 2.

3.7.1 Requirements and limitations for maize

An optimal water supply for maize (*Zea mays* L.) can be secured in regions that receive 1000-1500 mm y^{-1} or 500-1200 mm in the growing cycle. Rainfall during the growing period should be well distributed along the vegetative cycle and not be below 200 mm. Grain ripening and harvesting should be completed during a dry period. Daily temperatures should be between 22°C and 27°C, and higher temperatures causes damage to the pollen. The optimum temperature for germination is 18-21°C; below 13°C it is greatly reduced and fails below 10°C. Tolerance to frost is very low and hail can cause great damage to the crop. No excessive air humidity and a good radiation are favourable.
It is a deep rooting (90 cm) and nutrient demanding crop, especially nitrogen, and pH should preferably be between 6.6 and 7.2. In a young stage, the erosion hazard is high due to the limited soil protection. The soil, preferably of medium to fine texture and with sufficient organic matter content, should be well drained and well structured. Sites with an impeded drainage, as shown by mottling within 1.0 m from the surface, may not be suitable. The 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 preferred.

3.7.2 Evaluation of NG 22 and NG 23

The characteristic thick cloud cover which reduces the solar radiation is a major constraint. However, the constraint is more severe for maize than for example yams. Rainstorms are common and may reduce maize yields. The stakes provided as support for yam under the traditional farming system, reduce the effect of rainstorms on yam. Given the steepness of the slope (14%) of the site were soil NG 23 was studied, and the many quartz gravels and stones in the upper horizons, it is advisable that the land should not be used for arable farming to avoid severe erosion. The moderate hazard for erosion on the almost flat terrain around NG 22, is based on the condition that the very steep upper slope remains under vegetative cover; the exposure of the upper slopes may aggravate erosion and cause sedimentation problems downslope.
The oxygen availability in NG 22 is suboptimal, and that in Reference soil NG 23 optimal. Rooting conditions are satisfactory in NG 22 but less optimal in NG 23 due to the stoniness of the profile, which also affects the workability and the water holding capacity.
The nutrient availability and CEC of both soils is low (low Base Saturation, low pH, low organic C content, and low ECEC). In order to get a good crop yield and a sustained production, the fertility of the soil should be given attention. Potassium fertilizers need to be applied to raise the inherently low level. Soil acidity also needs to be considered; the low pH may decrease under continuous cultivation without the application of lime. Liming reduces the high exchangeable acidity in the soil. Regarding the undulating terrain and the leaching of nutrients, especially bases, appropriate tillage practices and proper crop residue management should be adopted and the soil should be kept under a vegetative cover. Indiscriminate bush clearing should be avoided. Adequate attention should be given to the agricultural practises on the upper slopes and quartzite ridges, as any disruption to the delicate ecology may have a direct and devastating effect downslope.

Site of NG 22 regenerating vegetation after clearing

Site of NG 22 burning of vegetation debris after clearing

Site of NG 23 fallow vegetation

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Annex 1A ISIS Data Sheet NG 22

ISIS 4.0 data sheet of reference soil NG 22 Country : NIGERIA Print date (dd/mm/yy) : 25/04/95

FAO/UNESCO (1988) : Ferric Acrisol (1974 : Ferric Acrisol)
USDA/SCS SOIL TAXONOMY (1992) : Typic Kanhaplustult, sandy over loamy, kaolinitic, isohyperthermic
LOCAL CLASSIFICATION : Etionni Series

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

LOCATION : Ondo State, Effon Alaye
Latitude : 7°39′ 0′′ N Longitude : 4°55′ 0′′ E Altitude : 0 m a.s.l.
AUTHOR(S) : Fagbami, Mokam Date (mm/yy) : 3/91

GENERAL LANDFORM : low hill Topography : undulating
PHYSIOGRAPHIC UNIT :
SLOPE Gradient : 4% Aspect : Form : convex
POSITION OF SITE : lower 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

PARENT MATERIAL 1 : slope wash derived from : acidic schist
Texture : sandy clay
Weathering degree : partial or moderate Resistance :
PARENT MATERIAL 2 : Derived from : quartzite
Texture : gravelly
Weathering degree : partial or moderate Resistance : high
Remarks :

EFFECTIVE SOIL DEPTH : 176 cm

WATER TABLE Depth : Kind : no watertable observed
DRAINAGE : moderately well
PERMEABILITY : No slowly permeable layer(s) cm
MOISTURE CONDITIONS PROFILE : 000 - 176 cm dry

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

ADDITIONAL REMARKS :

BRIEF CHARACTERIZATION OF THE SOIL:
Very deep, moderately well drained brown to red sandy clay loam derived from acidic schist; with moderate mottling in the subsoil.

CLIMATE : Köppen: Aw

Station: IFE	7 24 N/ 4 33 E	0 m a.s.l	47 km WSW of site	Relevance: moderate
Station: ADO EKITI	7 37 N/ 5 14 E	480 m a.s.l	30 km E of site	Relevance: moderate

		No. years of record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
precipitation	mm	25	15	40	130	180	200	260	250	140	270	235	80	20	1820
T mean	°C	20	26.0	28.0	28.0	27.0	26.0	25.0	24.0	24.0	25.0	25.0	26.0	26.0	26.0
precipitation	mm	26	10	33	100	123	159	170	125	91	226	176	73	15	1301

PROFILE DESCRIPTION :

Ap 0 - 15 cm brown (7.5YR 4.0/4.0, dry) sandy loam; moderate medium crumb, non plastic, friable, soft; few fine continuous exped interstitial pores and few fine horizontal continuous exped vesicular pores; many medium roots throughout and many medium roots throughout; gradual smooth boundary to

Bt1 15 - 50 cm 5.0YR 4.0/4.0, dry sandy loam; weak medium crumb, non plastic, friable, slightly hard; few very fine continuous inped tubular pores; many fine roots between peds and many fine roots between peds; very few small spherical soft manganiferous concretions; few fine weathered quartz fragments; gradual wavy boundary to

Bt2 50 - 114 cm 5.0YR 4.0/4.0, dry sandy clay loam; weak medium crumb slightly sticky, non plastic, friable, slightly hard; few very fine discontinuous inped interstitial pores; few fine roots between peds and few fine roots between peds; gradual smooth boundary to

ISIS 4.0 data sheet of reference soil NG 22 Country : NIGERIA Print date (dd/mm/yy) : 25/04/95

PROFILE DESCRIPTION (cont'd):

Bt3 114 - 176 cm dark red (2.5YR 3.0/6.0, dry) sandy clay loam; weak medium subangular blocky slightly sticky, firm, slightly hard; common medium distinct clear mottles (5.0Y 8.0/0.0); few very fine roots between peds and few very fine roots between peds; very few fine weathered quartz 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	13	17	16	14	5	65	4	9	13	23	7.0	-	-	-	-	-	-	-	-	-
2	15 - 50	0	17	15	10	9	4	53	2	7	9	38	27.4	-	-	-	-	-	-	-	-	-
3	50 - 114	0	12	14	11	9	4	51	3	8	11	38	1.0	-	-	-	-	-	-	-	-	-
4	114 - 176	0	15	14	10	9	4	53	3	6	9	38	1.0	-	-	-	-	-	-	-	-	-
5	176 - 197	12	16	15	9	9	5	54	4	7	10	36	1.8	-	-	-	-	-	-	-	-	-
6	197 - 263	0	18	14	9	8	4	55	4	11	15	31	0.9	-	-	-	-	-	-	-	-	-
7	263 - 294	18	18	14	9	9	5	55	5	11	17	28	1.4	-	-	-	-	-	-	-	-	-
8	294 - 332	10	20	16	10	9	4	59	5	9	14	28	0.5	-	-	-	-	-	-	-	-	-
9	332 - 372	0	16	17	10	9	4	55	5	8	13	32	0.0	-	-	-	-	-	-	-	-	-
10	372 - 412	0	19	17	11	9	4	60	4	7	12	29	0.0	-	-	-	-	-	-	-	-	-

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}
						cmol$_c$ kg^{-1}													
1	4.4	3.9	-	1.34	0.12	0.4	0.1	0.1	0.1	0.7	2.2	1.8	6.3	28	4.7	2.9	11	29	0.11
2	4.6	3.9	-	0.56	0.06	0.6	0.3	0.1	0.0	1.0	2.9	2.3	6.3	17	2.0	3.9	16	37	0.04
3	4.6	4.0	-	0.35	0.04	0.2	0.1	0.1	0.1	0.5	2.7	2.3	4.9	13	1.2	3.2	10	47	0.02
4	4.7	4.0	-	0.23	0.03	0.2	0.1	0.1	0.0	0.4	3.2	1.6	4.0	10	0.8	3.6	10	40	0.02
5	4.7	4.0	-	0.22	0.03	0.2	0.3	0.0	0.0	0.5	2.0	1.6	3.0	8	0.8	2.5	17	53	0.02
6	4.8	4.1	-	0.15	0.02	0.2	0.3	0.0	0.0	0.5	1.6	1.1	2.3	8	0.5	2.1	22	48	0.01
7	4.9	4.2	-	0.09	0.02	0.0	0.3	0.0	0.0	0.3	1.3	0.9	2.1	7	0.3	1.6	14	43	0.01
8	4.9	4.2	-	0.07	0.01	0.0	0.3	0.0	0.0	0.3	1.6	0.9	2.6	9	0.2	1.9	12	35	0.01
9	4.9	4.1	-	0.13	0.01	0.0	0.3	0.0	0.0	0.3	2.0	1.6	3.2	10	0.5	2.3	9	50	0.01
10	4.9	4.1	-	0.08	0.01	0.0	0.0	0.0	0.0	0.0	2.0	1.6	3.0	10	0.3	2.0	0	53	0.01

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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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	-	-	-	-	-	-	-	-	-	-	-	-	0.10	0.12	0.00	1.30	0.27	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	0.12	0.12	0.00	2.31	0.46	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	0.10	0.12	0.00	2.11	0.40	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-	0.10	0.10	0.00	1.84	0.33	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-	0.08	0.08	0.00	1.65	0.27	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-	0.10	0.10	0.00	2.60	0.36	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-	0.05	0.08	0.00	2.40	0.33	-	-	-	-
8	3	-	-	-	8	-	3	-	1	-	3	-	0.07	0.07	0.00	2.84	0.31	-	-	-	-
9	3	-	-	-	8	-	3	-	2	-	4	-	0.02	0.07	0.00	2.14	0.24	-	-	-	-
10	3	-	-	-	8	-	3	-	1	-	3	-	0.03	0.08	0.00	1.53	0.18	-	-	-	-

remarks (hor. 8 -10): MIX=random chlor-smec

Annex 1B ISIS Data Sheet NG 23

ISIS 4.0 data sheet of reference soil NG 23 Country : NIGERIA Print date (dd/mm/yy) : 25/04/95

FAO/UNESCO (1988) : Ferric Acrisol (1974 : Ferric Acrisol)
USDA/SCS SOIL TAXONOMY (1992) : Udic Kandiustult, sandy over loamy, kaolinitic, isohyperthermic
LOCAL CLASSIFICATION : Erinoke Series

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

LOCATION : Ondo State, Effon Alaye
Latitude : 7°35' 0'' N Longitude : 4°56' 0'' E Altitude : 0 m a.s.l.
AUTHOR(S) : Fagbami, Edosonwa Date (mm/yy) : 3/91

GENERAL LANDFORM : low hill Topography : rolling
PHYSIOGRAPHIC UNIT :
SLOPE Gradient : 14% Aspect : Form : straight
POSITION OF SITE : middle slope
MICRO RELIEF Kind :
SURFACE CHAR. Rock outcrop : nil Stoniness : stony
Form : angular irregular Av.Size (cm) : .3
Cracking : nil Slaking/crusting : nil
Salt : nil Alkali : nil
SLOPE PROCESSES Soil erosion : slight
Slope stability : stable

PARENT MATERIAL 1 : colluvium derived from : acidic schist
Texture : sandy clay
Weathering degree : partial or moderate Resistance :
PARENT MATERIAL 2 : Derived from : quartzite
Texture : gravelly
Weathering degree : partial or moderate Resistance : high
Remarks :

EFFECTIVE SOIL DEPTH : 136 cm

WATER TABLE Depth : Kind : no watertable observed
DRAINAGE : well
PERMEABILITY : No slowly permeable layer(s) cm
MOISTURE CONDITIONS PROFILE : 000 - 175 cm dry

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

ADDITIONAL REMARKS :

BRIEF CHARACTERIZATION OF THE SOIL:
Deep well drained reddish sandy clay loam, derived from acidic schist colluvial material, with moderate mottling and fine mica and quartz fragments in the subsoil.

CLIMATE : Köppen: Aw
Station: IFE 7 24 N/ 4 33 E 0 m a.s.l 47 km WSW of site Relevance: moderate
Station: ADO EKITI 7 37 N/ 5 14 E 480 m a.s.l 30 km E of site Relevance: moderate

		No. years of record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
precipitation	mm	25	15	40	130	180	200	260	250	140	270	235	80	20	1820
T mean	°C	20	26.0	28.0	28.0	27.0	26.0	25.0	24.0	24.0	25.0	25.0	26.0	26.0	26.0
precipitation	mm	26	10	33	100	123	159	170	125	91	226	176	73	15	1301

PROFILE DESCRIPTION :

A1 0 - 20 cm very dark grayish brown (10YR 3.0/2.0, dry) sandy loam; weak medium crumb, non plastic, friable; many fine discontinuous exped and inped tubular pores; many medium roots throughout and many fine roots throughout; frequent medium weathered quartz fragments; diffuse wavy boundary to

BA 20 - 42 cm 2.5YR 4.0/3.0, dry sandy loam; weak medium subangular blocky, non plastic, friable, slightly hard; many fine discontinuous exped and inped tubular pores; many medium roots throughout and many fine roots throughout; frequent medium weathered quartz fragments; diffuse wavy boundary to

Bt1 42 - 60 cm reddish brown (2.5YR 4.0/4.0, dry) sandy loam; moderate medium crumb slightly sticky, firm, slightly hard; many fine continuous inped tubular pores; many fine roots between peds; frequent fine weathered quartz fragments; clear smooth boundary to

PROFILE DESCRIPTION (cont'd):

Bt2 60 - 98 cm red (2.5YR 4.0/6.0, dry) sandy clay loam; moderate medium subangular blocky slightly sticky, firm, slightly hard; many fine discontinuous exped interstitial pores; few very fine roots matted around stones or gravel; few fine weathered quartz fragments; diffuse wavy boundary to

Bt3 98 - 136 cm red (2.5YR 4.0/6.0, dry) sandy clay loam; moderate medium subangular blocky slightly sticky, firm, slightly hard; many medium distinct diffuse mottles (2.5Y 8.0/2.0); few fine discontinuous inped interstitial pores;; few fine weathered mica fragments; clear smooth boundary to

BC 136 - 175 cm dark red (2.5YR 3.0/6.0, dry) sandy clay loam; moderate medium subangular blocky slightly sticky, firm, slightly hard; many medium distinct clear mottles (2.5Y 8.0/2.0); few very fine continuous inped interstitial pores;; few fine fresh mica 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 - 20	40	25	18	14	11	4	71	4	7	11	18	11.5	-	-	-	-	-	-	-	-	-
2	20 - 42	40	23	16	10	8	3	59	4	6	10	31	25.3	-	-	-	-	-	-	-	-	-
3	42 - 60	36	19	14	7	6	3	48	24	9	32	20	32.9	-	-	-	-	-	-	-	-	-
4	60 - 98	19	15	11	8	7	4	45	2	9	11	44	1.5	-	-	-	-	-	-	-	-	-
5	98 - 136	0	8	7	6	7	4	33	4	12	16	52	1.0	-	-	-	-	-	-	-	-	-
6	136 - 175	0	8	8	8	9	4	37	5	11	16	47	1.0	-	-	-	-	-	-	-	-	-
7	175 - 256	0	12	10	9	9	4	44	5	13	18	38	1.0	-	-	-	-	-	-	-	-	-
8	256 - 297	0	8	10	10	11	5	44	5	15	20	36	0.4	-	-	-	-	-	-	-	-	-
9	297 - 343	0	4	11	18	21	10	64	8	18	26	10	0.0	-	-	-	-	-	-	-	-	-
10	343 - 395	0	3	12	18	22	10	65	9	19	28	8	0.0	-	-	-	-	-	-	-	-	-
11	395 - 433	0	4	12	19	21	11	67	8	19	27	6	0.0	-	-	-	-	-	-	-	-	-

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}
						cmol$_c$ kg^{-1}													
1	5.7	4.6	-	1.21	0.11	1.8	1.0	0.1	0.0	2.9	0.4	0.2	4.9	27	4.2	3.3	59	4	0.04
2	5.0	4.1	-	0.70	0.06	0.6	0.3	0.1	0.0	1.0	2.1	1.6	4.9	16	2.5	3.1	20	33	0.02
3	4.9	4.1	-	0.56	0.05	0.4	0.3	0.0	0.0	0.7	2.3	2.3	4.8	25	2.0	3.0	15	48	0.02
4	4.9	4.1	-	0.37	0.04	0.4	0.0	0.0	0.3	0.7	2.5	2.5	5.2	12	1.3	3.2	13	48	0.01
5	5.0	4.1	-	0.26	0.03	0.4	0.0	0.0	0.0	0.4	2.8	2.7	5.6	11	0.9	3.2	7	48	0.01
6	5.2	4.1	-	0.25	0.03	0.2	0.0	0.0	0.1	0.3	2.3	1.8	4.5	10	0.9	2.6	7	40	0.01
7	5.2	4.2	-	0.12	0.02	0.2	0.3	0.0	0.0	0.5	1.7	1.1	4.4	12	0.4	2.2	11	25	0.01
8	5.1	4.1	-	0.11	0.01	0.0	0.0	0.0	0.2	0.2	1.7	1.1	4.2	12	0.4	1.9	5	26	0.01
9	5.4	4.2	-	0.03	0.00	0.0	0.0	0.0	0.0	0.0	1.2	0.7	2.6	26	0.1	1.2	0	27	0.01
10	5.4	4.3	-	0.17	0.01	0.2	0.0	0.0	0.0	0.2	1.2	1.1	2.6	34	0.6	1.4	8	42	0.01
11	5.1	4.3	-	0.03	0.00	0.0	0.0	0.0	0.0	0.0	1.2	0.9	2.6	41	0.1	1.2	0	35	0.01

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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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	-	-	-	8	-	3	2	-	2	3	-	0.10	0.08	0.00	1.59	0.24	-	-	-	-
2	3	-	-	-	8	-	3	1	-	2	4	-	0.13	0.13	0.00	2.71	0.42	-	-	-	-
3	1	-	-	-	8	-	3	1	-	2	4	-	0.12	0.12	0.00	3.62	0.59	-	-	-	-
4	1	-	-	-	8	-	3	-	-	2	4	-	0.12	0.12	0.00	4.24	0.56	-	-	-	-
5	1	-	-	-	8	-	1	-	-	2	4	-	0.13	0.15	0.03	4.74	0.43	-	-	-	-
6	1	-	-	-	8	-	2	-	-	2	4	-	0.13	0.15	0.03	4.42	0.44	-	-	-	-
7	-	-	-	-	8	-	2	-	-	2	4	-	0.10	0.10	0.02	4.18	0.34	-	-	-	-
8	-	-	-	-	8	-	2	-	-	1	4	-	0.07	0.10	0.02	4.10	0.30	-	-	-	-
9	-	-	-	-	8	-	1	-	-	-	4	-	0.05	0.05	0.02	4.70	0.15	-	-	-	-
10	-	-	-	-	8	-	-	-	-	-	4	-	0.05	0.05	0.00	5.18	0.12	-	-	-	-
11	-	-	-	-	8	-	-	-	-	-	4	-	0.05	0.05	0.00	5.28	0.15	-	-	-	-

remarks (hor. 1 - 9): MIX=random chlor-ill

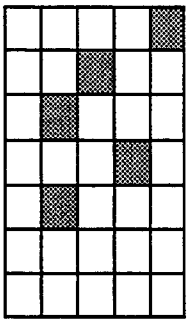
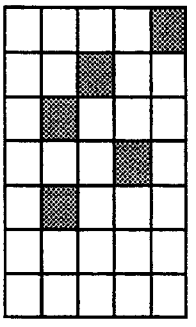
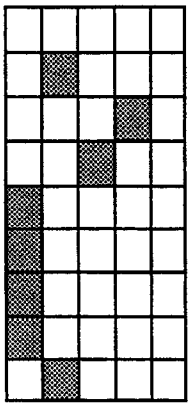
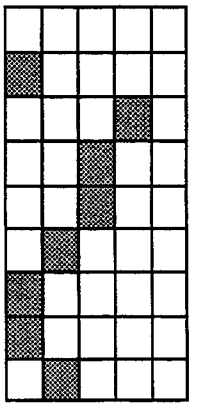
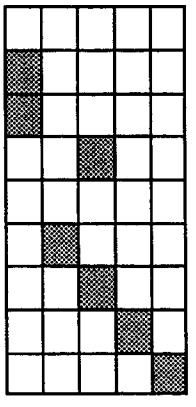
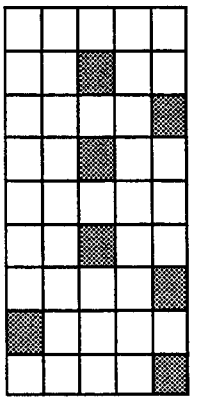
Annex 2 Evaluation of Soil/Land Qualities

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 22	NG 23
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° 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

$cmol_c\ kg^{-1}$	centimol charge per kilogram (formerly meq/100 g; 1 meq/100 g = 1 $cmol_c\ kg^{-1}$)
μm	micro-metre: $1/1000^{th}$ 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) 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_2O

< 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

(ISSN: 1381-5571)

No.	Country	No. of soils*	No.	Country	No. of soils*
1	Cuba	22	15	Gabon	6
2	P.R. of China	51	16	Ghana	in prep.
3	Turkey	15	17	Philippines	6
4	Côte d'Ivoire	7	18	Zimbabwe	13
5	Thailand	13	19	Spain	20
6	Colombia	18	20	Italy	17
7	Indonesia	48	21	Greece	in prep.
8	Ecuador	in prep.	22	India	in prep.
9	Brazil	28	23	Kenya	in prep.
10	Peru	21	24	Mali	in prep.
11	Nicaragua	11	25	Nigeria	in prep.
12	Costa Rica	12	26	Mozambique	in prep.
13	Zambia	11	27	Botswana	in prep.
14	Uruguay	10			

* State of reference collections as of January 1995