A DETAILED SOIL SURVEY OF THE SEED MULTIPLICATION FARM AT KONTAGORA, NIGER STATE

BY

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Approved by



D E C L A R A T I O N

I hereby declare that this thesis has been composed by myself and that it is a record of my own research work. It has not been accepted in any previous application for a higher degree. All quotations are distinguished by quotation marks and the sources of information are specifically acknowledged by means of references.

(Aliyu Nuhu)

Date: June, 1983

A B S T R A C T

A detailed soil survey at a scale of 1:5,000 was conducted at the Kontagora seed Multiplication farm of Niger State of Nigeria.

The soils are formed from residual parent material derived from weathered coarse Nupe Sandstone. These soils are reddish in colour, deep, well drained, non-concretionary and gravel-free. They are sandy in the surface horizons, though the texture becomes finer with depth as a result of increase in clay content with depth. Low silt content is common in all the soils. The soil structure is better developed in the subsoils than in the surface horizons. The soils exhibit low to moderate cation exchange capacity, exchangeable bases and base saturation percentage. They are characteristically strongly acid to neutral with very low to low organic matter and nitrogen contents.

Three mapping units were delineated. The soils of mapping unit 1 have a thin sandy to loamy sand surface overlying sandy clay to clay loam. They classify as Typic Haplustults. The thick sandy to loamy sand surface of soils of mapping unit 2 is underlain by clayey materials that vary between sandy clay loam to sandy clay. These soils have been classified as Arenic Haplustults. The mapping unit 3 soils have a very dark reddish brown sandy to sandy loam surface. They have more or less darker surface than soils of the other mapping units and are classified as Typic Rhodustults. All the mapping units qualify as Orthic Acrisols.

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CHAPTER I

INTRODUCTION

1.1: HISTORICAL BACKGROUND

The Kontagora Seed Multiplication Farm was established in 1972 by the defunct North Western State Government to serve as a cotton seed multiplication centre. The farm was also to serve as a model farm for progressive large scale farmers in the area. Soil erosion control structures such as terraces and grassed water ways have been constructed. A large section of the farm has been divided into blocks of two hectares each. The blocks are separated from each other by either a farm road, a terrace or a grassed water way. There is a small portion of the farm that has been left under fallow since its establishment. Before the establishment this farm, the land was being cultivated by peasant farmers on a small holder basis. Various crops, mostly guinea corn, millet, maize, cotton and groundnut, were then being cultivated.

The farm is within the former Utachu farm settlement area. The farm settlement scheme was a project designed by the colonial Government with the aim of producing oil seeds, for example groundnut and cotton, for their home industries. In 1974, 400 hectares of cassava and guinea corn were cultivated in this area under the emergency food production programme. This programme was planned to provide food in order to avert the famine threat of the 1973/74 sahelian drought.

The farm is also within the Kontagora crop development area proposed by Emirate Technical Service Limited (1975).

This farm was therefore choosen for study because of its significant position in the seed multiplication programme of the Niger State Government. It is presently devoted to cotton and groundnut cultivation only (Plate I). Therefore, a groundnut - cotton-fallow rotation is practised.

1.2: PURPOSE

The present study involved characterization of the morphological, physical and chemical features of the soil and detailed soil mapping.

The objective of this study is to provide the fundamental soil information that can be used by the Niger State Government in planning the management of the farm in particular and in general the larger Kontagora environment especially areas underlain by the Nupe sandstones. A proper farm management is the building block for a sound land use planning (Ojanuga, 1977). A sound land use planning is the only sure means of sustaining the development of any Nation's agriculture. It provides the means of deriving the maximum benefits from land resources while at the same time conserving the same for future generations.

1.3: PREVIOUS WORK

The soils of the area had been classified according to d'Hoore's legend of soil Map of Africa (South of the Sahara) as Ferrallitic and according to the United States Department of Agriculture's soil classification (7th approximation) as Oxisols (Tomlinson, 1965). Valette (1973) in his study of the Mokwa - Kontagora - Kainji area reported that the soils are coarse - sand dominated well

drained, deep, red (2.5 YR cv 10R but rarely 5 YR) and non concretionary sandy clays between 64 and 152 cm. Plate II illustrates the depth of the soils.

Plate 1: Crops cultivated on the Farm



A : Groundnut



B: Cotton

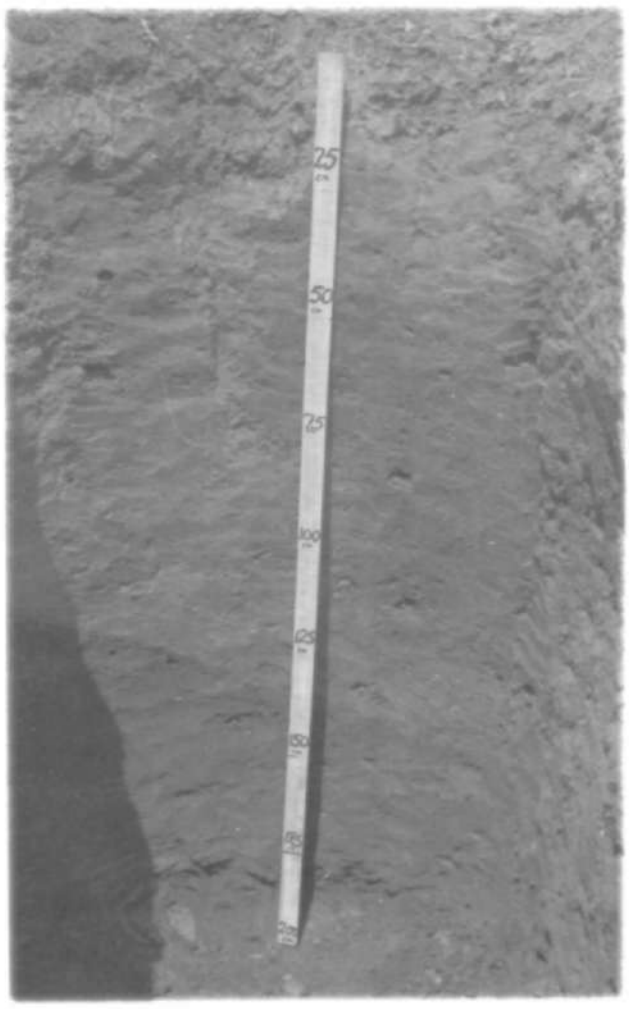


Plate II : Profile pit AN003

CHAPTER 2

GENERAL DESCRIPTION OF THE AREA

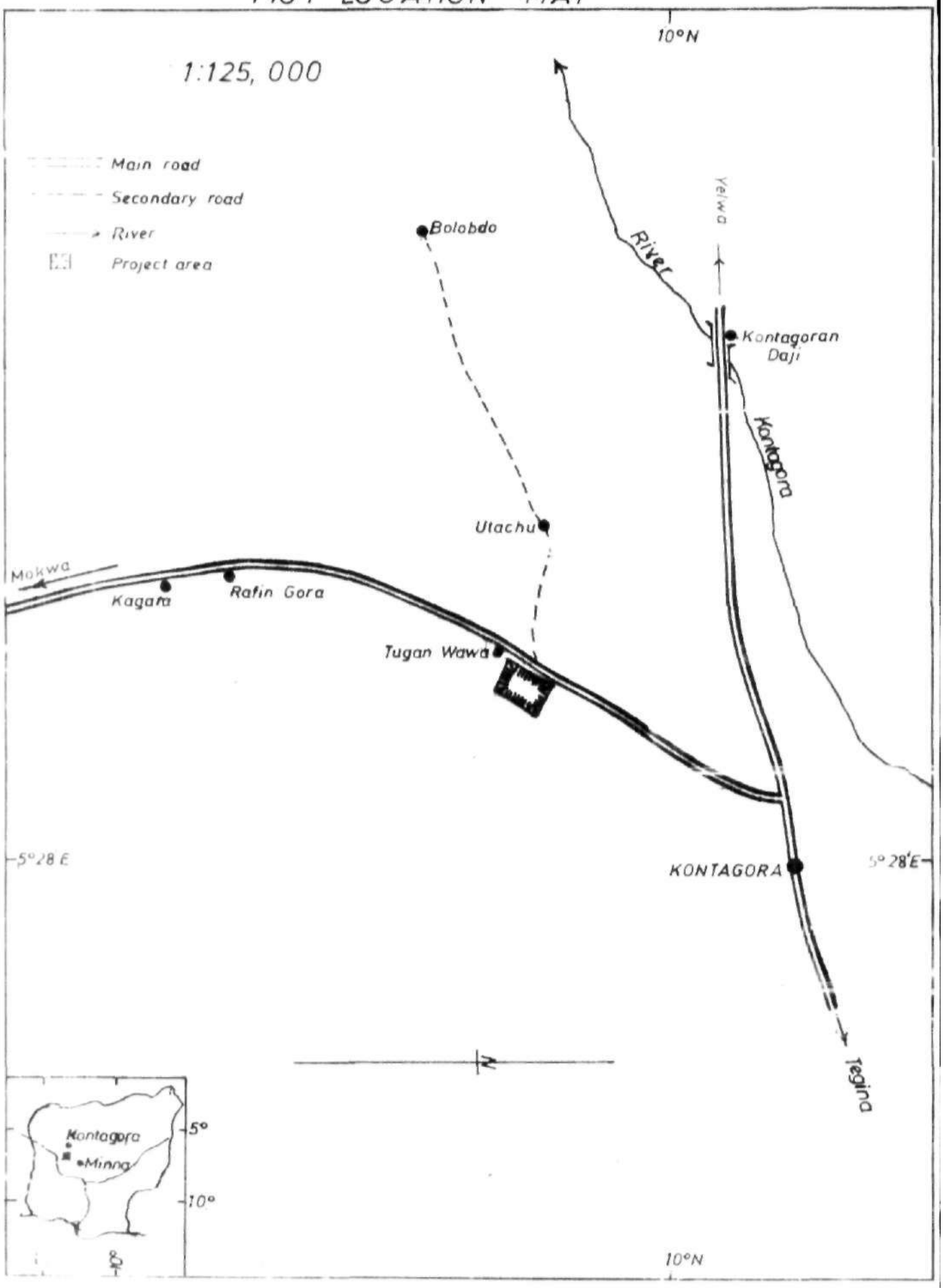
2.1: LOCATION AND EXTENT

The farm is located south of Kontagora (10.24°N and 05.28°E) along the Kontagora-Mokwa road at about 7.3 kms from the Kontagora-Mokwa and Kontagora-Yelwa roads junction (see Fig. 1). It lies north of Tungan Wawa (New) Village, hence it is locally referred to as the Tungan Wawa seed multiplication centre. The area is fenced and occupies about 120 hectares.

2.2: GEOLOGY

An imaginary Kontagora - Auna line (Fig. 2) forms a boundary between the central basement complex (McCurry, 1976) to the north and the sediments of the middle Niger basin to the south. Hence, the study area is situated within the middle Niger Basin. The geology of the Basin has been described by various workers, notably Faconer (1911), Tattam (1943), Adeleye (1976) and Ojo and Ajakaiye (1976). The basin covers an extensive tract of country extending southwards from Kontagora to Mokwa and Bida further along the Niger valley. It is underlain by sedimentary rocks which were named Lokoja series (Falconer 1911). These sediments do not show traces of a marine series, trace of limestone or of carbonaceous or calcareous shales suggesting a shallow water accummulation. These unfossiliferous sediments were later referred to as Nupe Sandstones (Russ, 1930) and Falconer's Lokoja series was dropped. These sandstones have recently been renamed Nupe groups (Adeleye and Dessauvagie, 1972).

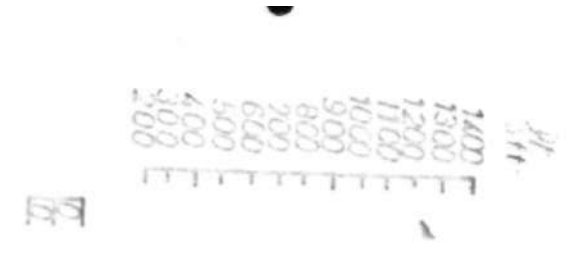
FIG 1 LOCATION MAP



Falconer (1911) and Russ (1930) considered the sandstones to be of Eocene age. Tattam (1943) described the beds at Lokoja as unconformably underlying the coal measures in Dekina destrict and concluded that the sandstones of the Niger basin north of Lokoja were of upper Senonian age. The sediments of the northern part of the basin have been described as a southward continuation of the Illo Formation which Jones (1948) ascribed to the Cenomanian or older period. However, it has now been generally accepted that the Nupe Sandstones (Nupe groups) are of Cretaceous period (Adeleye and Dessauvagie, 1972; Ojo and Ajakaiye, 1976).

The stratigraphy and sedimentation of the Nupe Sandstones have been described by Adeleye (1976), Falconer (1911), Klinkenberg (1965), Pullan and de Leeuw (1964) and Velette (1973) as consisting of coarse basal sediments directly overlying Precambrian to Paleozoic Basement Complex. As shown in Fig. 3, the basal materials underlie fine sediments which are in turn overlain by post cretaceous ironstones. Also lenses of interbedded silts and clays occur within the formation (Higgins et al, 1960).

The fine surface sediments are removed locally by major streams and subsequently expose the basal materials. The basal sediments consist of partly consolidated, rounded to sub-rounded coarse conglomerates, clay-sand-pebble admixtures and cross-stratified sandstones (Adeleye, 1976). Locally, scattered pebbles, cobbles and boulders occur within the basal sediments. Ogunwale (1973) described the



basal sediments as a conglomerate of well rounded quartz pebbles in a matrix of white clay. Arkoses and feldspathic sandstones are common (Adeleye, 1976). The fine materials are mainly fine grained quartzose sandstones with subsidiary claystones, fine conglomerates and siltstones.

Much of the thin, not more than 50m thick, ironstone capping which is believed to be partly of sedimentary origin and partly lateritic that occurred over the sandstones has been eroded by tertiaty earth movements (Ojo and Ajakaiye, 1976). Presently the remains of the cappings are found on flat - topped ironstone-capped hills. The Nupe Sandstones find their highest elevations in these hills which are believed to be reminants of the older surfaces (Kowal and Knabe, 1972). Most often these are associated with the fine sandstones, though strips of coarse grained conglomeratic sandstones, still partially capped by ironstone measas and their degraded forms occur along the border with Basement Complex (Valette, 1973). The ironstones are oolitic and pisolitic (Adeleye, 1976; Reyment, 1965).

2.3: GEOMORPHOLOGY

The topography of the middle Niger basin is largely determined locally by the texture of the Nupe Sandstones. Areas underlain by coarse-textured sandstones are relatively flat to undulating and have less dissected appearance than those underlain by fine-textured sandstones. The study area, underlain by coarse-textured sandstones, is relatively flat to undulating with flat topped ironstone-capped hills breaking the monotony of the landscape (Reyment, 1965). The

area shows little dissection due to widely spaced stream systems. The farm falls within the basin of the Deri river which drains south and east of Kontagora into the Kaduna river. The Kontagora town itself if located on the watershed between this basin and the catchment areas of two other rivers (Maxlock Goup Nigeria Limited, 1980). The Kontagora river which drains south-west and flows into river Niger just above the Kainji dam, and the Malendo river system about 10 km north of the town drains to the Niger river near Yelwa at the northern end of the Kainji reservoir. Tributaries to the main stream are well developed in areas underlain by the fine-textured sandstones. These are characterised by locally steep fluff flanked by 15m or more deep valleys. Landforms consisting of plains, mesas and flood plains are recognised in the basin.

The plains are flat-lying to gently rolling with conical or flat-topped residual hills occuring to break the monotony of the scenery (Adeleye, 1976). Many of such hills are common in the Mokwa - Bida - Zungeru - Kontagora area. The plains lie between 60-430 metres above sea level.

Mesas are recognised in the gently undulating to flat lying plains. These are flat topped or tabular surfaces usually rising few metres above the lower lying surfaces from which they are separated by distinct scarps. The mesas form a discontinuous belt which runs from east of Mokwa through areas south of Bida to Baro, Lokoja and south-west of Dekina (Adeleye, 1976). River Niger and its tributaries have irregularly dissected the mesas and many have been

transformed to more or less irregular or rounded hills with remnants of an old ironpan or ironstone rubble or both (Valette, 1973). However, some well preserved mesas are usually found associated with strongly dissected areas.

The flood plains of River Niger are broad and marked in most areas by series of elongated ponds running paralled to the river channel. The tributaries are also marked by fairly wide flood-plains (fadama).

From the account above, it is evident that the present landscape of the middle Niger basin which consists of level plains alternating with belts of dissected country descending towards River Niger has been formed by at least two major erosional cycles. Several hypotheses have been considered to explain the evolution of these surfaces. Pugh and King (1952) and Pugh (1956) have advanced the theory of pediplanation to explain the manner by which successive cycles might have been initiated. Briefly, they suggest that each change of base-line is accompanied by the formation of an almost level surface graded to the new base level pediplain. This is caused by escarpment retreatment into the raised block. A further uplift would give rise to a further scarp and a lower pediplain; the land eventually acquiring a steplike appearance. It should be borne in mind that the higher surface will remain substantially unaltered until obliterated by retreating scarp. Two erosion surfaces, the lower African erosion surface (365-609m) seen around Kontagora and the "Niger" surface (228-289m) which is extensive along the Niger Valley, have been recognised by Higgins and others (1960). Pullan and

de Leeuw (1964) and Vallette and Higgins (1967) reported the presence of the lower African surface from the Auna-Birnin Yauri area and north-east of Auna respectively. Valette (1973) reported the presence of a surface similar to the Niger surface from south of Soforami.

De Swardt (1946) proposed that the changing climatic conditions during the Tertiary period could be the major cause of the process of landscape evolution in the Kaduna valley. Briefly, he suggested that the formation of the ironcapped landscape took place during a humid climatic condition when rock weathering and soil formation were dominant. When the climate became progressively more arid, the weathered residues were dissected. This caused the formation of the present extensive undulating plains lying beneath the higher laterite-capped mesas occupying the crestal areas as remnants of the middle Tertiary peneplain surface. Another return of humid climate resulted in the incision of the lower lying surface creating valley sides. The floodplains were formed where the incision was severe. The period of aridity that followed caused the filling of the valleys with alluvial and colluvial materials. The onset of the present climatic era resulted in further rejuvanation with a resultant stream incision into the alluvium.

This theory could possibly be used to explain the evolution of the landscape of the middle Niger basin because de Swardt (1946) assumes that "the result obtained in the Kaduna valley might have more than a local application and

that some light may be thrown on the recent geomorphic history of the country as a whole".

2.4: CLIMATE

The climate of Kontagora and its environ and indeed the whole of the middle Niger basin has a marked seasonality owing to the alternation of two air masses moving over the area. These are the dry continental air mass (the harmattan) blowing from the north-east across the sahara desert and the rain-bearing south westerly air mass. The zone where the two air massess meet is referred to as the Inter Tropical Convergence Zone (ITCZ). The ITCZ which extends roughly east-west across West Africa migrates north and south being situated approximately $8^{o}N$ in January and $20^{o}N$ in July (Rackham and Rose-Innes, 1978). This movement of ITCZ influences the climatic pattern of Nigeria . Due to this movement, the length of the rainy season decreases from south to north and because the south westerly air mass loses moisture on it way inland, the rainfall decreases from the south and southwest to the northeast (Bawden and Jones, 1973). Consequently, the annual amount, the seasonal distribution and duration of rainfall are significantly correlated with latitude.

Kontagora lies in a transitional belt between the northern zone having a single peak rainfall regime and the southern zone with a consistent dual peak regime. Therefore, the pattern of rainfall regime is not quite constant. Three types of rainfall regimes have been recognised in the area (Pullan and de Leeuw, 1964). These types of regimes are:

Type a: a distinctive dual peak rainfall regime; the peaks normally occuring around July and September. August is never devoid of rain, but the contrast with the August fall in type b is great; occassionally a heavy rainfall in the month of May can give the impression of the presence of a triple peak regime;

Type b: A single peak rainfall regime with a steep decline after the maximum fall in August; and

Type c: There is no notable peak and the significant rainy period is longer than in other years with appreciable rainfall in April, May and October.

The climatic regime with a single rainfall peak and dry season of five months from early November until mid March is the most common in the study area. The mean annual rainfall is about 1222mm (Table 1) with lower and upper limits of 870mm and 1470mm respectively (Emirate Technical Services Limited, 1975). A close examination of the mean monthly rainfall destribution shows that the rains effectively begin in April and steadily increase to a maximum of 290mm in September and then virtually cease by the end of the month of October. Also there is a wide variation in the duration of the rains. Generally, if the rains begin late the amount of rainfall will also be less. According to Kowal and Knabe (1972) Kontagora lies to the south of 1143mm isohyet and the 21-30 April and 1-10 October isochrones of the start and end of rainy period respectively. Also the length of the rainy period is between 180 and 170 days.

TABLE 1: AVERAGE ANNUAL AND MONTHLY RAINFALL

(After Velette, 1973)

	MOKWA	KONTAGORA	YELWA
Latitude N	(09°18')	(10°25')	(10°53')
Longitude	(05°04')	(05°28')	(04°45')
Height 'in m	(152)	(396)	(149)
No. of years over which average was calculated	12	38	20
Average annual rainfall (mm)	1122.68	1221.74	1005.84
JAN.	3.30	5.33	0.25
FEB.	5.33	2.54	2.29
MAR.	28.19	17.02	8.36
APR.	91.19	54.36	19.81
MAY	132.08	107.19	119.38
JUN.	197.61	136.65	143.51
JUL.	170.18	228.60	231.39
AUG.	139.70	238.00	223.52
SEP.	243.59	290.07	244.60
OCT.	98.55	128.02	78.74
NOV.	7.87	11.68	0.00
DEC.	3.81	1.78	0.00

Temperature records for Kontagora are not available, however, there is a close similarity between the temperature regimes of Yelwa and Kontagora (Kowal and Knabe, 1972; Pullan and de Leeuw, 1964). Temperature records for Yelwa, Kaduna, Mokwa and Minna are given in Table 2. The mean maximum temperatures are highest during the dry season especially in February, March and April, and lowest in August, the time of greatest rainfall. The mean minimum temperature is highest in April at the on-set of rains and lowest in December and January at the height of the dry season when the ITCZ is approximately at 8^{o}N and the harmattan winds blow over the area north of the latitude. The mean minimum and maximum temperature ranges for Yelwa are 14.44 - 26.67^{o}C and 29.44 - 38.89^{o}C respectively. The corresponding figures for the other stations are 15.56 - 23.89^{o}C and 29.44-78^{o}C for Mokwa, 18.89-23.89^{o}C and 28.33-36.67^{o}C for Minna, and 14.44-22.22^{o}C and 29.22-25.55^{o}C for Kaduna.

Kontagora falls within the area served by the Yelwa synoptic and rainfall station, and considering the thiesson polygon of the annual pattern of evaporation and precipitation, the evaporation is less than precipitation during the period of 10th June to 10th October. The maximum monthly evaporation occurs in March. The study area is located south of the 1448mm potential evaporation line.

2.5: VEGETATION

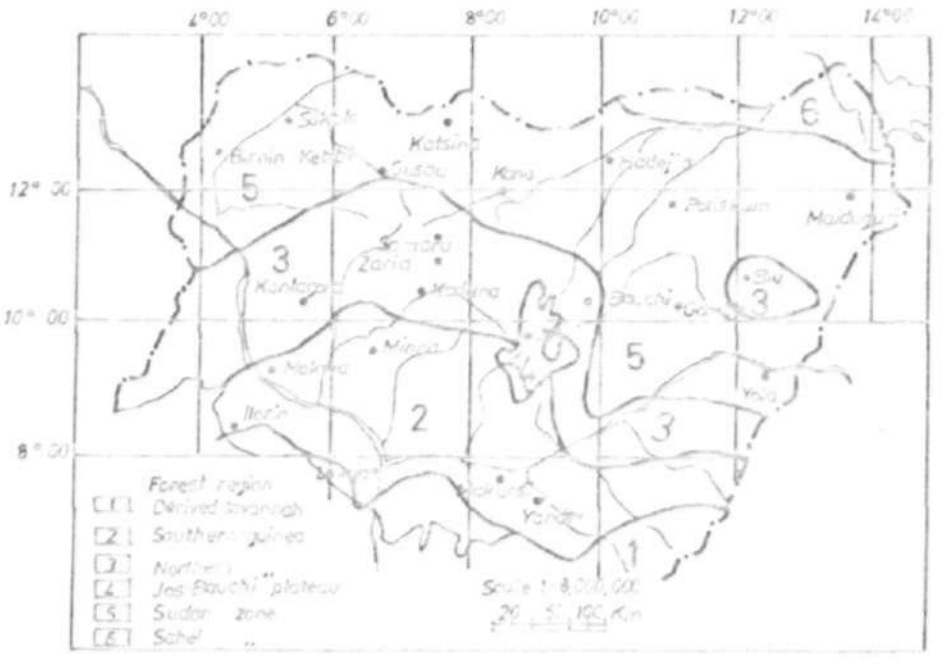
The middle Niger basin is broadly classified as southern and northern Guinea Savanna , but Kontagora environ falls within the Northern Guinea Savanna (Fig. 4) which is

TABLE 2: MONTHLY MEAN OF TEMPERATURES: MAXIMUM, MINIMUM, AND AIR TEMPERATURE IN DEGREE CENTIGRADE

(After Kowal and Knabe,1972)

S T A T I O N	TEMPERATURE	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
NOKWA	Mean Max.	34.8	37.2	37.6	35.8	33.7	31.5	30.2	29.5	30.3	32.1	34.1	34.3
Lat. 9° 18'	Mean Min.	15.6	19.0	23.3	24.1	23.3	22.1	21.7	21.7	21.4	21.2	18.2	15.8
	Air	25.2	28.1	30.4	29.9	28.5	26.8	26.9	25.5	25.8	26.6	26.2	25.1
MINNA	Mean Max.	34.3	36.4	36.9	34.8	32.5	30.2	29.0	28.4	29.6	31.4	34.2	34.8
Lat. 9° 37'	Lat. 9° 37'	19.9	22.2	24.1	24.4	23.3	22.2	21.8	21.7	21.3	21.3	19.2	19.1
	Air	27.1	29.3	30.5	29.6	27.9	26.2	25.4	25.1	25.5	26.3	26.7	26.9
KADUNA	Mean Max.	31.5	33.9	35.3	34.0	32.2	29.7	28.1	27.3	29.3	31.3	31.9	32.3
Lat. 10°36'	Mean Min.	14.9	17.4	20.6	22.0	21.4	20.1	19.7	19.6	19.3	18.6	15.2	14.3
	Air	23.2	25.6	27.0	28.0	26.8	24.9	23.9	23.4	24.3	24.9	23.6	23.3
YELWA	Mean Max.	35.8	37.9	39.0	37.9	35.2	32.6	30.7	29.7	30.6	32.8	35.5	35.7
Lat. 10°53'	Mean Min.	15.4	19.2	23.7	26.4	25.3	23.5	22.9	22.6	22.2	22.2	17.0	14.5
	Air	25.7	28.6	31.3	32.2	30.0	28.0	26.2	26.1	26.4	27.5	26.2	25.0

Fig 4 NORTHERN NIGERIA VEGETATION ZONES



characterised by Savanna woodlands. The vegetation consists of communities ranging in physiognomy from 10 to 15 metres high in a well developed undisturbed woodland (Keay, 1959). Most of the trees are broad leaved and in places cast enough shade to supress grass growth especially where their crowns are more or less touching. However, grasses distinctly shorter than those in the wetter southern Guinea Savanna zone occur where the cannopy is open. Afzelia africana, Butyrospermum paradoxum, Isoberlinia doka, Detarium microcarpum, Terminalia avicennioides, and Monotes kerstingii are among the constant and common constituents. Also erect shrubs such as Gardenia spp and Protea elliolli are frequent but woody climbers are only locally present. The vegetation of the farm could be described as predominantly secondary shrub and parkland. The secondary communities form an intricate complex of several vegetation types representing farm regrowth in different stages of successional development. This is believed to develop as a result of differential fallow periods of shifting cultivation. This vegetation type is represented in parts of the farm left under fallow for a long period. However, parkland vegetation type replaces the secondary shrub vegetation type in the portion of the farm under contineous cultivation. Plate III illustrates the vegetation types in the study area.

Although the vegetation type of an area is largely an expression of the overall climatic control, their component species and sometimes their structure are modified by activities of man, fire and soil (Benette et al, 1978). The present vegetation of the study area has been greatly

modified by prolonged continous cultivation. Consequently, the Savanna woodland has been modified to parkland vegetation which has reverted to Savanna shrubland in the section of the farm left under long fallow periods.

2.6: PRESENT LAND USE

The project area is located in an area with abundant good agricultural land. This area is particularly sandy and pervious to water thus forming a good aquifer with an average depth of water-table of 46-91m (Kowal and Knabe, 1972). Access to this area is limited by scarcity of water and by poor communications. This fact, compounded by the terrible effect of the past slave raiding in the area, led to a very low population density of the area. However, the installation of wells in the villages along the Kontagora-Mokwa road has markedly increased the attractiveness of the area to farmers, and the population of the area has more than doubled within a period of eleven years; 1952-1963 (Valette, 1973). Use of manure for restoration of the fertility of the land after it has been under contineous cultivation for a few years is not possible due to the limited number of livestock kept in the area. Shifting cultivation, therefore, provides a reasonably satisfactory answer to the problems of declining fertility and soil erosion.

A communual land tenure system is practised in the area. Farmers are permitted to take up land for farming anywhere they choose unless it was previously cultivated by someone else. In which case permission of the last owner and/or of the village head is required before such piece of

land is cultivated by another person. Though land is neither bought nor sold, the individuals who have cleared virgin lands establish a right to its use for an indefinite period. Payment of compensation for clearing, crops grown and economic tress may be made if the land is allienated by Government.

Sorghum and early millet are the major food crops grown in the area. They are grown either as single crops or inter-cropped with cowpeas, groundnuts, cotton or maize. Rice production is confined mainly to the flood plains (fadams) along the streams; irrigated rice production is rarely practised in the area. Cotton and groundnuts are the major cash crops. Cassava, like cotton, is cultivated throughout the area, but cassava, unlike cotton, is cultivated as a mono-crop. Other crops being cultivated include vegetables, sweet potatoes, yams and late millet. Plates IV and VIA illustrate the kind of cropping pattern commonly practised in the study area.

Plate III: Vegetation Types of the study Area



A : Typical parkland vegetation



B : Typical secondary shrub vegetation

Plate IV : Land use



A: Guinea corn interplanted with cowpea



B : Early millet interplanted with groundnut

CHAPTER 3

LITERATURE REVIEW

3.1: SOIL FORMATION

3.1.1: CONCEPTS OF SOIL

Simonson (1959) gave a brief evolutionary trend of concepts of soil and subsequent theories advanced to explain its formation. Earlier soil scientists thought of soil as disintegrated rock mixed with some decaying organic matter. Considering this concept, weathering alone provides adequate explanation for soil formation. Later on, this idea was replaced by a concept which regarded soils more than weathered rock, and according to this concept, soils had profiles consisting of genetically related horizons. With this new concept, weathering alone was no longer adequate to explain soil formation. Consequently, soil formation was considered to be due to a combination of weathering and certain additional changes resulting from interactions between weathered rocks and living organisms. This view and many others have long been replaced also, however, the soil profile character remains important tough it has to share place with other features of the soil. The present concept regards soils as natural bodies formed on the land surface, occupying space and having a unique morphology (Simonson, 1957).

This geographical approach entails that soil is a three dimentional entity with length, breadth and depth. The surface of the earth where soil meets the atmosphere forms the upper boundary of the soil. This boundary is distinct

in contrast to the lower one where the soil grades into weathered rock or water. Rarely are individual bodies of soil set apart from their neighbours by sharp boundaries. The boundaries of adjacent individual soils are transitional and inter-grades are common. Thus the soils of the world from a contineous mantle over most of the land surface.

All these variation of individual soils notwithstanding all soils are alike in some ways. For instance, they are all three-phase systems (Brady 1974), all or nearly all consist of some major components; mineral materials, organic materials, water and air. Therefore, any theory which adequately explains soil formation must be consistant with similarities and differences known to exist among soils of the world, (Simonson, 1959).

3.1.2: SOIL FORMING PROCESSES

Studies of soils throughout the world have shown that soils form as a result of the combined effects of many processes. Even so, soil formation can be considered as consisting of two overlapping steps; mainly the accumulation of parent materials and the differentiation of horizons in the profile. Out of these two steps, the second is of more immediate concern to soil scientists. The process of soil formation that intimately effects the soil parent materials onto which it operates is not simple. It is a complex of or sequence of events, both complicated reactions and comparatively simple arrangement of matter. These events may take place simultaneously or in sequence to matually re-enforce or contradict each other (Rode, 1962). A specific

process may tend to change the soil or maintain it in its current condition.

Four basic kind of changes in the soil system, namely addition, removal; translocation and tranformation may be caused by the events (Simonson, 1959). Many substances comprising soil may be affected by any of these changes. For example, there may be additions, transformations, translocations and removal of carbonates, organic matter, sesquioxides, silicate clay minerals or soluble salts. All these changes effect horizon differentiation of most soil. However, the relative importance of each process operating in differentiating horizons is not uniform for all soils. Furthermore, the relative importance of the processes differ from one soil to another and may change with time. Also change in one or more of the processes may alter the relative importance among the processes. It would be noted that some processes are of little importance in a certain combination. This notwithstanding, the full chain of processes seems to leave its imprint on soil character in the long run (Simonson, 1959). Nonetheless and without any prejudice to the relative importance of each process in any given combination, the balance among the individual processes in the combination is the key to the nature of the soil. However, the relative importance of each process in the combination is reflected in the ultimate character of the soil itself.

3.1.3: SOIL FORMING FACTORS

Some simple processes and basic reactions that proceed

in the soil govern the variety of changes that take place during horizons differentiation. They include hydration, oxidation, leaching and precipitation. These processes in their turn, are controlled by factors such as climate, living organisms, parent materials, topography and time. These factors are the soil forming factors and knowledge of their relative importance is necessary to understand the processese operating in the soil (Jenny, 1941, and Brady, 1974). Climate determines the degree and nature of weathering. Considering the different aspects of climate, temperature and precipitation have greater influence in soil development. The rates of physical and chemical reactions that are essential for hotizons differentiation are governed to a great extent by temperature and precipitation. For instance, for every $10^{o}C$ rise in temperature, the rate of chemical reactions approximately doubles. The effect of climate on soil formation does not stop at the chemical and physical processes that take place within the soil, but it has great influence also on living organisms. "The bio-chemical changes by soil organisms are most sensitive to temperature as well as moisture" (Brady, 1974). Also, climate determines the natural vegetation. This way, climate controls the quantity of organic material developed in or returned to the soil and the activity of decay organisms. All these have bearing on the amount of organic matter in a soil. The influence of climate on relief and time though indirectly through erosion is quite obvious.

The nature of the parent material may greatly influence the characteristics of young and even oldest soils. Many properties of parent materials such as texture, mineralogical composition and degree of stratification greatly affect soil development (Miller, et. al., 1965). The mineral composition of soil parent material determines greatly the characteristics of the profile that developed. If parent material is composed mostly of minerals which weather slowly, there will be very little clay formation or clay accummulation in the B horizon. On the other hand, if the material contains minerals that weather easily, there will be much clay formation and some will accummulate in the B horizon. Even the type of clay mineral that develops is influenced by parent material. Soil development may be delayed where parent material is rich in lime. This is a reflection on the effect of the reaction of parent material on soil development. Acid condition encourages mineral decomposition, translocation of colloids and on overall development of the soil profile (Brady, 1974). The texture of the parent material influences soil development through its effect on soil permeability, soil organic matter content and soil solum thickness. For example, fine-textured material may enhance plant growth by providing greater water and nutrient supply. This results in a greater annual addition of organic matter to the soil. Also fine-textured materials tend to be less well aerated and consequently have slightly lower temperature, thus slowing down organic matter decomposition. These conditions favour organic matter accumulation.

There are several ways through which other soil forming factors affect soil development. Topography may modify soil development through its influence on the (i) quantity of precipitation obsorbed and retained in the soil, thereby affecting soil moisture relations (ii) rate of removal of soils by erosion, and (iii) movement of materials in suspension or solution from one place to another.

The major role of living organisms in soil development can not be over emphasized. Profile mixing, structural stability, organic matter accummulation and nutrient cycling, and reduction of natural erosion rates have all been possible due to the presence of living organisms. The actual length of time materials are exposed to various processes and reactions plays a significant role in soil formation.

In discussing the effects of soil forming factors on profile development, it is usually assumed that all other factors except the one being discussed are held constant. In reality, the interactions among these factors is too obvious to be ignored. Rarely does a single factor govern exclusively the kind of soil that develops. The time taken for a horizon to develop will undoubtedly be related to the parent material, the climate and the vegetation. There is a definate relation between vegetation effects and climate but a lesser difinite one between parent material and topography on one hand and the vegetation on the other. It is therefore easy to visualize the interdependence of these factors in determining the kind of soil that develops (Brady, 1974).

3.2: SOIL SURVEY

3.2.1: DEFINITION AND OBJECTIVE

Soil survey can be defined as the determination of the pattern of the soil and the division of this into relatively homogenous units. Also, it involves mapping of the distribution of these units and their characterization. The purpose of a soil survey is to study the characteristics of the soils and evaluate their potentialities to determine their suitabilities for the intended purpose. The accuracy with which the soil properties are mapped and the relevance of the properties to the intended purpose for which the soil survey was conducted determines the usefulness of the survey. Making a soil map is sometimes regarded as the purpose of soil survey. This concept creates an impression that the soil survey is an end in itself and thus, without due regard to the relevance of the determined soil properties and to the intended use. The usefulness of a soil survey is equated with the accuracy with which the soil properties are predicted. Soil survey is no more than an aid to making wise decisions about land use and management.

3.2.2: KINDS OF SOIL SURVEYS

Soil surveys can be made at various levels of intensity depending on the purposes and the prevailing field condition of the area to be surveyed. The differences between the various types of soil surveys are based on density of observation in the field and scale of the final map. The density of observations determines the details with which boundaries between mapping units are plotted in the field.

Soil surveys are described as exploratory, reconnaissance, and detailed (Soil Survey Staff, 1951). Exploratory soil soil surveys are made largely by drawing inferences and locating boundaries of mapping units after studying available maps and information concerning geology, relief, climate, vegetation and other factors. The boundaries are checked, if possible, by making traverses in the area. Exploratory surveys result in schematic maps and are used in nation wide surveys to show in a very schematic form the broad differences in soil conditions. The mapping scale of this kind of survey is 1:1,000,000 or smaller (Dent and Young, 1981).

A reconnaissance soil survey is used to identify the range of soils in a given area and to delineate the areas having potential for a given project for further investigation of the relationships among broad soil units. It is also used for collecting general data for land use potentiality. A reconnaissance soil survey is made by observing soils and soil boundaries along traverse lines through an area, then extending the boundaries of mapping units between traverses after studying available information and maps on geology, and aerial photographs. In essence only part of the course of the boundaries of the mapping units are actually observed in the field (Soil Survay Staff, 1951). A reconnaissance soil survey is relatively of very low intensity, though it is more detailed than an exploratory survey. The mapping scale ranges from 1:500,000 to 1: 120,000, however, 1:250,000 is the most

commonly used scale (Dent and Young, 1981).

Generally speaking, in a detailed soil survey, the soil boundary is plotted after observing the soil surface throughout the course of the boundary. A detailed soil survey serves in the operational planning for land development and forms the basis for planning soil management systems and determination of the possibility of soil improvements. It is the most intensive and is furhter subdivided into sub-classes according to the intensity of coverage. The sub-classes are as follows:-

(i) Low intensity

(ii) Medium intensity

(iii) High intensity.

In fact, many soil surveyers consider these subclasses of detailed soil survey to be different types of soil survey. In detailed soil surveys of high intensity (intensive) soils and geologic materials are examined to a depth of a few meters. Such soil survey is made where the land is to be used so intensively that all the significant soil areas need to be known (Steels, 1976). This type of soil survey may be made for development of irrigation projects or in areas where much of the land is to be used for housing. The scale of mapping is frequently 1:10,000 or larger. In detailed soil surveys of medium intensity the routine soil examination ends at a depth of about one meter or two meters. These are the most common kind in many countries. The scale of mapping ranges from 1:250,000 to 1:10,000. The detailed soil survey of low intensity, is

called a semi-detailed soil survey in many countries (Steele, 1976). The type of soil survey provides basic information of soil for land classification, planning of engineering, regional and town planning projects. Also, it can be used in arid regions for the purpose of planning grazing projects. Often a low intensity soil survey is used as a basis for planning for other levels of detailed soil survey of a project area. The mapping scale ranges from 1:100,000 to 1:30,000.

3.2.3: METHODS OF FIELD WORK

In soil survey, field work can be conducted by adapting either the traverse survey or the free survey methods. Traverse survey methods are of two types, the rigid grid and grid methods. In both methods, observations are made along evenly spaced paralled traverses cut at a specified angle to the baseline. However, in a rigid grid method, the soil observation points are at a specified interval along the traverses while in the grid method observation points along the traverses are not predetermined. Although traverse survey methods could be tedious and expensive, they are found to be more appropriate in areas where the vegetation cover is quite dense and the road network is not adequate and in areas for which aerial photograph or topographic maps are not available. (Dent and Young, 1981). A good feature of the traverse survey is that it requires less experienced staff than the free survey.

The free survey method is used in open terrain as in savanna regions. In this method the selection of soil

examination points is highly subjective. This type of survey demands that the surveyor has a sound understanding of the relationships between soils, landform, climate, geology and vegetation. Therefore, experienced soil surveyors prefer to use this method.

3.3: SOIL CLASSIFICATION

3.3.1: PURPOSE

A population consists of individuals that have many common properties, but with great variations. An individual has been defined as the smallest natural body that can be referred to as a thing complete in itself (Cline, 1967). Man is unable to see similarities and understand relationships among individuals in the disorderly arrangement in which he finds them. In an attempt to make the variation in order for his convenience, man groups individuals that are alike in selected characteristics. The grouping of individuals that are alike in selected properties and distinguished from all other individuals of the same population by differences in these properties is referred to as classification (Buol et. al., 1973). The purpose of classification is to organise our knowledge so that the properties of objects may be remembered and their relationships may be understood most easily for a specific objective (Cline, 1967). Therefore, soil classification is an arrangement of soils into groups according to their characteristics. General soil characteristics are used as the basis for broad groupings, while subdivisions are made

on the basis of more detailed differences in specified properties.

3.3.2: CLASSIFICATION SYSTEM

Soil classification systems have been developed to enable man to study soil comprehensively and to communicate in an orderly manner information about it. Different classification systems are in use in different countries. Most of these systems are based on the recognition of soils as natural entities possessing definite unique characteristics. Modern soil classification systems in USSR continued the general approach first outlined by Dokuchaev and his associates. They are all based on the genetic approach (Rozov and Ivnova, 1968). Five different categories of soil classification systems may be recognised in USSR. The systems may be based on the conditions of pedogenesis, the factors controlling pedogenesis, the character of pedogenetic processes, evolutionary stages in these processes or a single process, (Basinsk, 1967). The Russian soil classification systems are of little use outside the Soviet Union.

The French soil classification system has been used in many African countries especially the French speaking ones. The French system is hierarchial with classes subdivided into sub-classes, groups and sub-groups. On the whole there are ten classes. The degree of evoluation of the profile as reflected by horizon differentiation, hydromorphic conditions and kind of weathering as indicated

by the composition of the soil and humus type are the main features used in classifying at the highest category of the system (Buol et. al., 1973). The degree of physical translocation of clay particles is used in differentiating classes in the lower categories.

The British classification system described by Avery (1956) is also hierarchial. It has at its highest level a binary classification into hydromorphic and automorphic classes. Each of these classes is further subdivided into five groups with differentiating features based on soil moisture regimes and form or type of humus. Profile type (kind and arrangement of horizons) is used as the basis for dividing the groups into subgroups.

The soil classification system developed in the United States Soil Taxonomy (Soil Survey Staff, 1975) is another hierarchial system. Unlike the British system, this system has six categories which are, from the highest to the lowest levels, order, suborder, greatgroup, subgroup, family and series. Diagnostic horizons are the differenting characteristics employed in grouping soils into the highest category. The two stricking features of this system are

(i) Properties of soils as found in the field (properties which can be measured quantitatively) are used as the basis for identifying different classes, and

(ii) The nomenclature employed especially for the broader classification categories.

The FAO soil classification system is bicategorical with the higher class approximating to the great group level of Soil Taxonomy. Diagnostic horizons are the

differentiating features of the classes. Some of these diagnostic horizons were drawn from the criteria for diagnostic horizons of the United States classification and the others from other classification systems (Dudal, 1968a). The lower category is composed of soils with special horizons or features of note. Features, such as textural classes, stoniness, slope and presence of indurated layers, hardrock and salinity, important in the use and management of the soils are used to subdivide the lower categories into phases (Dudal, 1968b). Admittedly, this system is not a classification system but a map legend of the soil map of the world (FAO-UNESCO, 1974). It is therefore, to serve as a common denominator to other national classification systems, but is not intended to replace any.

Presently, there is no soil classification system developed specifically for Nigeria. Many systems had been used in the past in different parts of the country. However, for our present purposes, it has been agreed to adopt the United States soil classification system and the FAO-UNESCO map legend of the soil map of the world (Federal Department of Agriculture, 1965).

CHAPTER 4

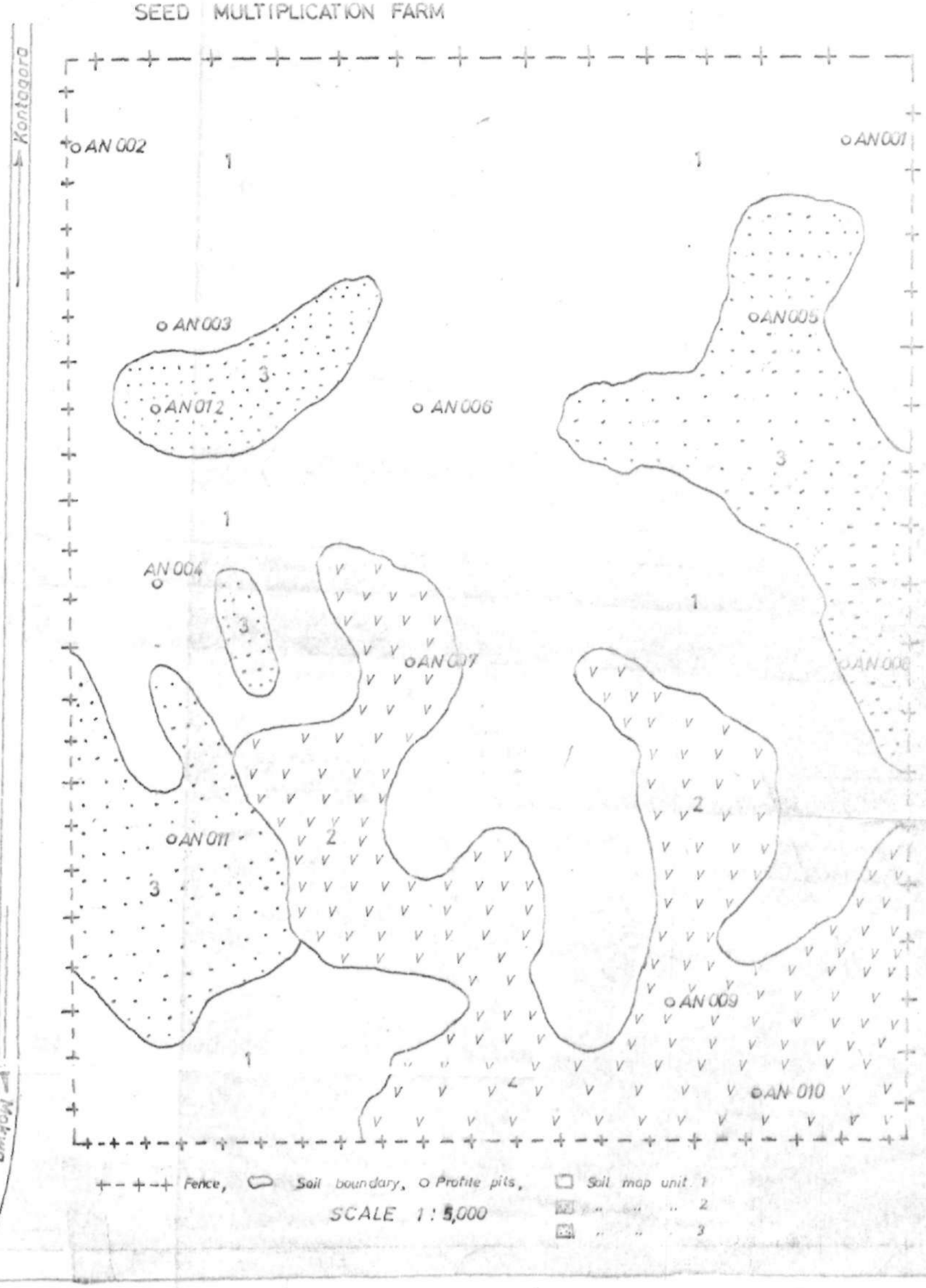
METHODS AND MATERIALS

4.1: FIELD STUDIES

For a general-purposes soil survey, like this project the soil are usually mapped and classified according to their morphological and chemical characteristics. Soil morphological characteristics can be observed on the field; thus field studies were conducted for morphological studies. As the area involved is relatively small and the main objectives of this soil survey is to map soil properties as accurately as possible, the rigid grid soil survey method was employed. Traverses running at right angles to the baseline, which was aligned paralled to the Kontagora-Mokwa road, were out at an interval of 100m across the farm. A total of 14 traverses covered the whole area. Soils were examined to a depth of 150cm at an interval of 100 m along the raverses. However, whenever soil pattern at two consective examination points differs, augering was done along the traverse between these two points to locate the soil boundary. Soil boundaries between traverses were similarly established. The auger points were plotted showing the different types of soil. Based on the soil patterns show on this map, the locations of soil profile pits were determined (Fig. 5). Profile pits 200 cm long, 100 cm wide and 200 cm deep were dug. A total of twelve profile pits were dug. Three to five profile pits were dug in each of the soils mapping units determined.

The profile pits were studied for morphological properties, such as soil structure, consistence, colour,

FIG 5 DETAILED SOIL SURVEY MAP OF THE STUDY AREA-KONTAGORA SEED MULTIPLICATION FARM



voids and horizon differentiation. Soil samples were later collected from all the identified horizons of each profile for laboratory physical and chemical characterization studies. The samples were properly labelled to indicate the location of profile pits and depth of horizons. The samples were taken to laboratory where they were air-dried for a week. The air dried samples were sieved with a 2mm sieve after having been crushed in a mortar to break up the clods. The soil, the fine earth fraction, that passed through the sieve was saved for laboratory analysis. No soil material was retained on the sieve.

4.2: LABORATORY STUDIES

Some physical and chemical properties of the fine earth material were measured in the laboratory. Particle size distribution, organic matter content, total nitrogen content, cation exchange capacity (CEC), exchangeable bases, total free iron and pH (soil reaction) were determined.

4.2.1: Particle Size Analysis

Particle size analysis was carried out as described by Day (1965). One hundred millilitres of 5% Calgon (Sodium hexametaphosphate) solution and 300 ml of distilled water were added to 50 gm of soil material contained in a beaker. The mixture was allowed to stand for 10 minutes after which it was transferred to a baffled cup of an electric stirrer. The mixture was electrically stirred for five minutes. The suspension was transferred to a 1000 ml sedimentation cylinder, brought to volume with distilled water and mixed

thoroughly. A blank suspension containing no soil material was also prepared.

A hydrometer was carefully lowered into the cylinder and a reading was taken after 30 seconds, and without removing the hydrometer another reading was taken at the end of one minute. Henceforward readings were taken at progressive time intervals of 3 minutes, 10 minutes, 1½ hours, 4½ hours, 12 hours and 24 hours without remixing the suspension but with the hydrometer carefully removed after each reading.

The sand fraction was fractionated by wet sieving through a set of sieves with openings of 100 um, 250 um and 500 um. The sand subfraction retained on each sieve was oven dried at 105°C for 24 hours after being thoroughly washed with water. The subfractions were then weighed and their percentages calculated. The percentage composition of the suspended materials was computed from the hydrometer readings. These percentages were plotted against corresponding sizes on a semi-log paper. The resulting graph permits determination of the proportions of sand, silt and clay fractions.

4.2.2: Organic Matter

Organic carbon determination is frequently used as the basis for organic matter estimation. This is because of all the elements of soil organic matter, carbon is the most readily quantitatively measured element.

Organic carbon was determined by acid dichromate digestion methods as described by Walkley-Black (1965).

Two grams of soil materials were weighed into a 250 ml Erlenmeyer flask and then 10 ml of 1N $K_2 Cr_2 O_7$ (Potassium dichromate) were added and the mixture properly swirled to bring the soil materials into suspension. Twenty millilitres of concentrated sulphuric acid ($H_2 SO_4$) were rapidly added and the flask was swirled again to ensure thorough mixing of the reagents. The flask and its content were allowed to stand for 30 minutes. Than 100 ml of distilled water were added and the mixture filtered into another Erlenmeyer flask. Ten millimitres of orthophophoric acid and 3 drops of orthophenantholine - ferrous complex indicator were added before titrating with 0.5 N ammonium ferrous sulphate. To standardize the potassium dichromate solution, a blank containing all the reagents was prepared and titrated as above.

The percentage organic carbon was calculated using the volume of ammonium ferrous sulphate used.

4.2.3: Total Nitrogen

Total nitrogen was determined by a modified semimicro Kjeldahl method (Soil Conservation Service, 1972). Ten millilitres of distilled water were added to 2 gm of soil material in a 500 ml Kjeldahl digestion flask and allowed to stand for 30 minutes. Three grams of Kjeldahl catalyst mixture, 15 ml of concentrated sulphuric acid and few glass chips were added to the flask before digestion. The content of the flask was digested for at least an hour to ensure complete digestion. The flask was allowed to cool to room temperature before 100 ml of distilled water and 75 ml of

approximately 10N NaOH were added. Antifoam, 3 chips of granular zinc, was added to the content of the Kjeldahl flask before the commencement of distillation. The flask was then connected to the distillation apparatus and about 100 ml of the content was distilled into a 250 ml Erlemeyer flask containing 30 ml of 2% boric acid. The content of the Erlenmeyer flask was titrated with 0.025N H_2SO_4. Mixed indicator was used for this titration.

Total nitrogen was calculated from the volume of sulphuric acid used, using the formula:

$$\text{Total Nitrogen} = \frac{\text{Volume of } H_2SO_4 \times \text{Conc. of } H_2SO_4}{\text{Weight of soil material}} \times 1.4$$

4.2.4: Exchangeable Bases

The exchangeable bases (Ca, Mg, K and Na) were extracted with 1N. NH_4OAc at pH 7 as discribed below (Peech et al, 1947: Yuen and Polland, 1952).

Ten grams of air-dried soil material were weighed into a 250 ml Erlenmeyer flask and 50 ml of NH_4 OAc solution added. The mixture was shaken and allowed to stand overnight. The suspension was then filtered through a moist Whatman No. 42 filter paper. The soil

was leached with more NH_4 OAc solution. The leachate was brought to volume with more NH_4 OAc solution.

The leachate was used for the determination of calcium, magnesium, potassium and sodium. Five millilitres of the leachate was pipetted into a plastic bottle and diluted five or ten times before calcium and magnesium were determined using a Perkin Elmer atomic absorption spectrophotometer model 290B. However, potassium and sodium were read using EEL flame photometer without any dilution.

4.2.5: Cation-Exchange Capacity

The ammonium - saturated soil material and filter paper used in Section 4.2.4: were thoroughly washed with 95 percent methylated spirit and then transferred to a Kjeldahl flask in preparation for distillation as described by Peech et al (1947). Three hundred millilitres of distilled water, 10 ml of NaCl, 5 drops of antifoam mixture and 30 ml 1N NaOH were added to the flask and its contents. The Kjeldahl flask with its content was connected to a distiller and 200 ml of its content distilled into a conical flask containing 50 ml of 4% H_3BO_3 solution.

The content of the conical flask was titrated to an end point with 0.2N HCl using 10 drops of mixed indicator (methylred methylene blue and bromocresol green). The volume of the HCl used was noted and CEC in milligram equivalent per hundred grams soil (meq/100 g soil) was calculated from the following formula:-

$$\text{CEC (meq/100 g soil)} = \text{Volume of HCl} \times \text{concentration of HCl} \times \frac{100}{\text{Weight of soil material}}$$

Also, CEC in meq/100 g clay was calculated from CEC meq/100g soil and percent clay content of the soil material. The formula used for this calculation is given below;

$$\text{CEC meq/100 g clay} = \frac{\text{CEC meq/100 g soil}}{\% \text{ clay}} \times 100$$

The base saturation percentages (BS %) was calculated with the aid of the formula:

$$\text{BS (\%)} = \frac{\text{Sum of the Bases}}{\text{CEC meq/100g soil.}} \times 100$$

4.2.6: Soil pH

The soil pH was determined in a 1:1 soil to water paste and 1:2 soil to 0.01 M $CaCl_2$ suspension.. For the 1:1 soil to water dilution, 20 gm of soil material was weighed into a beaker and 20 ml of distilled water added. The mixture was thoroughly stirred for some minutes, and then intermitently for one hour. The pH of the paste was then measured using a glass electrode pH-meter Kent model 7010.

For the 1:2 soil to $CaCl_2$ suspension the same produce

as described above was used except that 40 ml of 0.01m $CaCl_2$ was used. (Peech, 1965; Schefield and Taylor, 1955).

4.2.7: Total Free Oxide

Total free iron oxide was determined by the sodium-citrate-bicarbonate dithionite extraction (CBD) method adapted by Ibanga (1980) from Mehra and Jackson (1960). The soil material was further ground and sieved with 0.21 mm sieved. One gram of this very fine soil material was weighed into a 75 ml centrifuge tube and 45 ml of sodium - citrate-bicarbonate buffer was measured into the tube. The centrifuge tube was brought to a temperature of about 80°C in a water bath and 1 gm of sodium dithionite ($Na_2S_2O_4$) powder was added and mixed thoroughly and constantly for one minute and intermitently till the iron extraction was completed; that is when the soil sample turns greyish or whitish.

The centrifuge tube was removed from the water bath and centrifuged at 1800 r.p.m. for 5 minutes. The supernatant solution was decanted into a 100 ml volumetric flask. The precipitate in the centrifuge tube was then washed with another 45 ml of the sodium-bicarbenate-sodium-citrate solution and centrifuged. The supernatant solution was decanted into the volumetric flask and brought to volume with distilled water. Five millilitres of the supernatant solution was pipetted into a container and diluted 10 or 20 times before iron was read using Perking Elmer atomic absorption spectrophotmeter model 290 B.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1: GENERAL

The parent material of the soils is residual material derived from the weathering of Nupe sandstones which are coarse-textured (Valette, 1973). Fine to coarse sand ratio of the soils ranges from 0.49 to 1.74. The soil profiles do not exhibit any evidence of weatherable minerals, however, coarse quartz particles are present throughout the depth of all the profiles. The morphological, chemical and physical characteristics of the soils are considered below.

5;2: SOIL MORPHOLOGICAL CHARACTERISTICS:

For better appreciation of the parent material and the soil morphological characteristics, the description of the different kinds of soils identified in the field is given below. Three soil mapping units were identified in the study area. The description of the units follows:

5;2.1: Soil Mapping Unit 1

Members of this unit are well-drained, deep, non-concretionary soils. The surface horizons are dominantly reddish brown (5YR 4/3, moist) and dark reddish gray (5YR 5/2, moist). At deeper depths the colour changes to red (2.5 YR 4/8, 10R 4/6, and 10R 4/8, moist).

The soils have B horizons of sandy clay loam to clay loam textures while the texture of the surface horizons ranges from sand to sandy loam. The soils are generally sandy in texture within 20 cm of the surface and exhibit

moderate to stong structural development. A representative profile of the soils (profile AN 003) is described below:-

Profile AN 003

Classification: Typic Haplustult

Geology: Sedimentary Rock (Nupe Sandstone)

Parent Material: Residual material.

Vegetation/Land Use: Guinea Corn Cultivated on ridges across the slope.

Drainage: Well drained.

Depth to water-table: Not encountered.

Depth to any inpenetrable layer: Not encountered

Horizon	Depth	Description
Ap	0 - 15 cm	Reddish brown (5YR 4/4, moist) sand; weak medium subangular blocky structure; soft dry, very friable moist, non-sticky non-plastic wet; many fine to coarse roots; gradual smooth boundary.
A3	15 - 33 cm	Yellowish red (5YR 4/6, moist) sand; weak fine to medium sub-angular blocky structure; soft dry, very friable moist, non-sticky and non-plastic wet; occasional fine and medium rootsp few fine vertical cracks; abrupt smooth boundary.
B1	33 - 86 cm	Red (2.5YR 4/8, moist) sandy loam; strong, medium and coarse sub-angular

Horizon	Depth	Description
		blocky; firm moist, sticky and plastic wet; occasional fine to coarse roots; many fine to medium vertical cracks; diffuse slightly wavy boundary.
B21t	125 - 152 cm	Red (10R 4/8, moist) sandy clay; strong medium and coarse subangular blocky structure; firm moist, sticky and plastic wet; occasional fine and medium roots; common fine and medium vertical cracks, common fine horizontal tubular pores with shiny surfaces, and termite therin; diffuse slightly wavy boundary.
B22t	125-152 cm	Red (10R 4/8, moist) sandy clay; strong fine to coarse subangular blocky structure; firm moist, sticky and plastic wet; occasional fine to medium roots; common fine and medium vertical cracks; common fine and medium horizontal tubular pores with shiny surface and white termite therein; diffuse slightly wavy boundary.
B23	152 - 200 cm	Red (10R 4/8, moist) sandy clay; strong medium to coarse subangular blocky structure; firm moist, sticky

Horizon	Depth	Description
		and plastic wet; occasional fine and medium roots; common fine and medium horizontal tubular pores with shiny surfaces and termite therein.

5.2.2: Soil Mapping Unit 2

Soil of unit 2 are unmottled, deep, and without iron concretions. The colour of the soils ranges from reddish brown (5YR 4/4, moist) in the surface horizons to red (2.5 YR 4/6, 10R 4/6 and 10R 4/8, moist) in the sub-soils.

The soils are predominantly sand in the surface horizons and differ from those of unit 1 by the thickness of the sandy surface horizons which is at least 50 cm in the soils of unit 2. The subsurface horizons are sandy clay loam to sandy clay. They exhibit a well developed moderate to strong subangular blocky structure.

They also have textural B horizons with peds having shiny surfaces; a characteristics they share with the soils of unit 1. These features are not necessarily clay skins (Velette 1973). Though soils of both units have an argillic horizon, clay skins are not common in the soils except in tubular terminite pores. A description of profile AN 009, a typical member of the unit, is presented below:-

Profile AN 009

Classification: Arenic Haplustults

Geology: Sedimentary Rock (Nupe Sandstone).

Parent material; Residual material.

Vegetation/Landuse: Terminalia SPP, Combretum Spp, Butyrospermum Spp, Isobelinia doka and tall grassess.

Drainage: Well drained

Depth to water-table: Not encountered.

Depth to impenetrable layer: Note encountered

Horizon	Depth	Description
A1	0 - 21 cm	Reddish brown (5YR 4/4, moist)sand; moderate fine and medium platy structure; loose dry, loose moist, non-sticky and non-plastic wet; many fine and medium roots; many horizontal tubular pores; clear smooth boundary.
B1	21 - 55 cm	Red (2.5YR 4/6, moist) loamy sand; moderate medium and fine subangular blocky structure; loose moist, non-sticky and non-plastic wet; occasional fine to coarse roots; few medium vertical cracks; many fine to coarse horizontal tubular pores; clear smooth boundary.
B21t	55 - 75 cm	Red (2.5YR 5/8, moist) sandy clay loam; strong medium to coarse subangular blocky; firm moist, sticky and plastic wet; occasional fine to coarse roots; many medium vertical

Horizon	Depth	Description
		cracks; many fine horizontal tubular pore with shiny surfaces, clear smooth boundary.
B22t	75 - 104 cm	Red (10R 4/8, moist) sandy clay loam; strong fine to medium subangular blocky structure; firm moist, sticky and plastic wet; occasional fine to coarse roots; many medium vertical cracks; many horizontal tubular pores with termites; gradual smooth boundary.
B23t	104 - 180 cm	Red (10R 4/6 moist) sandy clay; strong fine and medium subangular blocky structure; very firm moist, very sticky and very plastic wet; occasional fine and medium roots; many fine horizontal tubular pores with shiny surfaces, and termites; many fine horizontal interstitial pores; gradul smooth boundary.
B24	180 - 200 cm	Red (10R 4/8, moist) sandy clay loam; strong fine and medium subangular blocky structure; firm moist, sticky and plastic wet; occasional fine roots; few fine horizontal interstitial pores.

5.2.3: Soil Mapping Unit 3

Members of this unit are also deep well-drained soils without iron concretions. The surface horizons of these soils are dark reddish brown (5YR 3/4, moist). However, the sub-surface horizons are red (2.5YR 4/6 10R 4/6 and 10R 4/8, moist) to week red (10R 4/4; moist).

The soils have a well expressed subangular blocky structure. They have a well developed argillic horizon and are sandy loam, clay loam and sandy clay in texture. Presence of clay skin on aggregates is common in the soils of the unit. The texture of the A horizon is sand to sandy loam.

The soils of this unit differ from the soils of the other units by having surface horizons that have a colour value, moist, less than 4.

A representative profile, profile AN 005, is described hereunder:-

Profile AN 005

Classification: Typic Rhodustult

Geology: Sedimentary Rock (Nupe Sandstone).

Parent material: Residual material

Vegetation/Landuse: Terminalia Spp. Combretum Spp, Butyrospermum Spp. Parkia Spp and weeds.

Drainage: Well drained

Depth to water-table; Not encountered

Depth to impenetrable layer; Not encountered

Horizon	Depth	Description
A1	0 - 11 cm	Dark reddish brown (5YR 3/3, moist) sand; weak fine and medium subangular blocky structure; loose dry; loose moist, non-sticky and non-plastic wet, occasional fine to coarse roots; clear smooth boundary.
A3	11 - 33 cm	Yellowish red (5YR 4/6, moist) sandy loam; moderate medium subangular blocky structure; soft dry, very friable moist, slightly plastic wet; occasional fine to coarse roots; few fine channels of dead roots; clear smooth boundary.
B21t	33 - 55 cm	Red (2.5YR 4/6, moist) sandy clay loam; strong medium and coarse platy structure; firm moist, sticky and plastic wet; occasional medium roots; few fine vertical cracks; clear smooth boundary.
B22t	55 - 95 cm	Weak red (10R 4/4, moist) sandy clay; strong medium subangular blocky structure; very firm moist, very sticky and very plastic wet; many fine roots; few coarse hozirontal tubular pores with termites; many medium vertical

Horizon	Depth	Description
		cracks; clear smooth boundary.
B23t	95 - 136 cm	Red (10R 4/6, moist) sandy clay; strong coarse platy structure; very firm moist; very sticky and plastic wet; occasional fine roots; peds with clay skin; few medium vertical cracks; few fine horizontal tubular cracks with termites; clear smooth boundary.
B3	136 - 200 cm	Red (10R 4/8, moist) sandy clay loam; strong medium to coarse subangular blocky structure; firm moist, sticky and plastic wet; occasional fine roots; many fine vertical and horizontal cracks.

5.3. PHYSICAL CHARACTERISTICS

5.3.1: Textural Differentiation

Tables 3, 4 and 5 contain the results of the particle size analysis of all the profiles of soil mapping units 1, 2, and 3 respectively. The clay fraction increases with depth from 2% at the surface to about 50%. The silt content is generally low and almost constant with depth.

The sand fraction ranges between 50% and 90%, with the amount decreasing with depth. It is generally dominated by the coarse sand sub-fraction; with fine sand to coarse sand ratio between 0.48 and 1.76. Valette (1973) used the fine: coarse sand ratio to distinguish between fine sand and coarse sand dominated soils. He defined soils derived from coarse sandstone as having fine: coarse sand ratio of one or less and those derived from fine sandstone having ratio of 1.5 to 5. The highest and lowest amounts of the fine sand subfraction are 43 and 21% respectively; the corresponding figures for the coarse sand subfraction are 61 and 21%. Soils of units 1 and 2 have an average fine to coarse sand ratios of 0.79 and 0.76 respectively and the average for soils of unit 3 is 1. The depth of the sandy surface horizons is generally less than 40 cm in all the soils of units 1 and 3 except in profiles AN 001 of unit 1 and AN 009 of unit 3. The soils of unit 2 with possible exception of profile AN 007 have sandy surface horizons of more than 50 cm.

All the soil units have very low silt content that is almost uniform with depth. The silt content is less than

20% in all the soils. This contrasts with the high silt content of the loess soils of the neighbouring high plain of Hausaland in Samaru (Malgwi, 1979) which have as much as 54% silt content. This low silt content indicates a high degree of weathering (Steward et al, 1970) and/or lack of loess - derived materials in the study area (Awujoola, 1979; Harpstead, 1974).

Figure 6 illustrates the clay distribution of representative profile of the soil mapping units. The clay content of the A horizons is generally low, with a value ranging from 2 to 14%. Generally, the clay content increases from the surface to the underlying subsurface horizons with a maximum within the B horizons, and then decreases in the underlying deeper horizons. This pattern of clay distribution shows a true feature of soils with argillic horizons. However, only shiny surfaces not likely to be clay skins were observed in some profiles, especially such as profiles AN 005 and AN 012 of units 3 and on the termite channels in the soil profiles of the other units. Clay skin is not a prerequisite for argillic horizon in all soils (Nettleton et al, 1969).

The pattern of clay as described above is perhaps due to biogenetic sorting of soil materials; termite mounds (plate V) and termite channels in many profiles, evidences of termite activities, are commonly observed in the study area. Process of illuviation could be another contributing factor.

TABLE 3: PARTICLE SIZE DISTRIBUTION OF SOILS OF UNIT 1

Horizon	Depth (cm)	PARTICLE-SIZE ANALYSIS					Fine: Coarse Sand Ratio
		Gravel (>2000-µm)	Coarse Sand (2000-200,µm)	Fine Sand (200-50,µm)	Silt (50-2,µm)	Clay (<2,µm)	
			PROFILE AN 001				
A1	0 - 15	-	49	39	8	4	80
A3	15 - 49	-	43	43	6	8	1.00
B1	49 - 82	-	44	34	8	14	0.77
B21t	82 - 125	-	35	33	6	26	0.94
B22t	125 - 163	-	33	31	8	28	0.94
B3	163 - 200	-	41	39	6	14	0.95
			PROFILE AN 002				
A1	0 - 13	-	51	37	8	4	0.73
A3	13 - 40	-	52	34	6	8	0.65
B1	40 - 56	-	47	27	8	18	0.57
B21	56 - 96	-	39	25	6	30	0.64
B22	96 - 135	-	37	25	6	32	0.68
B3	135 - 200	-	31	25	8	36	0.81
			PROFILE AN 003				
A1	0 - 15	-	52	37	7	4	0.71
A2	15 - 33	-	49	39	9	3	0.80
B1	33 - 86	-	47	30	7	16	0.64
B21t	86 - 125	-	26	27	7	40	1.04
B22t	125 - 152	-	28	26	6	40	0.93
B23	152 - 200	-	31	25	6	38	0.81
			PROFILE AN 004				
Ap	0-- 18	-	60	30	7	3	0.50
A3	18 - 59	-	49	30	7	14	0.61
B21t	59 - 108	-	28	27	6	39	-.96
B22t	108 - 150	-	32	21	8	39	0.66
B23	150 - 200	-	32	27	6	35	0.84
			PROFILE AN 006				
Ap	0 - 20	-	57	35	6	2	0.61
A3	20 - 45	-	53	29	6	12	0.55
B21	45 - 79	-	35	25	6	34	0.71
B22	79 - 140	-	26	28	6	40	1.08
B23	140 - 200	-	24	28	8	40	1.17

TABLE 4: PARTICLE SIZE DISTRIBUTION OF SOILS OF UNIT 2

Horizon	Depth (cm)	PARTICLE-SIZE ANALYSIS					
		Gravel (>2000µm)	Coarse Sand (200-200,µm	Fine Sand (200-50,µm)	Silt (50-2 µm)	Clay (<2,um)	Fine: Coarse Sand Ratio
		PROFILE AN 007					
Ap	0 - 15	-	54	36	5	5	0.67
A3	15 - 49	-	43	37	8	12	0.86
B21t	49 - 69	-	28	31	8	33	1.11
B22t	69 - 103	-	29	28	10	33	0.97
B23	103 - 165	-	23	27	7	43	1.17
B24	165 - 200	-	23	27	10	40	1.17
		PROFILE AN 009					
A1	0 - 21	-	56	33	7	4	0.59
B1	21 - 55	-	59	29	6	6	0.49
B21t	55 - 75	-	45	26	8	21	0.58
B22t	75 - 104	-	34	28	5	33	0.82
B23t	104 - 180	-	30	26	5	39	0.87
B24	180 - 200	-	36	24	6	34	0.67
		PROFILE AN 010					
A1	0 - 24	-	61	29	7	3	0.48
B1	24 - 56	-	57	31	6	6	0.54
B21	56 - 76	-	48	26	6	20	0.54
B22	76 - 106	-	36	26	5	33	0.72
B23	106 - 149	-	37	23	6	34	0.62
B24	149 - 200	-	34	25	5	36	0.74

TABLE 5s PARTICLE SIZE DISTRIBUTION OF SOILS OF UNIT 3

Horizon	Depth (cm)	PAKTICLE-•SIZE Al . SIS					
		Gravel (?eoooнm)	GSoarse rid (200-200 ,*jxm)*	Fine Sand (200-	Silt (50-2, jim)	Clay (*2j	Fir. J Sa]
			•; AN 005				
A1	0 - 11	-	53	**35**	8	**U**	0.66
A3	11 - 33	—	1*7	30	15	8	0.6),
B21t	33 - **55**	-	37	29	9	25	0.78
B22t	***S5 - 3$***	-	26	31	7		1.19
B23t	95 - 136	-	26	27	7		1.01*
B3	136 -	-	***h3***	29	6	22	O.i
			PROFILE AN 008				
A1	**o - *2k***	-	51	**39**	7	3	0.76
B1	*2U - **hi***	-	**5>**	32	**5**	7	**..57**
B21	*hi* - **79**	-		1*6	**5**	22	1.7
B22	79 - 108	-	39	31	**5**		0.79
B23	108 - 114.2	-		33	8	3/	1.
33	11*2 - 200	-	27	27	7		1.0
		•	Oil				
Ap	0 - 17	*m*	*S6*	33	9	2	0 /
B1	17 - **3U**	-	***$5***		8	7	0.
B21t	*3U* -	-	***kh***	30	19	17	O.I
B22t	58 - 121	-	25		7	39	1.16
B3	121 - 200	-	26	31	9	3U	1.19
			. 012				
Ap	0 - 17	-	**I*o**	UO	10	10	1.0
B1	17 - 1+2	-	35	36	9	20	1.03
B21t	U2 - 77		25	27	8	UO	1.08
B22t	77 - 121*	-	20	30	2	U8	1.50
B23t	12U - 150	-	23	29	8	UO	1.26
B3	150 - 200	-	21	37	8	***3h***	1.76

Fig 6 Clay distribution with Depth for selected Soil Profiles

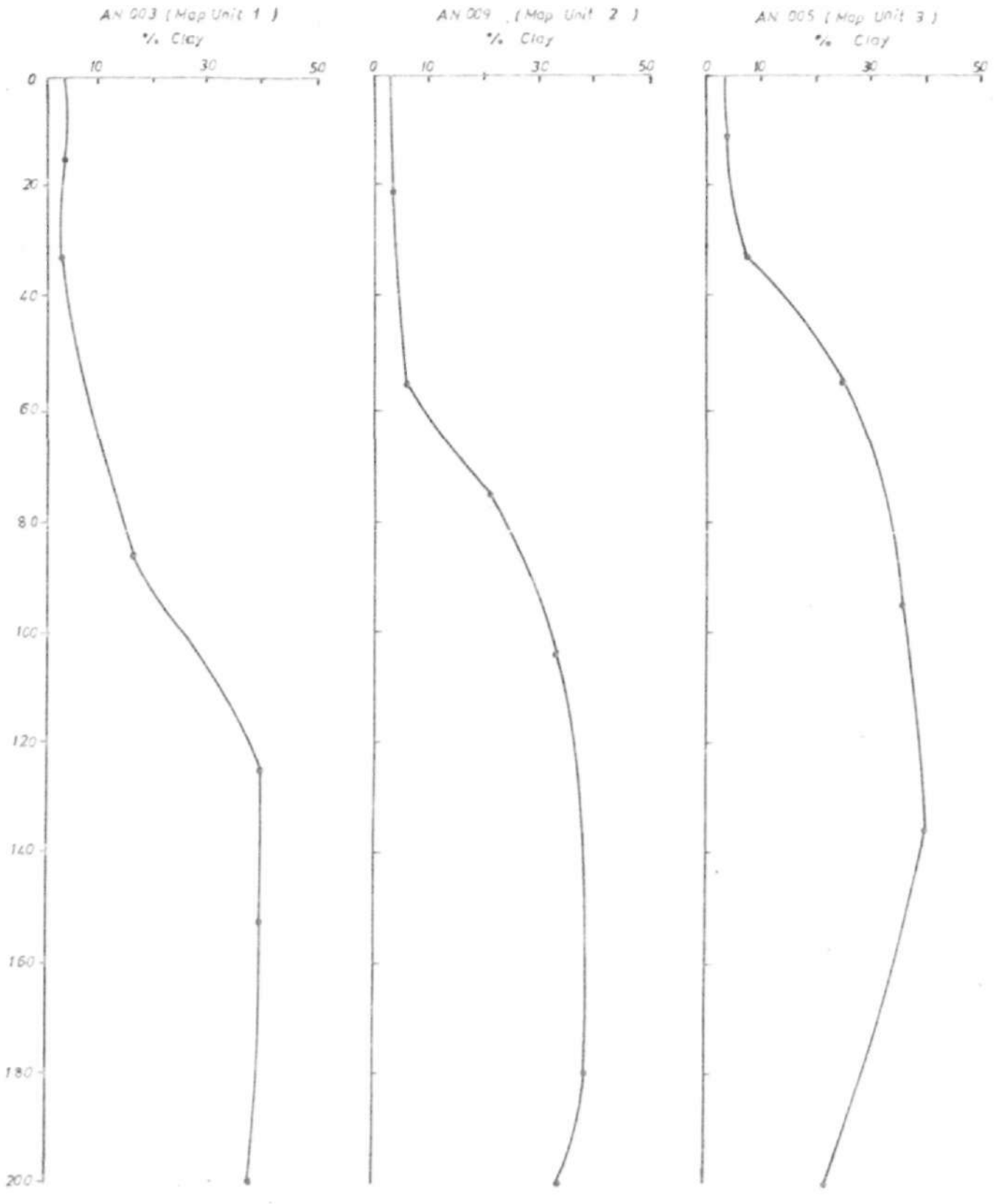




Plate V : Termite mound

5.3.2: Structural Development

The degree of structural development of the soils closely follows the pattern of textural differentiation. All the soils have a subangular blocky structure except in a few cases where platy or crumb structures were observed. The structural types are of various classes ranging from coarse to fine. The structural grade is generally weak to moderate in the A horizons . A maximum structural development is attained in the B horizons where the grade is strong.

The stability of soil aggregates is influenced mainly by climatic conditions, cultivation techniques, the humus content and mineral constituents of the soil (Baver et al, 1972). The distribution of the soils organic matter and the climatic conditions of the area, discussed in sections 5.4.1 and 2.4. respectively, are generally uniform. And the whole of the farm has been cultivated markedly in the recent past and a large part of it presently. Therefore, the increase in the structural development is mostly due to the pattern of clay distribution. The relatively high clay content and the low silt content of the subsurface horizons are the most likely factors contributing to good structural development in the B horizons (Heinonen, 1955; Ibadan, 1974).

The weak to moderate structure of the surface horizons of the soils imposes soil management problems to agriculturists. Such soil aggregates are liable to rapid break down at the onset of the rainy season due to the

impact of the rain drops and slaking in rain water. This may cause sealing of the surface soil which decreases water intake of the soil and increases run-off (Kowal, 1972).

5.3.3.: Soil Colour

The significant of soil colour is that it serves as an indirect measure of other important soil characteristics that are not so easily and accurately observed. Organic matter content, drainage condition, and aeration, for example, are soil characteristics related to soil colour. Generally, dark-coloured soils are relatively higher in organic matter than the light-coloured ones. Under imperfect to poor drainage conditions, soils are somehow mottled with different shades of brown, gray and yellow colours. Red and yellow colours are nearly always ascribed to hydrated and unhydrated iron oxides. But well developed red could be an indication that the soils are relatively old or at least have been subjected to relatively intensive weathering for considerable time (Soil Survery Staff, 1951). Consequently, soil colour is being used intensively for soil identification.

The colour of the soils of the study area is more variable in the surface horizons than in the subsoils. The colour of the surface soils varies from reddish brown (5YR 4/3 and 4/4, moist) and dark reddish brown (5YR 3/4, moist) to dark reddish gray (5YR 5/2, moist). While the surface soils of the map units 1 and 2 are generally reddish brown to dark reddish gray, most soils of the map

unit 3 exhibit dark reddish brown colour in the surface. The colour of the subsoils is generally red (2.5YR and 4/8 and 4/6, 10R 4/6 and 4/8, moist) and in few instances weak red (10 R 4/4, moist).

Although the organic matter distribution between the horizons does not differ greatly, the surface horizons are yet relatively darker in colour. This is because organic matter is the major colouring agent on the surface soils. However, the influence of organic matter on the colour of the subsurface horizons has been greatly masked by the clay colloids in the horizons. The red colour of these horizons could be related to the presence of unhydrated iron oxides. Hematite is likely to be the dominat iron mineral as asserted by Ibanga (1980) that light to dark red colour is associated with high hematite. Since unhydrated iron oxide is relatively unstable under moist conditions, red colour usually indicates good drainage and good aeration.

5.4. CHEMICAL CHARACTERISTICS

5.4.1. Organic Matter and Total Nitrogen

The organic carbon and nitrogen contents of the soils are shown in tables 9 to 11. All the soils contain low amounts of carbon and nitrogen, and their distribution with depth is almost constant. The organic carbon ranges from 0.3 to 1.0% with an average of 0.45%, and nitrogen ranges from 0.02 to 0.05% with an average of 0.03%. There is no appreciable difference in the status of organic matter and nitrogen of the soils of the three map units.

Savanna soils of tropical regions have characteristically low organic matter and nitrogen (Ahn, 1970). Organic matter status of a soil is closely related to the rate of return of organic residues to the soils and hence, the type of vegetation. But vegetation type is a function of factors such as rainfall, drainage, and human interference (Jones, 1973). The law annual rainfall of the area (table 1) does not support high annual production of organic material. Mineralisation of the small amount of the organic residues that is added to the soil is accelerated by the high temperature of the area (table 2) (Singh and Balasubramania, 1978). The degradative effect of cultivation on organic matter in tropical soils has long been appreciated and was fully discussed by Nye and Greenland (1960). They concluded that in addition to the return of low organic residues to the soil, chemical composition of tropical plants, perhaps, contributes to low organic status of tropical soils. Tropical plants contain more cellulose than lignin in comparison to the plants of temperate region (Tomlinson, 1962). Cellulose decomposes more rapidly than lignin. Furthermore, considering the coarseness of the soil materials, it is obvious that the soil will be sufficiently porous for easy movement of air in and out of the soil and its circulation within the soil. This, certainly, implies ample opportunity for rapid mineralization of organic matter. These factors collectively account for the low organic matter content of the soils.

The similarly of the amounts of organic carbon and nitrogen in both the surface and subsurface horizons, is probably due to biogenetic activities, such as termites, and ants (Robinson, 1936). In addition to the mixing of the soil, the tunnelling by termites and ants tends to accelerate mineralization of organic residues due to increased aeration (Kowal, 1972). Long history of annual bush burning in the area could also contribute to the low organic status of the the surface horizons.

The influence of organic matter on soil and crop has been fully discussed by Allison (1973). The low organic status of the soils will present management problems to the farmers. It has been mentioned that cultivation affects the amount of organic matter in a soil. When a virgin land is put under cultivation, organic matter losses are most rapid immediately and thereafter the rate of reduction is decreased and ultimately the organic content in the soil reaches a new equilibrium (Jones, 1971). Once the organic content has reached a low level, its restoration to its original level would require that the original vegetation be re-established (Foth and Turk, 1972). This is almost impossible as long as the land is being farmed. Therefore, frequent additions of small quantities of fresh organic materials so as to maintain the soil organic matter at a level consistent with good crop yields should be practised.

5.4.2: Soil Reaction (pH)

The values of pH in a 1:1 soil to water suspension of the soils of the study area range between 5.2 and 6.0,

indicating strong acid to neutral soil reactions (Soil Survay Staff, 1951). This range is in close agreement with the range (5 to 6.8) suggested By Foth and Turk (1972) as the pH of most agricultural soils in the tropics.

The pH values of all the soil profiles are given in tables 9 to 11. In general, the soils show relatively higher pH values (pH 5.8 - 7.0) in the A horizons than in B horizons. The pH values of the B horizons ranged between 5.2 and 7.0.

The soil pH values measured in 1:2 soil-calcium chloride suspension exhibit the same pattern as those measured in soil: water suspension, except that the former is consistently lower. The differences between the pH values determined by the two methods ranged between 0.5 and 1.4 pH units. This is accounted for by the fact that soluble cations in the salt solution displaced the acid hydrogen and the aluminium cations from the soil colloid surfaces and the subsequent hydrolysis of the released alluminium ions (Bohn, et al, 1979). The increase of hydrogen ions concentration caused the lower pH values of the soil solution. The low pH value in calcium chloride indicates that the soils possess low buffering properties (Uyovbisere, 1979).

The relatively lower pH values of the subsurface horizons is accounted for by the distribution of oxides of aluminium and iron, and silicate clay colloids which tend to accumulate in the lower horizons of the soils. The adsorbed hydrogen ion in the silicate clay colloids and the aluminium and iron oxides made contribution to the soil

solution hydrogen. The hydrogen ions thus released increased the acidity of the soil solution.

4.4.3: EXCHANGEABLE BASES

The results of exchangeable bases (Ca^{++}, Mg^{++}, K^{+} and Na^{+}) extraction from the soils are set out in tables 6 to 8. In all soils the degree of abundance of the basic cations is as follows: calcium, > magnesium, > sodium > potassium. Calcium ranges from 0.45 to 3.18 meq/100g soil; magnesium 0.25 to 1.52 meq/100g soil; sodium 0.06 to 0.83 meq/100g soil and potassium 0.05 to 0.5 meq/100g soil. If weighed against the exchangeable bases rating of Hills et al (1974), the base status of the soils is low to moderate, though they compare favourably, both in value and distribution, with soils of Samaru (Malgwi, 1979).

In most profiles the values of the exchangeable bases do not show any appreciable change with depth, except in some profiles such as AN 007 of soil unit 2 and AN 012 of soil unit 3 where the values of exchangeable calcium, magnesium and sodium increase appreciably with depth. The values for potassium are almost constant.

The amount and distribution of exchangeable bases are influenced by parent material of a soil and the extent of leaching. Considering the amount and distribution of the rainfall (table 1) and the potential evapotranspiration of the area, discussed in section 2.4, soil leaching is not likely to be very pronounced except during the short period when precipitation is more than evapotranspitation. This together with the recycling of bases by vegetation

could explain the distribution pattern of the bases. The amount of exchangeable base in the soils reflects their effeciency of replacement except sodium. The replaceability series of the bases is $Ca^{++} > Mg^{++} > K^{+} > Na$. Thus calcium which has higher replaceability suffers less losses than other bases. It has also been reported that in some soils the exchange sites show specific affinity for calcium (Beckett, 1965). The relatively low amount of potassium of the soils may be due to its low content in the Nupe Sandstones (Wild, 1971), a parent rock from which the soils parent material is derived.

5.4.4: CATION EXCHANGE CAPACITY (C.E.C.)

Tables 9, 10 and 11 show cation exchange capacities (C.E.C.) of the profiles of the soil units, 1, 2 and 3 respectively. Using the C.E.C. rating by Hill et al (1974) (appendix 1), the values of C.E.C. of the soils ranging between 3.1 and 18.4 meq/100g soil are low to moderate. In general, the soils exhibit lower C.E.C. (3.1 - 7.0 meq/100g soil) in the A horizons than in the B horizons (4.20 18.4 meq/100g soil). Thus, consistent increase in C.E.C. with depth is a common characteristics of the soils.

The C.E.C. values of soil unit 1 range between 3.1 and 18.4 meq/100g soil. The C.E.C. of the surface horizons ranges between 3.1 and 6.9 meq/100g soil in all the soil profiles of the mapping unit. The subsurface horizons have relatively higher C.E.C. values ranging between 7.5 and 18.4. The distribution and amount of C.E.C. values of the other soil units are similar to those of soil unit 1.

TABLE 6: EXCHANGEABLE BASES OF SOILS OF UNIT 1

Horizon	Depth (cm)	EXCHANGEABLE BASES				
		Ca	Mg	K	Na	Total
		meq/100g Soil				
		PROFILE AN 001				
A1	0 - 15	1.69	0.43	0.09	0.17	2.38
B3	15 - 49	0.96	0.29	0.09	0.16	1.50
B1	49 - 82	1.11	0.61	0.09	0.17	1.98
B21t	82 - 125	0.67	0.16	0.16	0.28	1.71
B22t	125 - 163	0.45	0.49	0.12	0.14	1.20
B3	163 - 200	0.68	0.49	0.11	0.38	1.66
		PROFILE AN 002				
Ap	0 - 13	1.17	0.35	0.07	0.14	1.73
A3	13 - 40	0.72	0.29	0.06	0.15	1.22
B1	40 - 56	0.91	0.49	0.06	0.28	1.72
B21	56 - 96	1.16	0.77	0.07	0.31	2.31
B22	96 - 135	0.74	0.49	0.08	0.41	1.71
B3	135 - 200	0.72	0.64	0.07	0.16	1.59
		PROFILE AN 003				
Ap	0 - 15	1.30	0.59	0.06	0.17	2.20
A3	15 - 33	1.54	0.49	0.08	0.17	2.28
B1	33 - 86	0.87	0.28	0.08	0.18	1.41
B21t	86 - 125	1.52	0.39	0.08	0.16	2.15
B22t	125 - 152	1.91	1.15	0.10	0.31	3.47
B23	152 - 200	1.98	1.16	0.10	0.19	3.43
		PROFILE AN 004				
Ap	0 - 18	1.82	1.15	0.10	0.31	3.38
A3	18 - 59	0.95	0.52	0.10	0.16	1.72
B21t	59 - 108	1.40	1.10	0.11	0.30	2.91
B22t	108 - 150	1.24	1.10	0.11	0.18	2.63
B23	150 - 200	1.44	1.13	0.10	0.30	2.97
		PROFILE AN 006				
Ap	0 - 20	1.39	0.29	0.05	0.16	1.89
A3	20 - 45	1.22	0.41	0.10	0.21	1.94
B21	45 - 79	1.34	0.61	0.10	0.18	2.26
B22	70 - 140	1.37	0.25	0.10	0.18	1.67
B23	140 - 200	1.20	1.16	0.07	0.17	2.60

TABLE 7: EXCHANGEABLE BASES OF SOILS OF UNIT 2

Horizon	Depth (cm)	EXCHANGEABLE BASES				
		Ca	Mg	K	Na	Total
		meq/100g Soil				
		PROFILE AN 007				
Ap	0 - 15	1.59	0.33	0.08	0.16	2.16
A3	15 - 49	1.39	0.41	0.11	0.22	2.13
B21t	49 - 69	1.62	0.83	0.11	0.11	2.67
B22t	69 - 103	2.32	0.96	0.12	0.19	3.57
B23t	103 - 165	2.76	0.96	0.12	0.21	4.05
B24	165 - 200	2.52	1.01	0.12	0.34	3.99
		PROFILE AN 009				
A1	0 - 21	2.10	0.46	0.06	0.28	2.9
B1	21 - 55	0.94	0.25	0.06	0.45	1.7
B21t	55 - 75	1.34	0.89	0.12	0.54	2.87
B22t	75 - 104	1.20	1.38	0.20	0.43	3.21
B23t	104 - 180	0.82	0.71	0.50	0.36	2.39
B24	180 - 200	0.69	0.51	0.30	0.39	1.89
		PROFILE AN 010				
A1	0 - 24	1.65	0.43	0.06	0.21	2.35
B1	24 - 56	1.06	0.25	0.06	0.29	1.66
B21	56 - 76	1.81	0.77	0.10	0.35	3.03
B22	76 - 106	1.61	1.20	0.13	0.35	3.30
B23	106 - 149	1.57	1.13	0.25	0.83	3.75
B24	149 - 200	0.98	0.65	0.25	0.68	2.56

TABLE 8: EXCHANGEABLE BASES OF SOILS OF UNIT 3

Horizon	Depth (cm)	EXCHANGEABLE BASES				
		Ca	Mg	M	Na	Total
		meq/100g Soil				
		PROFILE AN 005				
A1	0 - 11	1.58	0.28	0.07	0.18	2.11
A3	11 - 33	1.28	0.25	0.05	0.06	1.64
B21t	33 - 55	2.32	0.59	0.10	0.18	3.19
B22t	55 - 95	2.21	1.22	0.16	0.07	3.66
B23t	95 - 136	2.12	1.52	0.22	0.22	4.08
B2	136 - 200	1.64	1.28	0.23	0.20	3.35
		PROFILE AN 008				
A1	0 - 24	1.41	0.35	0.08	0.17	2.01
B1	24 - 47	0.90	0.40	0.06	0.06	1.42
B21	47 - 79	1.34	0.90	0.12	0.21	2.57
B22	79 - 108	1.37	0.68	0.09	0.17	2.31
B23	108 - 142	1.90	1.02	0.14	0.32	3.38
B3	142 - 200	1.57	1.33	0.10	0.30	3.30
		PROFILE AN 011				
Ap	0 - 17	1.50	0.31	0.06	0.23	2.3
B1	17 - 34	1.06	0.34	0.12	0.78	2.3
B21t	34 - 58	1.06	0.54	0.10	0.38	2.1
B22t	58 - 121	1.81	1.07	0.10	0.61	3.59
B3	121— 200	1.31	1.06	0.10	0.49	2.95
		PROFILE AN 012				
Ap	0 - 17	2.56	0.53	0.14	0.16	3.41
B1	17 - 42	1.95	0.58	0.13	0.28	2.94
B21t	42 - 77	2.63	0.96	0.14	0.39	4.12
B22t	77 - 142	3.12	1.05	0.16	0.39	4.72
B23t	142 - 150	3.14	1.10	0.15	0.38	4.77
B3	150 - 200	3.18	1.19	0.14	0.27	4.78

The ranges for unit 2 and 3 are 4.7 - 18.6 and 4.6 - 18.0 meq/100g soil respectively.

The C.E.C. of the soils per 100g of clay (tables 12 to 14) is quite variable. The values for the A horizons are high ranging between 38.75 and 265.0 meq/100g clay. The values in the B horizons range between 32.73 and 70.00 except in profiles AN 009 and AN 010 where the values for the upper B horizons are quite high. However, the values of C.E.C. per 100g clay decrease with depth.

The high values of C.E.C. per 100g clay of the surface horizons might be due to the very low clay content of the horizons. The C.E.C. of the surface soils is mainly due to the organic matter. Thus values of C.E.C. per 100g clay of the subsurface horizons give a better and more reasonable reflection of clay activities.

Organic matter, and the amount and type of clay mineral in a soil are the principal factors influencing the C.E.C. of a soil (Foth and Turk, 1972; Jones and Wild, 1975; Nye and Greenland, 1960). Since the organic matter status of the soils is generally low and its change with depth is insignificant, then, the observed increase in C.E.C. with depth could be due to the clay distribution which increases with depth. However, the effect of the soil organic matter on the C.E.C. of the soils could still be significant because Jones (1971) has observed that the C.E.C. of some Savanna soils was 368 meq per 100g carbon.

The C.E.C. of these soils may overstate their capacity to hold cations under field conditions. The clay

mineralogy of tropical soils are dominated primarily by kaolinite, halloysite, and oxides of iron and aluminium (Van Raij and Peech, 1972). These colloids, especially kaolinite and halloysite, have significant amount of pH-dependent charges (Sawhney and Norrish, 1971).
Considering the reaction of the soils and pH at which the C.E.C. was determined the pH-dependent charges of these colloids might contribute to the C.E.C. The exchange sites vacated by ferric ions (Fe^{3+}) could also add to the C.E.C. values. At low pH, iron is tightly adsorbed on soil clay, especially 1:2 layer clay, blocking some of the negatively charged sites, thus reducing the C.E.C. (Fitz Patrick 1980). With increase in pH, the iron precipitates and sites it was occuping become available. Ferric ions are not included in total exchangeable cations.

C.E.C. is a measure of the potential of a soil to attract positively charged ions and to adsorb them in such a way that they can be relatively easily given up and made available to crops. Thus, the low C.E.C. of the soils of the study area means that the soils have low capacity to hold cations (Ca, Mg, K and Na) required for crop nutrition. If such soils are put under intensive cultivation they become unable to meet nutrient requirements of the crops within a short period of time. This results in low fertility. Also, if crop nutrients, in form of fertilizers, are applied to these soil, they suffer from leaching since a large proportion of them will remain in the soil solution instead of being adsorbed by the clays to be

released only when needed. This fact is compounded by the very porous nature of the soils.

TABLE 9: CHEMICAL PROPERTIES OF SOILS OF UNIT 1

Horizon	Depth (cm)	Organic Carbon (OC) %	Total Nitrogen %	pH 1:1 Water	pH 1:2 $CaCl_2$	C.E.C. (meq/ 100g Soil)	Base Saturation
			PROFILE AN CO1				
A1	0 - 15	0.6	0.03	6.6	6.0	5.4	44.10
A3	15 - 49	0.5	0.03	6.6	5.8	3.1	45.40
B1	49 - 82	0.4	0.02	6.5	5.8	7.5	26.40
B21t	82 - 125	0.3	0.02	6.5	5.8	6.6	13.60
B22t	125 - 163	0.6	0.02	5.8	4.6	11.0	10.90
B3	163 - 200	0.4	0.03	5.8	4.5	12.8	25.00
			PROFILE AN CO2				
Ap	0 - 13	0.6	0.03	6.2	5.4	4.0	43.30
A3	13 - 40	0.5	0.03	5.8	4.9	4.1	29.80
B1	40 - 56	0.4	0.02	5.6	4.7	9.1	18.90
B21	56 - 96	0.5	0.02	5.8	4.8	18.0	12.50
B22	96 - 135	0.4	0.03	5.8	4.4	17.4	9.90
B3	135 - 200	0.4	0.02	5.8	4.4	17.8	8.90
			PROFILE AN CO3				
Ap	0 - 15	1.0	0.04	6.4	5.6	5.3	41.50
A3	15 - 33	0.6	0.03	6.4	5.2	6.5	35.10
B1	33 - 86	0.5	0.03	5.9	4.8	7.5	18.80
B21t	86 - 125	0.4	0.03	6.0	5.2	16.7	12.90
B22t	125 - 152	0.5	0.03	6.0	6.0	16.2	21.40
B23	152 - 200	0.6	0.02	6.0	5.4	15.2	22.60
			PROFILE AN CO4				
Ap	0 - 18	0.6	0.03	6.6	5.6	6.2	54.50
A3	18 - 59	0.4	0.02	6.0	5.2	6.9	25.10
B21t	59 - 108	0.4	0.03	5.6	4.9	18.4	15.60
B22t	108 - 150	0.4	0.02	5.4	4.8	17.9	14.70
B23	150 - 200	0.4	0.02	5.5	4.8	18.4	16.10
			PROFILE AN CO6				
Ap	0 - 20	0.5	0.03	6.4	5.6	4.9	38.60
A3	20 - 45	0.5	0.02	6.6	5.8	4.9	39.60
B21	45 - 79	0.5	0.02	5.2	4.6	17.0	13.30
B22	79 - 140	0.5	0.02	5.6	4.8	16.4	10.20
B23	140 - 200	0.4	0.03	5.7	4.8	18.0	14.4

TABLE 10: CHEMICAL PROPERTIES OF SOILS OF UNIT 2

Horizon	Depth (cm)	Organic Carbon (OC) %	Total Nitrogen %	pH 1:1 Water	pH 1:2 CaCl	C.E.C. (meq/ 100g Soil)	Base Saturation %
			PROFILE AN 007				
Ap	0 - 15	0.6	0.03	6.4	5.7	5.6	38.60
A3	15 - 49	0.4	0.03	6.4	5.7	6.0	15.00
B21t	49 - 69	0.3	0.03	6.4	5.7	10.8	27.70
B22t	69 - 103	0.5	0.03	6.0	5.4	18.0	19.90
B23t	103 - 165	0.3	0.04	6.0	5.5	16.0	15.60
B24	165 - 200	0.4	0.03	6.2	5.6	16.0	15.50
			PROFILE AN 009				
A1	0 - 21	1.00	0.04	6.4	5.4	5.2	55.80
B1	21 - 55	0.30	0.02	6.4	5.4	6.2	27.40
B21t	55 - 75	0.50	0.03	6.1	5.2	12.0	12.10
B22t	75 - 104	0.50	0.02	6.1	5.4	17.4	18.50
B23t	104 - 180	0.50	0.02	6.0	4.5	17.6	13.60
B24	180 - 200	0.30	0.02	5.9	4.4	17.2	9.80
			PROFILE AN 010				
A1	0 - 24	0.6	0.03	6.7	6.0	4.7	50.00
B1	24 - 56	0.3	0.02	6.4	5.4	6.2	26.80
B21	56 - 76	0.5	0.02	6.4	5.6	7.4	41.00
B22	76 - 106	0.3	0.02	6.4	5.8	12.8	25.80
B23	106 - 149	0.3	0.02	5.9	5.9	12.2	30.70
B24	149 - 200	0.4	0.02	5.9	4.6	15.0	17.10

TABLE 11: CHEMICAL PROPERTIES OF SOILS OF UNIT 3

Horizon	Depth (cm)	Organic Carbon (OC) %	Total Nitrogen %	pH 1:11 Water	pH 1:2 $CaCl_2$	C.E.C. meq/ 100g Soil	Base Saturation %
			PROFILE AN 005				
A1	0 - 11	0.5	0.03	6.8	6.0	5.3	39.80
A3	11 - 33	0.3	0.02	7.0	6.2	4.6	36.70
B21t	33 - 55	0.4	0.03	7.0	6.2	9.4	33.90
B22t	55 - 95	0.4	0.02	7.0	6.2	12.2	30.00
B23t	95 - 136	0.4	0.02	7.0	6.2	17.7	23.10
B3	136 - 200	0.3	0.02	6.4	5.7	10.6	31.60
			PROFILE AN 008				
A1	0 - 24	0.5	0.03	6.4	5.9	5.0	40.20
B1	24 - 47	0.4	0.02	6.1	5.6	4.2	33.80
B21	47 - 79	0.4	0.03	6.0	5.5	9.4	27.30
B22	79 - 108	0.3	0.03	5.9	5.2	14.0	16.50
B23	108 - 142	0.3	0.03	5.9	5.2	16.1	18.70
B3	142 - 200	0.3	0.02	5.9	5.3	17.4	17.00
			PROFILE AN 011				
Ap	0 - 17	0.7	0.03	6.4	5.8	5.3	43.40
B1	17 - 34	0.4	0.02	6.2	5.2	4.9	46.90
B21t	34 - 58	0.4	0.02	5.6	4.9	8.4	25.00
B22t	58 - 121	0.4	0.02	5.5	5.0	17.0	18.00
B3	121 - 200	0.4	0.02	5.7	4.8	18.0	16.00
			PROFILE AN 012				
Ap	0 - 17	0.7	0.05	6.6	6.0	7.0	48.70
B1	17 - 42	0.6	0.03	6.6	5.8	8.9	33.00
B21t	42 - 77	0.5	0.04	6.0	5.4	16.8	24.50
B22t	77 - 124	0.4	0.03	6.4	5.8	17.5	27.00
B23t	124 - 150	0.5	0.03	6.6	6.0	16.7	28.60
B3	150 - 200	0.4	0.02	6.6	6.0	14.2	33.70

5.4.5: BASE SATURATION

The percent base saturation of the soils ranged between 15 and 54% in the surface horizons, and 8.9 and 46% in the subsoils (tables 9 to 11). These values are low to moderate (Hill et al. 1974). Generally, the percent base saturation between the horizons showed a definate correlation with pH values of the soils. Many workers (Brady, 1974, Mehlich, 1943, Morgan, 1940, and Peech, 1941) have reported correlations existing between degree of base saturation and pH of soils. As the percent base saturation decreased with depth, the acidity of the lower horizons increased, consequently, the pH of the soils decreased.

This decrease in base saturation at depth might be due to relatively high C.E.C. of the subsoils (section 5.4.4) and the distribution of bases at depth (Section 5.4.3). Even in profiles where total bases increase with depth the increase is so disproportionate to that of C.E.C. that the percent base saturation of the subsoils is lower than that of the surface horizons.

5.4.6: FREE IRON OXIDE

The results of the sodium-citrate-bicarbonate dithionite extractions, given in tables 12 - 14, show that the amount and the distribution of free iron oxides are fairly comparable in the soil units. The values were between 0.73 and 4.55%. This range and the distribution with depth are similar to those of Iju series, Ibeshe series and Alagba series reported by Ogunwale and Ashaye (1975). These soils

are also derived from sandstones.

The free iron oxide content of the soils increases with increasing depth. This agrees well with finding of many other workers notably Awujoola (1979), Malgwi (1979) and Ojanuga et al. (1976). This observation permits the conclusion that iron oxides have moved vertically downwards in the soils. However, there is no evidence of lateral movement as suggested by Ojanuga et al., (1976). This might be due to the slope position and good drainage of the soils.

TABLE 12: FREE IRON AND CLAY ACTIVITY OF SOILS OF UNIT 1

Horizon	Depth (cm)	Free Iron %	Clay Activity meq/100g Clay
		PROFILE AN 001	
A1	0 - 15	0.73	135.0
A3	15 - 49	1.11	38.8
B1	49 - 82	1.43	53.6
B21t	82 - 125	1.79	45.0
B22t	125 - 163	2.05	47.1
B3	163 - 200	2.45	47.1
		PROFILE AN 002	
Ap	0 - 13	1.03	100.0
A3	13 - 40	1.70	51.3
B1	40 - 56	2.25	50.6
B21	56 - 96	2.90	61.7
B22	96 - 135	3.07	54.4
B23	135 - 200	3.10	49.4
		PROFILE AN 003	
Ap	0 - 15	0.92	132.5
A3	15 - 33	1.00	216.7
B1	33 - 86	2.15	46.9
B21t	86 - 125	3.10	41.2
B22t	125 - 152	3.15	40.50
B23	152 - 200	3.07	40.00
		PROFILE AN 004	
Ap	0 - 18	0.88	206.7
A3	18 - 59	1.87	49.3
B21t	59 - 108	4.00	47.2
B22t	108 - 150	3.75	45.9
B23	150 - 200	4.05	51.6
		PROFILE AN 006	
Ap	0 - 20	0.78	245.0
A3	20 - 45	2.00	40.8
B21	45 - 79	4.37	50.0
B22	79 - 140	4.35	41.0
B23	140 - 200	4.48	45.0

TABLE 13: FREE IRON AND CLAY ACTIVITY OF SOILS OF UNIT 2

Horizon	Depth (cm)	Free Iron %	Clay Activity meq/100g Clay
		PROFILE AN 007	
Ap	0 - 15	1.10	112.0
A3	15 - 49	1.93	118.3
B21t	49 - 69	3.45	32.7
B22t	69 - 103	3.80	54.5
B23t	103 - 165	4.05	60.5
B24	165 - 200	4.55	60.0
		PROFILE AN 009	
A1	0 - 21	1.17	130.0
B1	21 - 55	1.44	103.3
B21t	55 - 75	3.10	113.3
B22t	75 - 104	3.40	52.7
B23t	104 - 180	3.45	45.1
B24	180 - 200	3.53	50.6
		PROFILE AN 010	
A1	0 - 24	0.75	156.7
B1	24 - 56	1.55	103.3
B21	56 - 76	2.91	37.0
B22	76 - 106	3.55	38.8
B23	106 - 149	3.44	35.9
B24	149 - 200	3.55	41.7

CHAPTER 6

SOIL CLASSIFICATION AND CORRELATION

The soils studied were classified according to the USDA Soil Taxonomy (Soil Survey Staff, 1975) and the FAO/UNESCO soil legend (1974). The classification is shown in table 15. Also, a correlation of the soils has been attempted.

6.1: CLASSIFICATION ACCORDING TO THE USDA SOIL TAXONOMY

The soils of the area are classified into the Order ultisol. An argillic horizon has been identified and it has a base saturation of less than 35 percent (by NH_4 OAc) at least in the lower horizons. Also an ochric epipedon is diagnostic for all the soils. Considering the length of the dry season in Kontagora area (section 2.3), the upper 50 cm of the soil (the moisture control section) would be dry for more than 90 cummulative days in most years. An ustic soil moisture regime is thus inferred. The soil temperature regime is estimated to be isohyperthermic because considering the air temperature of the neighbouring areas (table 2) and soil temperature regime of Mokwa (Appendix I) it is expected that the mean annual soil temperature would be more than 22°C, and the difference of soil temperatures at hot and cool seasons would be less than 5°C at more than 50 cm depth. Therefore, these soils characterized closely into the suborder Ustult.

At Great Groups and Subgroups levels, Soils of units 1 and 2 classify together as Haplustults because they have

neither plinthite nor fragipan. Also they have a clay distribution with depth such that the percentage of clay decreases from its maximum amount by more than 20 percent of that maximum within 1.5 m of the soil surface, and the layer in which the percentage of clay is less than maximum does not have clay eluviation. These soils have colour value, moist, of 4 or more in some parts of the epipedon.

Soil mapping unit 2 further classified as Arenic Haplustults because its members have sandy surface horizons that are as thick as 50 cm. Soils of unit 1 do not have a sandy epipedon as thick as soils of unit 2 and so satisfy the requirements of a typic Haplustults.

Soils of unit 3 have properties which qualify them for Typic Rhodustults. These soils have an argillic horizons that have colour value, moist, of 4 in all parts and an epipedon that has a colour value, moist, less than 4 in all parts.

6.2: CLASSIFICATION ACCORDING TO THE FAO/UNESCO SOIL LEGEND

All the profiles of soils 1 to 3 have an argillic B horizon with a base saturation of less than 50 percent in all parts of the B horizon. Also an ochric epipedon is diagnostic for all the profiles. Thus they qualify for Acrisols. The soils have low organic matter content at both the surface and subsurface horizons. They lack plinthite, hydromorphic and ferric properties and so are classified as Orthic Acrisols.

TABLE 15: SOIL CLASSIFICATION

SOIL MAPPING UNIT	PROFILE (PEDON)	USDA SOIL TAXONOMY	FAO/UNESCO
1	AN 001		
	AN 002		
	AN 003	Typic	Orthic
	AN 004	Haplustults	Acrisols
	AN 006		
	AN 007		
2	AN 009	Arenic	Orthic
	AN 010	Haplustults	Acrisols
	AN 005		
3	AN 008	Typic	Orthic
	AN 011	Rhodustults	Acrisols
	AN 012		

6.3: CORRELATION

All the soil mapping units correlate well with Takumah Series (Valette, 1973), and the units may represent different phases of this series. However, the fine differences detected here between the different units could not have been possible during Valette's reconnaissance investigations. His final mapping scale was 1:250,000.

CHAPTER 7

SUMMARY AND CONCLUSION

There is relatively few account of climate, soils, and other environmental factors of Niger State of Nigeria; a state generally regarded exclusively as an agricultural state. This lack of adequate information on the environment militates against sound agricultural planning. An assessment of the properties of the soils and their response to management is required in modern agriculture and, infact, in many human endeavour that has land as its base resource.

This study is, therefore, concerned with the detailed examination of the morphological, physical and chemical features of soils of one of the Niger State Government's seed multiplication farms, the Kontagora seed multiplication farm. The morphological features aided the soil mapping exercise and all the featutes aided the classification exercise. The soils occupy middle slope positions and are formed from deeply weathered coarse Nupe sandstones. They are typically associated with termite mounds and termites activities.

The environment in which the soils are formed exhibits a distinct dry season of about six months with an annual rainfall of about 1221mm. The soil moisture and temperature regimes of the area are inferred to be ustic and isohyperthermic respectively.

Thes soils are deep, well drained, gravelless and non concretionary. They are coarse sand dominated and

generally sandy in the surface horizons, but becomes finer in texture in the subsurface horizons. The sand fractions of the soils range between 50% to 90%, and the clay fraction increase with depth, from about 2 to 14% in the surface horizons to about 48% at depth. This implies some migration of clay particles from the surface horizons and the subsequent formation of argillic B horizons. Low silt content (2% - 15%) is also a common characteristic of the soils. This distribution pattern of the particle-size fractions between the horizons seems to have influenced the structural development of the soils. Thus the structure of the surface soils is poor in contrast to the well developed strong structure of the subsurface horizons.

The soils are neutral to strong acid in reaction, with subsurface horizons more acid than the surface horizons. This is perhaps due to the accummulation of the acid cations in the subsurface horizons.

The soils have a very low content of organic matter and nitrogen. The amounts of organic matter and nitrogen in the soils are generally less than 1% and 0.06% respectively. Somehow, their distribution between horizons does not show any definite pattern. This could be due to a low rate of return of organic residues to the soils and their rapid mineralisation. Biogenetic activities could be another contribution factor.

The values of cation exchange capacity (C.E.C.) range from 3.1 to about 7.0 meq/100g soils in the surface horizons to a maximum of 18.4 meq/100g soil in the

subsurface horizons. This increase in C.E.C. with depth is in consonnance with increase in clay content. The soils have low to moderate levels of basic cations. The cations decrease in abundance as follows: calcium,> magnesium, > sodium and > potassium. Calcium ranges from 0.45 to 3.18 meq/100g soil, magnesium 0.02 - 1.52 meq/100g soil, sodium 0.06 to 0.83 meq/100g soil and potassium 0.05 to 0.05 meq/100g soil. The low levels of potassium in the soil could be due to the low content of the element in Nupe sandstone. The distribution of the basic cations between the horizons does not show any definite patterns. This contrasts with that of percent base saturation which decreases with depth. The percent base saturation of the soils is generally low to moderate and ranges from 15% to about 54% in the surface horizons to a minimum of 8.9% in the subsoil. This decrease in percent base saturation with depth is perhaps due to increases in C.E.C. with depth.

The distribution of free iron oxide between the horizons is a clear evidence of vertical downwards migration of ferric ions. The amount of free iron oxide ranges from 0.73% to about 2.00% in the surface to a maximum of 4.55% at depth.

Following the USDA Soil Taxonomy, the three soil mapping units identified classify as Typic Haplustult, Arenic Haplustult and Typic Rhodustult. However, they all classify as Orthic Acrisols under the FAO/UNESCO soil legend.

Considering the sandy texture and the week structure of the surface soils, adoption of practices which would ensure adequate protection of the soils from the menace of agents

of erosion would be necessary. Such practices would include planting on ridges across the slope. This will stop or at least lessen run off. The contrasting effects of ridge-planting and flat-planting on soil erosion are illustrated by plates VIA and VIB. Evidence of erosion (rills) are conspicuous in the plot where maize was planted on flat (plate VIA) while the adjacent groundnut plot (plate VIB) does not show any sign of erosion. Also, an effort should be made to ensure that the soil surface is not left bare at any time of the year. This calls for a complete stop to the perenial bush burning in the area. Furthermore, the engineering structures constructed on the farm should be adequately maintained. Also, use of green manuring and suitable cover crops during the fallow period is recommended.

All these measure together with a good crop rotation, judicious use of chemical fertilizers and other cultural practices will ensure improvement and maintenance of the fertility of the soils. Thus making the soils capable of producing good and sustained yields. These notwithstanding, care should be taken in the use of chemical fertilizers on these soils which have low cation exchange capacities. The conventional practices of applying one or two nutrient fertilizers could lead to nutrient inbalance. Nutrient deficiency symptom on crops could be a result of nutrient inbalance since many deficiency symptoms are not always due to actual lack of nutrients in a soil. For instances, soil reaction (pH) may cause nutrient deficiency symptoms on

crops through its influence on the availability of the nutrients. Several essential elements, such as iron, manganese, and zinc, tend to be less available under high soil pH. On the other hand, the availability of other essential elements, such as molybdenum, and sulphur is reduced under low soil pH. It is imperative, therefore, that fertilizers, such as amonium sulphate which tend to acidify soils are avoided, and the nutrient status of the soils should be checked through periodic samplying and analysis of the soils. Such analysis should include determination of soil reaction, exchangeable basic cations, organic matter status of the soils, available phosphorus and other elements that are essential for plant growth. It will be noted that these points are particularly important in any part of this area, such as the seed multiplication farm, where the soils are put under intensive and continous cropping.

Plate VI : Control of Erosion by crop management



A : Maize planted on flat



B : Groundnut planted on ridges

LITERATURE CITED

Adeleye, D. A. 1976. The geology of the Middle Niger Basin in Geology of Nigeria, C. A. Kogbe (Ed), Elizabethan Publishing Co. Box 174 Surulere, Lagos, Nigeria.

Adeleye, D. R., and T.F.S. Dessauvagie, 1972, Stratigraphy of the Niger Embayment near Bida, Nigeria. In African Geology, T.F.J. Dessauvagie and A. J. Whiteman (Ed), University of Ibadan Press.

Ahn, P. M. 1970. West African Soils. Oxford University Press, Ely House, London W. I.

Allison, F.E. 1973. Soil organic matter and its role in crop production. Developments in Soil Science P.277-378. American Elsevier Publishing Company, INC. 52 Vanderbilt Avenue, New York, New York 10017.

Awujoola, A.I. 1979. Soil Mapping and Soil characterization Studies in the Zaria Area, Nigeria. Unpublished M.Sc. Thesis, Department of Soil Science, Ahmadu Bello University, Samaru - Zaria, Nigeria.

Avery, B. W. 1956. A classification of British soils. Trans. 6th Intern. Congr. Soil Sci. (Paris, France) E: 279-85.

Basinsk, J. J. 1967. The Russian approach to soil classification and its recent development. In Selected Papers in Soil Formation and Classification. Drew, J.V., R.B. Grossman, J. L. Retzer, R.W. Simonson, H.W. Smith and M.E. Springer (Ed), Soil Science Society of American, Inc. Publishers, Madison, Wisconson, USA.

Bawden, M.G. and J.A. Jones. 1973. The Physiography of the Northern Plains. Unpublished Miscellaneous report No. 154. Land Resources Division, Tolworth Tower, Surbition, Survey, England.

Bawden, M.G., and P. Tuler. 1966. Land Sesources of Southern Sardauna and Southern Adamawa Provinces, Northern Nigeria, Land Resources Division, Tolworth Tower, Surbiton, Survey England

Baver, L.D., W.H. Gardner and W.R. Gardner 1972. Soil Physics. John Wiley and Sons, Inc., New York.

Beckett, P.H.T. 1965. The Cation Exchange Equilibria of Calcium and magnessium. Soil Science 100; 118 - 123.

Bennett, J.G., A.A. Hutcheon, I.J. Ibanga, W.B. Kerr, J.E. Mansfield, L.J. Rackham and J. Vallette, 1978. Land Resources of Central Nigeria; Environmental Aspects of the Kano Plains. Land Resources Development Centre Tolworth Tower, Surbition, Survey, England.

Bohn, H. L., B.L. McNeal and G.A. O'Connor, 1979. Soil Chemistry. John Wiley and Sons, New York.

Brady, N.C. 1974. The Nature and Properties of Soils. MacMillan publishing Company Inc. 866 Third Avenue, New York, New York 10022.

Buol, S.W., R.J. McCracken and F.D. Hole, 1973. Soil Genesis and Classification. The Iowa State University Press, Ames.

Cline, M.G. 1967. Basic Principles of Soil Classification. In Selected Papers in Soil Formation and Classification. Drew J.V., R.B. Grossman, J.L. Retzer, R.W. Simonson, H.W. Smith and M.E. Springer (Ed) Soil Science Society of America, Inc., Publishers, Madison, Wisconson, USA.

Day, P.R. 1965. Particle fractionation and Particle-size Analysis. In C.A. Black (Ed) Methods of Soil Analysis, Part 1. Amer. Soc. Agron. 9: 545 - 577.

Dent, D. and A. Young. 1981. Soil Survey and Land Evaluation. George Allen and Unwin (Publishers) Ltd. London .

de Swardt, A.M. 1946. The recentv erosional history of the Kaduna Valley. Niger. Geology Sur. Department Annual Report 1946. p. 39 - 45.

Dudal, R. 1968a. Problems of international soil correlation, pp. 137 - 143. In World Soil resources report 32. Food and Agricultural Organisation, Rome, Italy.

Dudal, R. 1968b. Definitions of soil units for the soil map of the world. In World soil resources report 33. Food and Agricultural Organization, Rome, Italy.

Emirate Technical Services Limited. 1975. Crop Production in North Western State, Nigeria. Emirate Technical Services Limited, 35 Bornu Crescent, Apapa, Lagos.

Falconer, J.D. 1911. The Geology and Geography of Northern Nigeria. MacMillan and Co. London.

FAO/UNESCO. 1974. Soil Map of the World, Vol. 1 Legend. UNESCO - Paris.

Federal Department of Agriculture. 1965. Report on the 3rd National Soil Correlation Meeting (Jos, Nigeria)

Fitz Patrick, E.A. 1980. Soils, their Formation, Classification and Distribution. Longman Group Limited, New York.

Foth, H.D. and Turk, L.M. 1972. Fundamental of Soil Science. John Wiley and Sons, Inc. New York.

Harpstead, M.I. 1974. The Classification of Some Nigerian Soils. Soil Science 116: 137 - 1443.

Heinone, R. 1955. Soil Aggregation in Relation to Texture and Organic matter. Agrogeological Publication No. 64. Agricultural Research Centre, Development of Soil Science, Helsinki.

Higgins, G.H., D.M. Ramsay and R.A. Pullan. 1960. A Report on the climate, soils and vegetation of the Niger Trough. Soil Surv. Bull. 10, Regional Research Station, Samaru, Zaria, Northern Nigeria.

Hill, I. D., A.W. Wood, A. A. Hutcheon and L.J. Rackhan. 1974. The Land Resources of Central Nigeria. Phase 1 Interim Report on the Land Forms, Soils and Vegetation of the Bauchi Area Vol. 1.

Ibanga, I.J. 1974. Effects of Soil Texture on Soil consistence. Unpublished M.Sc. Thesis, Department of Agronomy, Kansas State University, Manhattan, Kansas.

Ibanga, I.J. 1980. The Physical, Chemical and Mineralogical Properties of Lateriate Samples Formed in Various Environments, Unpublished Ph.D. Thesis, Department of Soil Science, North Carolina State University, Releigh, USA.

Jenny, H. 1941. Factors of soil formation. McGraw-Hill, New York.

Jones, B. 1948. The Sedimentary Rocks of Sokoto Province, Bull. Geol. Surv. Nigeria, 18.

Jones, N.J. 1971. The maintenance of soil organic matter under contineous cultivation at Samaru, Nigeria. J. Agric. Sci. 77: 473 - 482.

Jones, N.J. 1973. The Organic matter content of the Savanna Soils of West Africa. Journal of Soil Science. 24: 42 - 53.

Jones, N.J. and A. Wild. 1975. Soils of West African Savanna Tech. Comm. No. 55, Commonwealth Bureau of Soils, Harpenden, Cambrian News Ltd. 218p.

Keay, R.W.J. 1959. An outline of Nigerian Vegetation. Lagos, Nigeria.

Klinkenberg, K. 1965. Report on the reconnaissance Soil Survey of part of Borgu Division, Ilorin Province. Soil Surv. Bull. 28, Inst. for Agric. Research, Samaru, Zaria, Nigeria.

Kowal, J. M. 1972. Study of soil surface crusts in loess of plain soil of Northern Nigeria. Nigerian Joun. of Science 6: 93 - 100.

Kowal, J.M. and D.T. Knabe. 1972. An agroclimatological atlas of the Northern States of Nigeria with explanatory notes. Ahmadu Bello University Press, Samaru, Zaria, Nigeria.

Malgwi, W.B. 1979. A study of soils on the high plain of Hausaland Samaru - Zaria, Nigeria. Unpublished M.Sc. thesis, Department of soil Science, Ahmadu Bello University, Samaru - Zaria, Nigeria.

Maxlock Group Nigeria Limited (1980). Kontagora master plan 1980 - 2000, preliminary report. Maxlock Group Nigeria Limited, Maiduguri, Borno State, Nigeria.

McCurry, P. 1976. The geology of the Precambrian to Paleozoic rocks of Northern Nigeria - A review. In Geology of Nigeria. C.A. Kogbe (Ed.) Elizabethan Publishing Co., Surulere, Lagos, Nigeria.

Mehlich, A. 1943. The significant of percentage base saturation and pH in relation to soil differences. Soil Sci. Soc. Amer. Proc. 7:167 - 174.

Mehra, O.P., and M.L. Jackson. 1960. Iron oxide removal from soils and clays by a dithionite - citrate systems buffered with sodium bicarbonate. Clays and Clays and Min. 317 - 327.

Millar, C.E., L.M. Turk and H.D. Foth. 1965. Fundamentals of Soil Science. John Wiley and Sons, Inc., New York.

Morgan, M.F. 1940. Base exchange capacity and related characteristics of Connecticut soils. Soil Science Soc. Amer. Proc. 4:145 - 149.

Nettleton, W.D., K.W. Flach, and B.R. Brasher. 1969. Argillic horizon without clay skins. Soil Science Soc. Amer. Proc. 33:121 - 125.

Nye, P.H. and D.J. Greenland. 1960. The soil under shifting cultivation. Tech. Comm. 51, Commonwealth Bureau of soils, Harpenden, Cambrian News Ltd.

Ogunwale, J.A. 1973. The genesis and classification of soil derived from Sandstones of various lithological origin in Nigeria. Unpublished Ph.D. Thesis, Department of Agronomy; University of Ibadan, Nigeria.

Ogunwale, J.A. and S.T.I. Ashaye, 1975. Sandstone-derived soils of a catena at Iperu, Nigeria. Journal of Soil Sci. 26:33 - 31.

Ojanuga, A.G., G.B. Lee and H. Folster. 1976. Soil stratigraphy of mid to lower slopes in the South Western upland of Nigeria. Soil Science Soc. Amer. Journal, 40: 287 - 292.

Ojanuga, A.G. 1977. Land use planning in agricultural development in Nigeria. Proceedings of 13th Annual Conference of the Agricultural Society of Nigeria. ABU, Zaria, Nigeria.

Ojo, S.B. and P.E. Ajakaiye. 1976. Preliminary interpretation of gravity measurements in middle Niger Basin area, Nigeria In Geology of Nigeria, G.A. Kogbe (Ed). Elizabethan Publishing Co., Surulere, Lagos, Nigeria.

Ologe, K.O. 1971. Gully development in Zaria area, Northern Nigeria, with a particular reference to the Kubani basin. Ph.D. thesis, University of Liverpool, Vol. 1. 285p.

Peech, M. 1941. Availability of ions in light sandy soils as affected by soil reaction. Soil Science 51:473-486.

Peech, M. 1965. Lime requirement. In Methods of Soil analysis. Monog. 9.V.2, pp. 927 - 932. Amer. Soc. Agron., Madison.

Peech, M., L.T. Alexander, L.A. Dean and J.F. Reed. 1947. Methods of soil analysis for soil fertility investigation. U.S. Department Agr. C. 757, 25 pp.

Pugh, J.C. 1956. Isostatic readjustment in the theory of pediplanation. Quart. J. Geol. Soc. London 111:361.

Pugh, J.C. and L.C. King 1952. Outline of the geomorphology of Nigeria. South African Geographycal Journal; XXXIV: 30 - 36.

Pullan, R.A. and P.N. de Leeuw. 1964. The land capability survey prepared for the Niger Dams Resettlement Authority Soil Surv. Bull. 26, Institute for Agricultural Research, Samaru, Zaria, Nigeria.

Rackham, L.J. and R.I. Rose-Innes. 1978. Land resources of central Nigeria, Environmental aspect of Kano plains, Vol. 2, Land Resources Development Centre, Tolworth Tower, Surbiton, Survey, England.

Reyment, R.A. 1965. Aspect of the geology of Nigeria, Stratigraphy of the Createous Cenozoic deposits. Ibadan University Press, Ibadan.

Robinson, G.W. 1936. Soils their origin, constitution and classification: An introduction to pedology. Thomas Nurby and Co., 1, Fleet Lane, E.C. 4 London.

Rode, A.A. 1962. Soil Science (Pochvovedeniye). (Transl. by A Gourevich). Israel prog. for Sci. Trans., Jerusalem.

Rozov, N.N., and E.N. Ivanova. 1968. Soil Classification and nomenclature used in Soviet pedology, agriculture and forestry, pp 53 - 77. In World Soil resources report 32. Food and Agricultural Organisation, Rome. Italy.

Russ, W. 1930. The geology of the Minna - Birnin Gwari belt. Ann. Report Geol. Surv. Nigeria.

Sawhney, B.L. and Norrish, K. 1971. pH dependent cation exchange capacity: minerals and soils of Tropical regions. Soil Sci. 112: 213 - 215.

Schofield R.K. and A.W. Taylor. 1955. The measurement of soil pH. Soil Science Soc. Amer. Proc. 19: 164 - 167.

Simonson, R.W. 1957. What soils are. In USDA yearbook of Agr. Soil U.S. Government Printing Office, Washington, D.C. p. 17 - 31.

Simonson, R.W. 1959. Outline of a generalized theory of soil genesis. Soil Sci. Am. Proc. 23: 152 - 156.

Singh, L. and Balasubramania, V. 1978. Effect of continous application of chemical fertilizers on organic matter levels of soils at Samaru, Nigeria. Samaru Conference Paper No.17. Institute for Agric. Research Samaru, Zaria, Nigeria.

Soil Conservation Service, 1972. Soil Survey Laboratory methods and precedures for collecting soil samples. Soil survey investigation, Report No.1, U.S.D.A. Washington, D.C.

Soil Survey Staff. 1951. Soil Surv. Manual. Handbook No.18, U.S.D.A. Washington, D.C.

Soil Survey Staff. 1975. Soil Taxonomy: a basic system of soil classification for making interpreting soil survey; Agr. Handbook No. 436. U.S.D.A. Washington, D.C.

Steele, J.G. 1976. Soil survey interpretation and its use. Food and Agricultural Organisation, Rome, Italy.

Steward, V.I., W.A. Adams and H.H. Abdullah. 1970. Quantitative pedological studies on soils derived from Silurian mud-stone. 1. parent material and the significance of the weathering process. J. Soil Sci. 21:242 - 247.

Tattam, C.N. 1943. A review of Nigerian stratigraphy. Ann. Rept. Geol. Survey, Nigeria.

Tomlinson, P.R. 1962. Interpretation and utilization of soil analytical data. Regional Research station, Ministry of Agriculture, Northern Region Nigeria, Technical Report No.21, 9p.

Tomlinson, P.R. 1965. Soils of Northern Nigeria. Samaru Misc. Pap. No.11. Institute for Agricultural Research, Samaru, Zaria, Nigeria.

Uyevbisere, E.O. 1979. Phosphate uptake as related to extractable and inorganic phosphate fractions in some savanna soils of Nigeria. Unpublished M.Sc. thesis, Department of Soil Science, ABU, Zaria, Nigeria.

Valette, J. 1973. The reconnaissance soil survey of the Mokwa - Kontagora - Kainji area, North - Western and Kwara States, Nigeria. Soil Survey Bulletin 44, Institute for Agricultural Research, Samaru, Zaria, Nigeria.

Valette, J. and G.M. Maggins, 1967. The reconnaissance soil survey of an area near Auna, Niger Province, Northern Nigeria, Soil Surv. Bull. 34, Institute for Agricultural Research, Samaru, Zaria, Nigeria.

VanRaij, B. and M. Peech, 1972. Electrochemical properties of some Oxisols and Alfisols of the tropics. Soil Sci. Soc. Amer. Proc. 36: 587 - 593.

Walkley, A. and I. A. Black (1965). Organic carbon. In C. A. Black (Ed.) Methods of Soil analysis, part 2. Amer. Soc. Agron., 9: 1372 - 1376.

A P P E N D I X I

Glossary of terms (After Hill et al., 1974)

1.	Very Shallow	< 30cm
	Shallow	30 - 50cm
	Moderately Deep	50 - 1m
	Deep	> 1m
2.	Soil Reaction Rating P.H.	
	Extremely Acid	< 4.5
	Very Strongly acid	4.5 - 5.0
	Strongly Acid	5.1 - 5.5
	Moderately Acid	5.6 - 6.0
	Slightly Acid	6.1 - 6.5
	Neutral	6.6 - 7.3
	Slightly Alkaline	7.4 - 7.8
	Moderately Alkaline	7.9 - 8.4
	Strongly Alkaline	8.5 - 9.0
	Very Strongly Alkaline	> 9.1
3.	Organic Matter Rating	
	Very Low	< 0.4% Carbon
	Low	0.4 - 1.0%
	Moderate	1.0 - 1.5%
	High	1.5 - 2.0%
	Very High	> 2.0%

4. EXCHANGEABLE CATIONS

Rating	Range meq/100g Soil			
	Ca	Mg	K	Na
Very High	> 20	> 8	1 - 2	> 2
High	10 - 20	3 - 8	0.6 - 1.0	0.7 - 2.0
Moderate	5.- 10	1 - 3	0.3 - 0.6	0.3 - 0.7
Low	2.- 5	0.3 - 1	0.2 - 0.3	0.1 - 0.3
Very Low	< 2	< 0.3	< 0.2	< 0.1

5. Cation Exchange Capacity Rating

Very Low	< 6 meq/100g Soil
Low	6 - 12 meq/100g Soil
Moderate	12 - 25 meq/100g Soil
High	25 - 40 meq/100g Soil
Very High	> 40 meq/100g Soil

6. Percentage Base Saturation Rating:

Very Low	0 - 20%
Low	20 - 40%
Moderate	40 - 60%
High	60 - 80%
Very High	80 - 100%

APPENDIX II

THE MONTHLY MEAN EARTH TEMPERATURE IN DEGREES

CENTIGRADE AT NOKWA FOR YEARS 1954-1968

(After Kowal and Knabe, 1972)

Depth (cm)	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
30	28.6	31.2	34.4	34.2	32.5	30.2	28.8	28.2	28.3	29.2	29.9	29.1
120	29.3	30.3	32.2	33.7	32.8	31.4	30.1	29.2	29.0	29.3	29.8	29.7