PHYSICAL PROPERTIES AND ELEMENTAL ABUNDANCES OF THE NIGERIAN SAVANNAH SOILS

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AHAMDU BELLO UNIVERSITY, ZARIA,
NIGERIA

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DEPARTMENT OF PHYSICS
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AHAMDU BELLO UNIVERSITY, ZARIA, NIGERIA

AUGUST, 2007

DECLARATION

I, declare that the work in the Thesis entitled "**Physical Properties and Elemental Abundances of the Nigerian Savannah Soils**" has been performed by me in the Department of Physic under the supervision of Dr I. O. B Ewa and Prof M. O. A Oladipo.

The information derived from the literature has been dully acknowledged in the text and list of references provided. No part of this thesis was previously presented for another Degree or Diploma in another University.

_____	_____	_____
Name of student	Signature	Date

CERTIFICATION

This Thesis entitled "**PHYSICAL PROPERTIES AND ELEMENTAL ABUNDANCES OF THE NIGERIAN SAVANNAH SOILS"** by Karans Shillingford Abubakar meets the regulation governing award of the degree of Master of Science (Physics) of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literacy presentation.

_____	_____
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Head of Department (Prof. N. Hariharan)	Date
_____	_____
Dean, Postgraduate School	Date

DEDICATION

To

The Entire Family

For their Love, Understanding and Support

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First and foremost, I am grateful to my creator for sparing my life and sustaining me through out my studies.

I am indebted to my supervisors, Dr I. O. B Ewa and Prof. M. O. A Oladipo, both of the Centre for Energy Research and Training (CERT), A.B.U Zaria for their sincere guidance and support through out my work.

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ABSTRACT

In this work investigations of physical properties, Colour, conductivity, bulk-density and pH, of the Nigerian savannah soils (*Sahel, Sudan* and *Guinea*), Mean soil bulk-densities determined for the Sudan, Sahel and Guinea savannah were 1.40±0.17gcm$^{-3,}$ 1.25± 0.17gcm^{-3} and 1.40±0.17gcm^{-r}especively. The mean soil conductivities were 29±22μScm^{-1}; 57±22μScm^{-1} and 66±2μScm^{-1}, while the measured soil pH were in the range of 4.72 -5.73, 5.00 -6.05, and 5.40 for the Sudan, Guinea and Sahel savannah respectively. Instrumental Neutron Activation Analysis (INAA) was used for the determination of the concentration of elements from these soils sampled at twenty-two sites within the savannah. Elements determined include Al, Ba, Br, Ca, Ce, Cl, Co, Cr Cs, Dy, Eu, Fe, Hf, K, La, Lu, Mg, Mn, Na, Rb, Sb, Sc, Sm, Ta, Th, Ti, V, and Yb. Some of the essential elements determined for the three savannahs were in the range of 1.20 – 2.46% (Fe), 1.37-2.67 %(K); 0.24-0.32 %%(Mg) and 322.61ppm (Mn). The large data sets of elements determined by INAA were subjected to multi-variant statistical analysis using the cluster procedure and Ward Method. This procedure using squared Euclidean distances showed segregation of the element data for the Sudan savannah from the Guinea and Sahel savannah. This statistical result confirms the reliability of the data sets and uniqueness of element data for each of the savannahs investigated

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CHAPTER ONE

INTRODUCTION

1.1 Overview of the Project

In recent years, a large number of different physical and chemical techniques have been developed for the measurement of the elemental composition at the microgram-per-gram and nanogram-per-gram levels, in the field of trace analysis.

One of the widely used techniques is Instrumental Neutron Activation Analysis (INAA), which is a nuclear analytical technique for measuring the concentrations of a large number of elements in a single sample, and can be applied to the analysis of a wide variety of sample types. Instrumental neutron activation analysis stands at the forefront of techniques as a non-destructive analytical technique where the sample or artifact may be returned to the researcher after analysis.

Major, minor and trace element abundance in either terrestrial or aquatic environments such as sediments rocks and solids have been the subject of investigations using INAA (Valkovice, 1975; Gordon *et al*., 1968; Ewa *et al.,* 2000). The association of elements in varying concentrations in soils is indicative of the mineral content, which in turn serves as a measure of soil fertility.

The savannah soils in Nigeria cover an extensive landmass that support agrarian activities for the socio-economic development of Nigeria and therefore need continuous investigations, as new techniques unfold and are available for the study of the region.

The thesis generally examines the physical properties of the savannah soils as well as the trace element composition of these soils for the different sampling points and the implication of these data for the agrarian communities sampled.

1.2 Literature Survey and Previous Work

The savannah soils of Nigeria have been the subject of investigations over the years by several field workers (Kowal, 1970, Kowal and Andrews, 1973; Ewa *et al*., 2000). These authors studied the morphology and the survival of cereals and other crops under drought conditions. According to the inter-African pedological classification of D'Hoore (1968) the Nigerian loess plain soil, is grouped amongst the Ferruginous tropical soils because of the presence of hard concretions from iron-pan formations of different geological ages.

Lombin and Esu (1987) studied characteristics and management problems of soils of the Nigerian Savannah. They discussed the morphological properties, particle size, chemical properties etc but did not investigate the elemental abundances of these soils.

Trace analysis of major and minor elements either in aquatic or terrestrial environments such as sediments, rocks, and soils has equally been carried out using micro-probe techniques (Ewa and Dim 1989; Borkhodoer, 1998; Haskin, 1998; Duliu *et al.,* 1999). These works were limited and not directed to the Nigerian savannah soils

Bromfield (1972) investigated Sulphur in Northern Nigeria soils limiting his work to only one element. Mosugu et al., (1999) equally studied the *Alfisols* of the savannah basing his data on one element which is Iron.

Jayeoba (1997) assessed soil fertility restoration under fallow in Nigerian savannah. His work included soil property, organic matter with a few inorganic elements.

Land use aerial photographs for the Nigerian savannah have been identified without reference to soil element content by Field and Collins (1986)

Some of the earlier studies including Kowal (1970); Jones (1973) were limited to the Samaru Savannah soils with reference to particle size distribution, density, hydraulic conductivity field capacity, porosity and organic matter measurements.

Further attempt on trace element analysis of Nigerian soils is as reported by Ewa *et al*., (2000) for Zaria soils. This study goes beyond all these previous work reported in that soil samples were obtained from ten states within the three savannah belts (Guinea, Sudan, Sahel) and at twenty–two agrarian locations.

The samples were collected within the savannah regions of northern Nigeria across ten states namely, Adamawa, Borno, Yobe Bauchi, Gombe, Plateau, Jigawa, Kano, Zamfara and Sokoto. The sampling locations in these states are fair representations of soils of the Guinea, Sudan and Sahel savannah belts.

1.3 Justification

One of the applications of a research reactor like the Nigerian Miniature Neutron Source Reactor (MNSR) is in the field of Neutron Activation Analysis (NAA) of environmental and geological samples like soils for the determination of trace elements. The activation analysis has been applied to a variety of samples, and is particularly useful for small sample weights (1mg or less).

Among the various forms of NAA that is currently being undertaken at the Center for Energy Research and Training (CERT), Ahmadu Bello University, Zaria using this reactor, is both the standard and single comparator method. The latter has become the most popular and relatively faster analytical method (De Corte, et al 1987). It is not an expensive method and is the best and cheapest method of acquiring necessary data quickly more so if the samples are many. The Miniature Neutron Source Reactor (MNSR) used for this work is available at the Centre for Energy Research and Training (ABU Zaria) thereby justifying the methodology proposed for the work.

Another major justification of this work is that the identification of the trace elements in the soils serve as a measure of soil fertility. Since the savannah soils are useful for the growth of cotton, groundnuts and cereals, trace element data obtained in this work will be useful for the agrarian communities of Adamawa, Borno, Yobe, Bauchi, Gombe, Jigawa, Kano, Zamfara and Sokoto where the soils were sampled.

Agrarian investigations for soil require adequate knowledge of their physical properties. It is for this reason that each sample site should be investigated for the soil Colour, bulk density, conductivity and soil pH which are all collective variants that assist in soil formation and could in-turn indicate the soil fertility for the growth of crops for human sustenance. These are the major justifications for this work.

1.4 Objective

There is tremendous macro-and micro variability of elements in the various types of soils that occur in the Nigerian savannah as is the case with most lands which fall within the tropical latitudes of the ten soil types classified according to the USDA (1975) soil survey. The major soil orders that favor agro-ecological development include, Alfisols, Inceptisols, Entisols and Vertisols. Klinkenberg and Higgins (1963) identified Alfisols as the most common of the 23 units occurring in the savannah. It had 10 units thus comprising about 43% of the soil of the area. Derived from pre-Cambrian crystalline basement complex, these leached and slightly acid (pH 5.0 – 7.0) soils are commonly found in the Guinea savannah zones. Savannah soils are well drained and shallow and have loamy sand to sandy loam texture in the top-soil and argilic sub-soils (Harpstead, 1973; Ewa *et al.*, 2000)). The soils are susceptible to erosion as a result of their sandy nature. It is for this reason that soil amendment processes mostly fertilizer applications have been constantly applied to the savannah soils. However, such agrarian interventions may not be self-assigned if the soil micro and macro nutrients in the form of trace elements are not known. Identification of these elements within the Nigerian savannah zones (Guinea, Sudan, and Sahel) became the main motivation for carrying out this research work. This study therefore has as its major objectives the following:-

(i) Application of the NIRR–1 research reactor for the socio-economic development of Nigeria through the determination of elemental abundances of the Northern Nigeria savannah soils.

(ii) Measurement of the physical properties of savannah soils such as soil Colour, bulk density, conductivity and pH.

(iii) Identification of elemental groupings based on their savannah zones (Guinea, Sudan, Sahel) for each site which in turn represents farming communities that support the turnover of agricultural products in the major cities within the savannah belts.

(iv) Stimulating the justification for the need for an extension of this project which presently covers a narrow grid thus sensitizing the need for a complete soil map of the northern savannah region.

CHAPTER TWO

SOILS OF NIGERIA AND SAMPLING

2.1 Classification of Soils

The major soils types of Nigeria based on the FAO genetic classification system are four namely:-

(i) Hydromorphic soils

(ii) Regosols

(iii) Ferralsols and

(iv) Highly ferruginous tropical soils

2.1.1 Hydromorphic Soils

The Hydromorphic and organic soils developed on alluvial, marine and fluvial-marine deposits of variable texture. Although there is a distinction between those developed on sandy deposits and those developed on fine texture parent materials, the one developed on fine texture have a higher natural fertility and greater water retention during the dry season, than the one developed on the sandy soils.

In the coastal depressions and flats the muddy deposits give rise to swamps. The most extensive mud flats are found in the Niger delta. But behind the coastal sand ridges and swamps is a flat area of land known as the “flat sandy plains”. The clay deposits occur in lenses on these sandy plains. The flat sandy plains are though to offer the greatest opportunities for developing dairy farming in the coastal region. (Areola and Faniran, 1975).

Also flood plain soils are found along the major river valleys such as those of the Benue, Niger and Sokoto.

2.1.2 Regosols

The Regosols soils occur mainly in the Chad Basin. They are brown to grey-brown coarse sandy soils developed on desert sand drift, found principally in central Borno and the north-eastern margins of the Kano region. These soils apart from the poor profile development and low water retention, their productivity are further impaired by the lack of adequate vegetation cover to supply soil organic matter. Then the river valleys and depressions have markedly clayey soils (Vertisols). These are the characteristics of wet-land soils locally termed "*Fadama*".

2.1.3 Ferralsols

The ferralsols soils cover large part of the country and follow the belt of, sedimentary rocks. Ferralsols are deeply weathered red and yellowish brown with abundant free iron oxides. The soils vary in the humid forest region to the drier savannah areas. The ferralsols are mostly loams, sandy loams, and in some places, sandy-clay loams, which makes them easy to cultivate.

In the south-eastern Nigerian, particularly in Enugu, Imo, Anambra and Abia states, the loose sandy soils have completely broken down structurally due to over cultivation. While in the hill summits and slopes the soils have been washed away leaving the fragments of degraded late rite crusts strewn all over the land surface.

But further north, on the Nupe sand stones, the soils are less leached because of lower mean annual rainfall. In the Cross-river basin to the lower Benue valley, mostly clayey soils developed on sedimentary deposits are found. Poorly drained, including swampy, soils occur extensively in this region as a result of the heavy red-yellow clay soils.

2.1.4 Highly Ferruginous Tropical Soils

The highly ferruginous tropical soils are probably the most important group of soils in Nigeria because they cover the greater proportion of the country. The soils are derived mainly from the basement complex and old sedimentary rocks; although over the northern high plains they are developed on drift material covering the both sedimentary and the crystalline rocks.

In the savannah regions to the north the terrain consists of isolated rocky hills and hill ranges rising above extensive plains dissected by streams.

The drift soils, which cover most of the northern plains, may be grouped in to two, the Zaria and the Northern drift soils. The northern drift soils are coarser and they tend to be shallower, less water retentive and lower in natural fertility.

The Zaria soils are very fine-textured heavy soils which became water logged during the rainy season. However, these clay soils with dark hummus-rich to horizons are the main stay of the cotton - growing for which Zaria region is famous. These soils have been studied extensively for trace element analysis (Ewa *et al.*, 2000).

The Zaria soils like those of the Cross-River, Benue valley, and the depressions and valleys in North-Eastern Nigeria are examples of Vertisols. Vertisols are wide spread

basalt, and alluvial clays. The clay fraction is generally more than 30% and cat ion-exchange capacity is in excess of 30 milli-equivalents per hundred grams of dry soil.

2.2 Savannah Soils in Nigeria

There are two broad vegetation zones in Nigeria mainly the forest and savannah belts (Fig. 2.1) each, with three sub-types viz:

Forests:	a.	Salt-water swamp
	b.	Fresh-water swamp
	c.	High Forest
Savannah:	a.	Guinea Savannah
	b.	Sudan Savannah
	c.	Sahel Savannah

There is also a rare type called the mountain vegetation sparsely distributed within the country in mountainous regions.

The savannah belts of Nigeria (Fig. 2.1) cover three – quarters of the entire land. It starts around Enugu (6.5^{o} S.E) up to Maiduguri (11.5^{o} N.E) across to Sokoto (13^{o}N.W). Samples were taken at sites located at Numan in Adamawa at latitude of 9.5^{o} N.E up to Maiduguri in Borno of latitude 11.5^{o} N.E across to Sokoto at latitude 13^{o} N.W. . The savannah series consists of moderately well drained, slowly permeable soils that have hard concretions. Where they are formed in loamy marine or fluvial terrace deposits they exhibit nearly level to moderately steep soils with ranges of 0 to 15 percent.

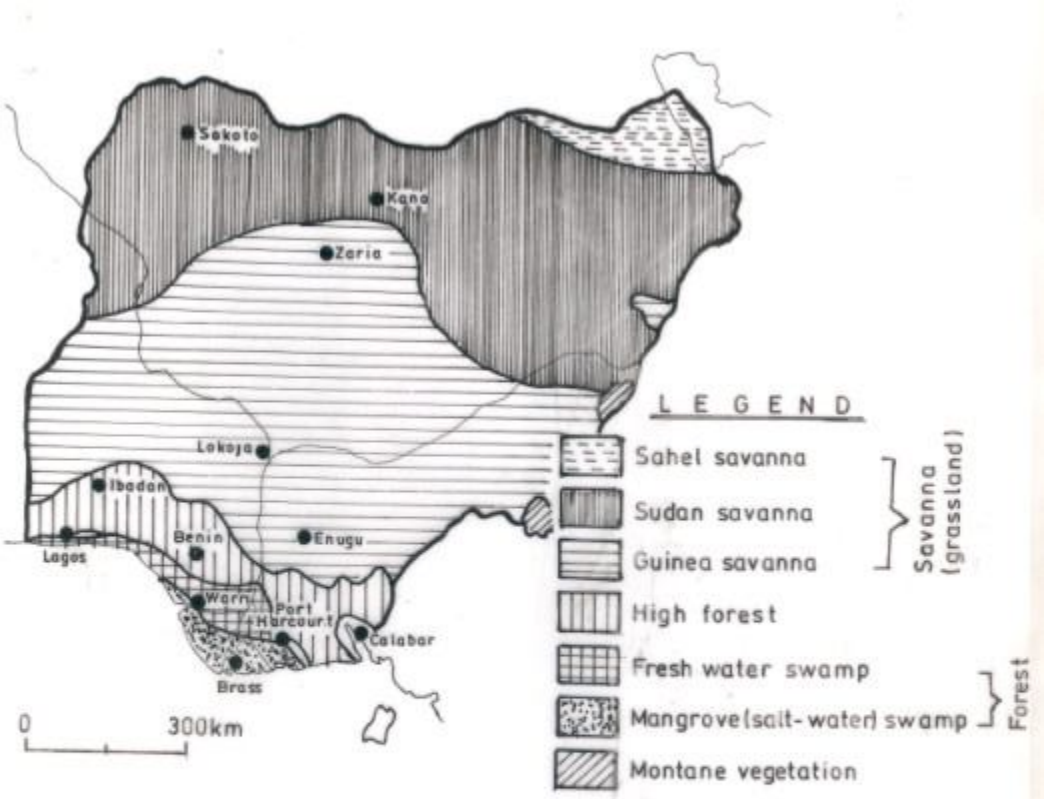


Fig. 2.1 Map of Nigeria showing the Savannah zones

The savannah vegetation cover is characterized with very few timbers and more of stunted shrubs only useful as firewood (Areola, 1980).

Within the savannah study zone, there are some soil factors, which make each soil to depart from the general pattern of the vegetation zones. Three of such soils are considered:

(i) Soils made up of clay, which makes them waterlogged in the wet season because of the impermeability. In the dry season, the clay dries, shrinks and cracks. These areas are known locally as *firiki*

(ii) Soils easily blown away by the wind, because they are composed of fine materials. The erosion leaves bare parches of exposed infertile subsoil, covered by few dwarfed plants and no grass at all. The local name for these areas is *farko,* and finally

(iii) Flat plains of rivers, where the soils are annually flooded in the wet season. They go by the local name ***Fadama***. These soils are economically viable because cash crops like rice, millet and corn are extensively cultivated on them in the wet season as well as the dry season

The study was limited to sampling sites along these savannah belts described above and sampled from agrarian communities near the cities as shown in Fig. 2.2. The major objective of this study also, is to determine the major, minor trace elements of the savannah soils in Nigeria, to serve as a measure of soil fertility (Fig. 2.2).

2.3 Physical Properties of the Nigerian Savannah Soils

The Nigerian Savannah Soils (NSS) comprise of the main savannah belts which include the Sudan, Guinea and Sahel. The physical properties of the NSS are horizon, soil Colour, soil conductivity, soil bulk density, and soil pH.

2.3.1 Soil Horizon

Most soil horizons are unique and therefore the nature of the horizon sampled for any analysis should be carefully chosen so as to obtain optimum physical properties of interest. For agricultural purposes the O horizon is usually the sampling zone of interest

and for this work the choice of this horizon was based on the information provided in Table 2.1

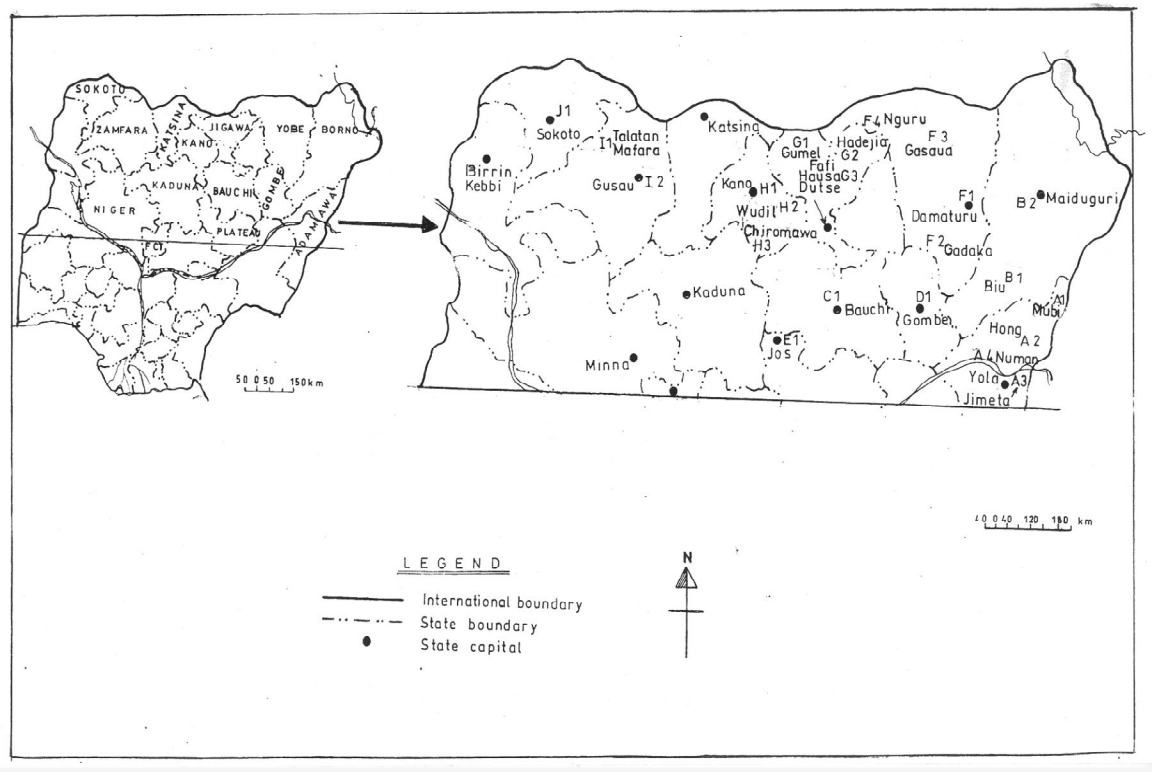


Figure 2.2 Map of Nigeria showing towns (sample site) that fall within the three savannah belts.

However knowledge of the different zones is usually necessary to complement the study data. Samples were taken at the depth of 40 cm basically within the O horizon. The major grown crops in the chosen sites of study are cereals such as, maize, millet, rice, acha, sorghum etc.

The grid system sampling was not adopted here due to its little significance to the socio-economic development of the inhabitant of savannah, rather sites were chosen where there highly developed farming communities exist.

For future work we recommend the use of the grid system though cost prohibitive for the sampling of the entire savannah belt so as to obtain an appropriate representation of the trace element levels of the savannah soils.

Table 2.1 Classification of Soil Horizons (After Miller and Donahue, 1997)

Current	Old	Description
O	O	Organic horizons of minerals soils. Horizon (i) Formed or forming in the upper part of the mineral Soils (ii) Dominated by Fresh or partly decomposed organic materials and (iii) Containing more them 3-% organic matter if the mineral fraction is more than 50% clay.
Oi	O1	Organic horizons in which essentially the original form at Most vegetative matter is visible to the naked eye. The Oi Corresponds to the L (litter) and Oe or Oa to fermentation Layer in forest soils designations and to the horizons Formerly called Aoo or O1.
Oa or Oe	O2	Organic horizons in which the original form of most plant Or animal matter cannot be recognized with the naked eye. The Oa corresponds to the H. (humifilation) and Oe to F (Fermentation) layers in forest soils designations and to the horizon formerly called Ao or O2.
A	A	Mineral horizons consisting of: (i) Horizons of organic matter accumulation formed or Forming at or adjacent to the surface, (ii) Horizons that have lost clay, iron, or aluminum With resultant concentration of quartz or other resistant minerals of sand or self.

2.3.2 Soil Colour

The fact that black-coloured clothes absorb more heat than white ones is a well-known principle in Physics. Similarly, dark soils absorb more heat than light coloured

ones. The Colour of a soil is used to indicate physical and chemical characteristics, which are due to two factors, humus content and the chemical nature of the iron compounds present in the soil. However, between contrasting climatic conditions, Colour is not a good indicator of organic matter content, because some partially decomposed humus is darker in some environments than in others.

Soil Colour determination can be standardized and determined by the comparison of the soil Colour and the Munsell colour charts (Miller and Donahue, 1997) as illustrated in Fig.2.3.

The Munsell colour chart is divided into three parts.

i. Hue with the dominant spectral or rainbow colour red, (R), green (G), or yellow (Y), with a score from 0 to 10 so that, the highest figure for red corresponds to the lowest figure for yellow.

ii. Value which is the variation in colour between black and white and it also ranges from 0 to 10 and

iii. Chroma which describes the purity of the hue and it has numerical value from 0 to 10.

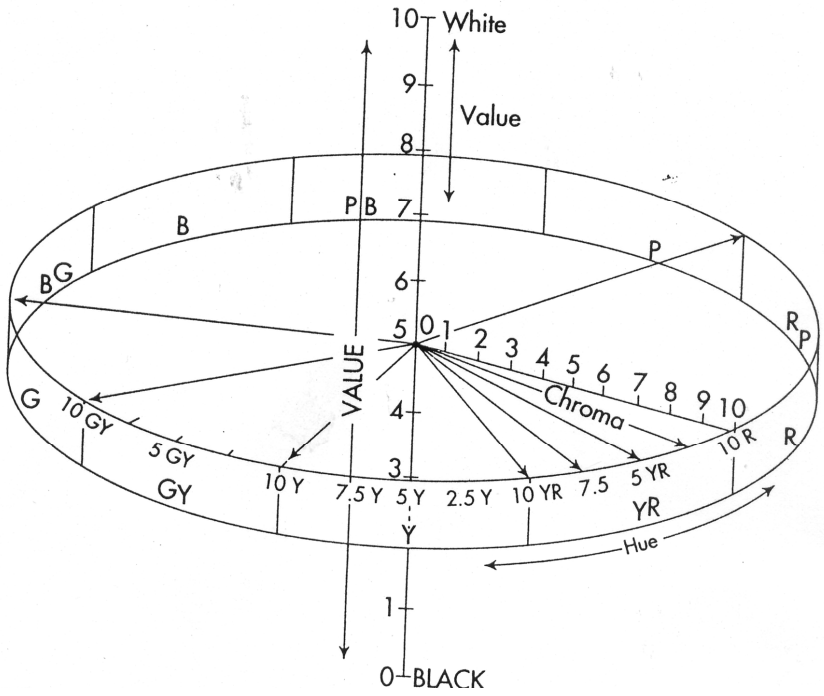


Fig. 2.3 Illustration of the Munsell Colour Scheme
(After Miller and Donahue, 1997)

The soil colour can be affected by moisture content, so it is necessary to specify either wet or dry soil. Using the Munsell score for each soil sample analysis for example 5R8/6 describes the colour of a certain red soil with a value of 8 and a Chroma of 6.

Table 2 .2 A typical profile of one site of the savannah soil sampled.

Depth (cm)	Description
0-11	Very pale brown (10YR 7/3, dry). Loam: Weak medium sub-angular blocky structure, slightly hard, moist firm, few grass roots, few quartz gravel, clear wavy boundary
11-27	Very pale brown (10YR 8/3, dry). Light loam: weak medium sub-angular blocky structure, dry slightly hard, few grass roots, few quartz gravel, clear wavy boundary
27-75	Light gray (10YR 7/3, dry). Mottled reddish yellow loam: moderate, medium sub-angular blocky structure, dry hard few quartz gravel, few ant holes, gradual wavy boundary
75-129	Light gray (10YR 7/3, dry). Mottled reddish yellow loam, moderate medium sub-angular blocky structure, dry hard, few quartz gravel and iron concretions, few medium ant holes, gradual wavy boundary.
129-148	Very pale brown (10YR 8/3, dry). Mottled reddish yellow light loam moderate, medium sub-angular blocky structure, dry hard few dead fibrous roots, gradual smooth boundary.
148-186	Very pale brown (10YR 8/3) mottled dark brown and reddish yellow fine sandy loam, moderate medium sub-angular blocky structure merging to similar layers.

Most of the colour scoreμ and value for these soils was in the range of 10YR which is characteristic of tropical hard pan ferruginous soils.

2.3.3 Soil Bulk Density

An important property useful in characterizing the structural state of a soil is the bulk density. The density of a volume of soil as it exists naturally includes any air-space and organic materials in the soil environment. Since the bulk density is usually calculated for dry soils it implies that water is not often included in the sample weight.

The fewer the pore spaces the greater the bulk density. These pore spaces are volumes occupied by air and water. Cultivation by tillage often increases these air spaces whereas uncultivated soils compacts the soil with decrease in air-space thereby increasing the density. Bulk density values could be used for the calculation of storage capacity per

unit soil volume and evaluation of soil horizons for compactness for the assessment of root penetration. It could be also used as a measure of assessment of the aeration for the root system penetration. Basically it was calculated in this work using the expression in Eqn. 2.1

$$\text{Bulk density} = \frac{\text{Weight of Soil}}{\text{Volume of Soil}} \qquad 2.1$$

Where the:

Weight of the soil is in grammes and the volume of soil measured in $(\text{centimeter})^3$

2.3.4 Soil Conductivity

Soil conductivity is a measure of the electrical conductivity of soluble salts present in a soil matrix. The S.I unit of conductivity is Siemens per meter (Sm^{-1}). Since soil solutions are often weak electrical solutions the unit is usually in the low range of μSm^{-1}. The conductivity for the samples investigated was determined using a soil to distilled water ratio of 1:2. The conductivity meter WTW Model LF90 was used for the measurements at temperature set at 27°C

2.3.5 Soil pH

The term *pH* is derived from the French word *pouvoir Hydrogène*, meaning 'hydrogen power'. Soil reaction could be expressed as a pH value. The pH is the scale of soil acidity or alkalinity whose unit is the pH value. The neutral point in this scale is at

a pH of 7.0. All values above pH 7.0 represent alkalinity and all values below 7.0 denote acidity level of the soil. The pH therefore is an indication of the acidity or basicity of the soil and measured in pH units.

The pH (logarithmic) scale ranges from 0 to 14 with pH 7 as the neutral point. At a pH of 7, hydrogen ion concentration (H^+) equals the hydroxyl ion concentration (OH^-). Using the scale it is known that from pH 7 to 0 the soil is assumed to be increasingly acidic whereas from pH 7 to 14 the soil is increasingly more alkaline (basic).

The pH values were measured using a soil to water ratio of 1:2. The mixture was well stirred, after which the electrode was dipped into the system, allowed to stabilize for five minutes thereafter the pH and temperature were read using the JENWAY pH meter model 3150. The meter was earlier calibrated using buffer solutions of pH 4.0 and 7.0. A two-point calibration was performed by dipping the electrode first into the buffer solution of pH=4 and the meter reading allowed to stabilize. The display was then updated and corrected to the standard buffer value. The electrode was removed, rinsed and the process repeated for a buffer solution of pH=7 and then the system was returned to the pH mode ready for use.

2.4 Soil Sampling and Sample preparation

2.4.1 Sampling

The samples were collected from the following farming communities in the Savannah belts of Nigeria, Mubi, Hong, Jimeta, Numan, Biu, Maiduguri, Bauchi, Gombe, Jos, Damaturu, Gashua, Nguru, Gumel,. Hadejia, Kafin-Hausa, Kano, Wudil,

Chiromawa, Talatan-Mafara, Gusau, Sokoto and Gadaka.(Fig. 2.2). Since the root penetration of cereals grown within the savannah are usually in the range of 20 to 50 cm depth, the top 20 cm of the soil were scrapped off in order to remove traces of surface contamination due to human activities. This allowed for representative sampling of an uncontaminated O horizon. About one kilogram of the soil sampled was taken to the laboratory for homogenization and quartering.

2.4.2 Sample Preparation

Sample preparation and encapsulation procedures in neutron activation analysis may be different for different matrices such as vegetation, rocks or soils. While rock samples require crushing soil samples may be merely ground to finer particles to allow for uniform fluency of neutrons through the samples during irradiation. The samples obtained from different sampling sites were exposed to ambient air in a dust-free environment before drying to constant weight in a monitored oven at a temperature of 50°C.

Soil samples were then pulverized with an agate mortar into a fine powder, reducing them to about 80 mesh size (IAEA, 1990). The major aim of this was to allow a representative sample to be chosen as an aliquot for the analysis.

Polyethylene vials and bags were washed in Nitric acid and rinsed in purely distilled water and dried. The samples were weighed into the bags wrapped, heat-sealed and placed into a 2/5 dram vials. The wrapped samples were plugged with cotton wool in the 2/5 dram vials so as to maintain a fixed geometry. Standards were prepared and packaged in the same manner as the samples. The International Atomic Energy Agency (IAEA) Soil –7 was used as the comparator Standard Reference Material (SRM). Both samples and standard were submitted into the reactor for irradiation.

CHAPTER THREE

METHODOLOGY

3.1 Trace Element Detection

In activation analysis, an element is always bombarded with neutrons, charged particles or photons. The excited intermediate is formed by the induced nuclear reaction of which it may be de-excited via the emission of prompt γ-rays

Trace element detection in neutron activation analysis consists of first irradiating a sample with neutrons from a source (e.g. a nuclear reactor) to produce specific radio nuclides of the elements of interest.

The sample to be analyzed is exposed to a flux of thermal neutrons. Some of the neutrons are captured by isotopes of elements in the sample, this result in the formation of a nuclide with the same proton number, but with one more mass unit of weight. Then a prompt gamma ray is immediately emitted by the new nuclide, hence the term (n, γ) reaction, expressed as:

$$^{m}_{z}A + {}^{1}_{0}n \rightarrow {}^{m+1}_{z}A + \gamma \qquad \textbf{3.1}$$

Where Z = refers to the proton number, and

M = the mass number

But usually the product nuclide $\left({}^{M+1}_{z}A\right)$ is radioactive, and by measuring its decay products one can identify and quantify the amounts of target element in the sample.

3.1.1 Neutron Activation Analysis (NAA)

The most common form of activation analysis is the Neutron Activation Analysis (NAA) in which the activating particles are the neutrons. Usually, after the activation the delayed γ radiation is detected from the radioactive product nuclide.

Neutron activation techniques fall into three categories. Firstly, if no chemical treatment is done, the process is called Instrumental Neutron Activation Analysis (INAA). Secondly, if chemical separations are done after irradiation to remove interferences, the techniques is called Radiochemical Neutron activation analysis (RNAA). Thirdly, an analysis is called Chemical Neutron Activation Analysis (CNAA) if pre-irradiation chemical separations are employed. The first method named INAA was used during this work.

3.1.2 Theory of Neutron Activation Analysis (NAA)

The basic equation used for the calculation of NAA with the account for the decay of the radio nuclides after the irradiation period is given as

$$A = Nf\sigma\left(1 - e^{\frac{-0.693t}{T_{1/2}}}\right) \qquad 3.2$$

Where A=activity of product nuclide (disintegrations per second)

N=atoms of target element

f=flux of neutrons (neutrons per cm^{2}-s)

σ=cross section of the target nuclide (cm^2)

$T_{1/2}$=half-life of induced radioactive nuclide

t =time of irradiation

To use the equation that involves the decay of the radio nuclides, the absolute activity of the irradiated sample most be measured. The use of a comparator method was employed in this work, where a standard containing a known amount of the element to be determined is irradiated together with the samples. In this case, it is assumed that the neutron flux, cross sections, irradiation times and all other variables associated with counting are constant for both the standard and the sample. Rewriting the equation using a comparator method we have:

$$\frac{R_{std}}{R_{sam}} = \frac{W_{std}(e^{-\lambda T})}{W_{sam}(e^{-\lambda T})} \qquad 3.3$$

Where R = Counting rates for standard (Std) and Samples (Sam)

W = mass of the sample (Sam) and (std)

T = decay time.

Most of the standard reference materials (SRM) sources often used as the primary standard are prepared by the National Institute of Standards and Technology (NIST) and the U.S Geological survey (USGS) in U.S.A. and the International Atomic Energy Agency (IAEA) in Vienna.

3.2 The MNSR Research Reactor

The Miniature Neutron Source Reactor (MNSR) is a nuclear facility, for neutron activation analysis. The neutrons produced emanate from a fission process. Through elastic collisions with moderator nuclei, the fission neutrons rapidly become thermalized creating a broad energy distribution consisting of three principle components thermal, epithermal and fast. Neutrons used in this work for INAA are usually the thermalized ones due to the relatively high cross sections for radioactive capture (n, γ) reactions. Basically the MNSR reactor in CERT, A.B.U., Zaria could be used for the preparation (in

a small quantity) of short-lived radioisotopes for research purposes and teaching and training. Such a low power reactor is useful for research purposes in universities.

The MNSR adopts the pool-tank type reactor configuration which gives multiple defenses for shielding radioactive materials and easy to control. There are five small rabbit irradiation sites inside beryllium annulus and two large rabbit irradiation sites and three small ones outside beryllium annulus. When the reactor operational power is about 30KW, the neutron flux inside the inner irradiation sites is $1x10^{12}n/cm^2s^{-1}$.,while the outside irradiation site is about $0.5x10^{12}n/cm^2s^{-1}$.

Table 3.1 Some of the main parameters of the Nigeria Research Reactor (MNSR).

Reactor Type	Pool Tank
Rated thermal power	31 kW
Fuel	UAl alloy dispersed in Al base material
U-235 Enrichment	90.2
Core Shape	Cylinder
Core Diameter	23 cm
Core height	23 cm
Fuel element shape	Thin rod
Refuel period	More than ten years
Control rod (Cd)	One in the Centre of the core
Thermal neutron flux (inner sites)	$1 \times 1\ 10^{12}$ n cm^{-2} s^{-1}
Thermal neutron flux (outer sites)	$5 \times 1\ 10^{11}$ n cm^{-2} s^{-1}
Reactor cooling mode	Natural convection

SOURCE: YANG (1992)

3.2.1 Irradiation

For the short-lived irradiation, the sample and standard were irradiated at the inner channel of the MNSR reactor operating at 30 kW thermal with a neutron flux of 2.5 x 10^{11} n cm^{-2} s^{-1}.for Long-lived irradiations were performed for six hours. After the short-lived irradiation the sample was allowed to decay for 5-15 minutes and counted for 600s in a HPGe detector. The cooling time for the long lived irradiation was 3-4 days and counting was performed for 1800s for the first count followed by another counting lasting 3600s. The HPGe detector was calibrated using ^{127}Cs and ^{60}Co sources. The relative efficiency of the HPGe detector was 43.4 for the 1332 keV peak of ^{60}Co while the Peak – to-Compton ratio was found to be 70.7.

3.3 Gamma Ray Spectroscopy

Detector efficiency depends on energy of the radiation, position of the sample relative to the detector, thickness and composition of the detector window. The efficiency curves of the detector system at near and far source-detector geometries have been determined by standard gamma-ray sources in the energy range of 59.5-2254 keV and were extended to 4000 keV by a semi empirical method (Jonah et al 2006). For the data processing, we use the gamma ray spectrum analysis software WINSPAN 2004 (Liyu, 2004), a software developed at CIAE, Beijing, China.

On the basis of the well-known activation equation, the software requires that calibration factors be pre-determined by a multi-element standard reference material for elements of interest using adopted irradiation and counting regimes. For the short irradiation regime, the first round of counting was performed for 10min (i.e.S1) after a

waiting time of 2min. Samples were placed on a plexi-glass sample holder designated as H2 which corresponds to source-detector geometry of 5cm. The second round of counting also carried out for 10min, following the short irradiation regime (i.e.S2) after a waiting period of 3-4hrs. Samples are counted on a plexi-glass holder designated as H1 corresponding to a source-detector geometry of 1cm. With respect to the long irradiation regime, the first round of counting was carried out for 30min, following the long irradiation (i.e.L1) scheme after a waiting period of 4-days and using the holder H1. The second round of counting was performed for 60min (i.e.L2) after a cooling time of 10-15days. Samples are counted using the plexi-glass holder H1. The choice of the cooling time and sample-detector geometry is such that the detector's dead time is controlled to be less than 10%.

3.4 Data Analysis

Data for the elemental analysis were subjected to statistical treatments using the Cluster Analysis

3.4.1 Cluster Analysis

Large data-sets of elements determine by instrumental neutron activation analysis (INAA) require meaningful interpretation in order to determine the pattern of their existence in host matrices. This could be achieved using cluster procedures. The abundances elements determine from the prepared soil samples from twenty-two sites of the three Nigerian savannahs. Were

(Al, Ba, Br, Ca, Ce, Co ,Cl, Cr, Cs, Dy, Eu, Fe, Hf, K, La, Lu, Mg, Mn, Na, Rb, Sb, Sc, Sm, Ta, Th, Ti, V, and Yb)

Cluster programmes produce a pattern that allows for a more resolved visualization of the similarity existing between objects (e.g. soil samples) from different savannah belt as related to their determined variables (i.e. element concentrations) especially when data set is very large as in the case of this study.

This statistical procedure systematically places objects into fairly homogenous groups called clusters. This is achieved by a reduction of the n-dimensional determined space in which the samples exist as points, to a plane permitting increased readability, pattern recognition and size reduction of the classifying parameters investigated (Ewa, 2003).

Cluster analysis is most useful where most statistical methods cannot satisfactorily interpret spatially heterogeneous concentrations associated with soil samples (Ewa, et al 1992).

Excellent treatment of cluster methods as a statistical tool could be referred to in works authored by Oladipo, (1987); Ewa (2003), and Ewa et al (1992).

3.4.2 Cluster Procedures

The data sets obtained were subjected to cluster analysis using the statistical Analysis System (MINITAB, 1985) computer software. The statistical analysis systems program of the computer MINITAB Inc, 3081 Enterprises Drive State College PA 16801 – 3801 was used. The statistical package MINITAB has six linkage method and five distance measure. For the analysis, ward linkage method were used and the measured. Euclidean distances

Ward's method commences with the number of clusters equal to the number of samples. This formation allows a cluster to be within another cluster and not overlapping with other clusters (Ewa, 2003). Cluster METHODS based an hierarchical procedures begin by taking each observation as a cluster itself followed by the merging of the two closest to form a new cluster thereby replacing the two old clusters merging of two closest clusters is then repeated until only one cluster is left at the final stage. Hierarchical clustering therefore completes (n-1) fusion steps starting from n clusters, with each step being assigned a similarity coefficient.

This method determines the similarity coefficients in the clustering as a measure of the minimum distance between clusters.

The objective of this cluster analysis was aimed at investigating existing similarities for different types of soils from Nigerian savannah belts based on the concentration of trace elements in each savannah belt. Ward linkage was chosen as a method suitable for cluster analysis in this work as a result of the fact that emphasis was needed to show how similar the data obtained from each soil sample could be with a view to clustering closest neighbours. Other methods used in computing clusters include, average, centroid, median, single and Mcquitt methods (MINITAB, 1985). These methods were not used in the analysis.

Hierarchical clustering of the data sets was achieved using MINITAB, (1985). The method chosen was WARD, aimed at obtaining optimum dispersion of the clusters as similarity decreases. This method determines the similarity coefficients in the clustering as a measure of the minimum distance between clusters.

Clustering methods define the algorithms used in agglomerative hierarchical clustering and consequently determine the manner in which the distance between two closest clusters is computed.

Ward linkage uses stored distance in computing the clusters. With ward linkage specified as method used in this work, the resulting dendrograms obtained show coefficients of the minimum distances between the clusters. Dendrograms were obtained from the output data set. The dendrograms show all the heights (vertical axis) of the nodes (horizontal axis) for flexibility of readership while comparing each cluster.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

The results and discussion on the physical properties of the savannah soils are hereby presented.

4.1 Soil pH

The significance of soil pH is that it affects various soil properties including conductivity (Ghidyal and Tripathi, 1987), soil mineral formation and soil structure. Fig 4.1 shows the relationship with soil pH and conditions for plant environments.

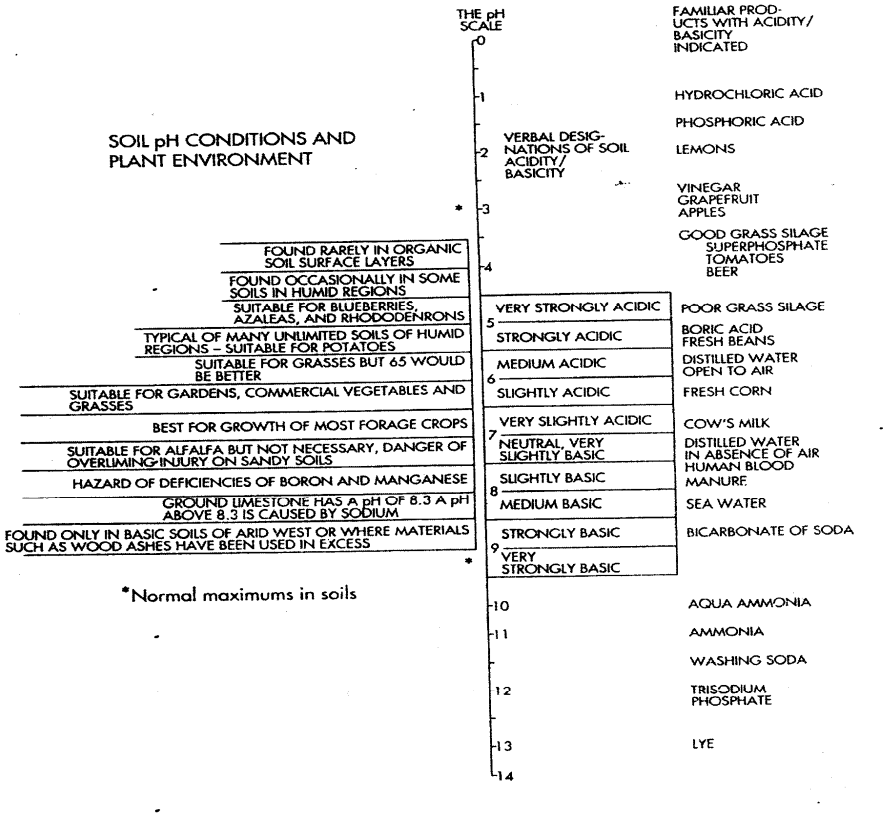


Fig 4.1 Range of pH values as they affect soil conditions and plant environment (After Miller and Donahue, 1997)

According to the pH range shown in Table 4.1 soils from Mubi, Bauchi, Gombe, Kano, Wudil, Chiromawa are strongly acidic.

This may be as a result of either leaching or high soil temperatures during the arid months leading to evaporation of soil water leaving residues of strong undiluted salts. There is therefore likely to be a continuous H^+ in soil solution. Such could be the case with soils of Nguru and Hadejia which are both very strongly acidic with pH values of 4.72 and 4.88 respectively. Soil amendment process such as addition of lime (CaO) will be preferable in order to reduce the acidity (Miller and Donahue, 1997).

Table 4.1 Soil pH values for the samples investigated at a temperature of 27°C

S/N	Soil Location	Savannah region	pH	Remarks
1.	Mubi	Guinea	5.00	Strongly acidic
2.	Hong	Guinea	5.51	moderately acidic
3.	Jimeta	Guinea	5.40	moderately acidic
4.	Numan	Guinea	5.50	moderately acidic
5.	Biu	Sudan	5.20	Strongly acidic
6.	Maiduguri	Sahel	5.40	moderately acidic
7.	Bauchi	Guinea	5.30	Strongly acidic
8.	Gombe	Guinea	5.14	Strongly acidic
9.	Jos	Guinea	6.05	Slightly acidic
10.	Damaturu	Sudan	5.73	Slightly acidic
11.	Gadaka	Sudan	5.52	Slightly acidic
12.	Gashua	Sudan	5.40	Strongly acidic
13.	Nguru	Sudan	4.72	Very strongly acidic
14.	Gumel	Sudan	5.27	Strongly acidic
15.	Hadejia	Sudan	4.88	Very strongly acidic
16.	Kafin Hausa	Sudan	5.10	Strongly acidic
17.	Kano	Sudan	5.23	Strongly acidic
18.	Wudil	Sudan	5.17	moderately acidic
19.	Chiromawa	Sudan	5.05	Strongly acidic
20.	Talatan-Mafara	Sudan	5.4	Strongly acidic
21.	Gusau	Sudan	5.5	Strongly acidic
22	Sokoto	Sudan	5.5	moderately acidic
	Mean values:	Guinea = 5.4 ± 0.3		
		Sahel = 5.3 ± 0.3		
		Sudan = 5.4		

4.2 Soil Conductivity

Conductivity range gives the range of tolerance of the plant root system to salt solutions. Miller and Donahue, 1977 gives the range of electrical conductivity as it affects growth of plants.

Table 4.2 Conductivity range and plant tolerance

Conductivity (μScm^{-1})	Growth reduction by salt in soil
0-20	Few plants are affected
20-40	some sensitive plants affected (Strawberries)
40-80	many plants are affected
80-160	most crop plants are affected
160 and above	Few plants grow well

From our results given in Table 4.3, soils from Mubi (Guinea) and Damaturu (Sudan) had high conductivity values. This implies soil vegetation may be affected by this value amongst other soil physical parameters. This explains probably why the vegetation in this savanna is usually sparse.

Table 4.3 Conductivity values for the samples investigated

S/N	Soil Location	Savannah region	Conductivity ($\mu S\ cm^{-1}$)
1.	Mubi	Guinea	332 ± 3.55
2.	Hong	Guinea	94 ± 1.2
3.	Jimeta	Guinea	32 ± 1.1
4.	Numan	Guinea	51 ± 2.2
5.	Biu	Sudan	81 ± 5.3
6.	Maiduguri	Sahel	66 ± 2.1
7	Bauchi	Guinea	60 ± 3.1
8.	Gombe	Guinea	23 ± 1.5
9.	Jos	Guinea	80 ± 1.1
10.	Damaturu	Sudan	512 ± 2.2
11.	Gadaka	Sudan	25 ± 1.4
12.	Gashua	Sudan	27 ± 2.1
13.	Nguru	Sudan	13 ± 2.1
14.	Gumel	Sudan	14 ± 1.1
15.	Hadejia	Sudan	18 ± 1.5
16.	Kafin Hausa	Sudan	20 ± 1.2
17.	Kano	Sudan	20 ± 0.12
18.	Wudil	Sudan	15 ± 1.1
19.	Chiromawa	Sudan	23 ± 1.4
20.	Talatan-Mafara	Sudan	19 ± 2.5
21.	Gusau	Sudan	38± 2.2
22.	Sokoto	Sudan	70 ± 1.2
Guinea average (excluding Mubi)			$57\pm27\mu scm^{-1}$
Sudan average (excluding Damaturu			$29\pm22\ \mu scm^{-1}$
Sahel average			$66\pm2\ \mu scm^{-1}$

4.3 Bulk Density

Table 4.4 shows a list of the bulk densities calculated from soil; sampled within the Savannah zones investigated.

Table 4.4 Soil Bulk densities from the sampled sites

S/N	Soil Location	Savannah region	Bulk density (g cm^{-3})
1.	Mubi	Guinea	1.25 ± 0.17
2.	Hong	Guinea	1.53 ± 0.11
3.	Jimeta	Guinea	1.25 ± 0.17
4.	Numan	Guinea	1.60 ± 0.18
5.	Biu	Sudan	1.20 ± 0.22
6.	Maiduguri	Sahel	1.25 ± 0.17
7.	Bauchi	Guinea	1.40 ± 0.02
8.	Gombe	Guinea	1.20 ± 0.22
9.	Jos	Guinea	1.53 ± 0.11
10.	Damaturu	Sudan	1.32 ± 0.10
11.	Gadaka	Sudan	1.35 ± 0.07
12.	Gashua	Sudan	1.30 ± 0.12
13.	Nguru	Sudan	1.56 ± 0.14
14.	Gumel	Sudan	1.60 ± 0.18
15.	Hadejia	Sudan	1.53 ± 0.11
16.	Kafin Hausa	Sudan	1.30 ± 0.12
17.	Kano	Sudan	1.23 ± 0.19
18.	Wudil	Sudan	1.75 ± 0.33
19.	Chiromawa	Sudan	1.33 ± 0.09
20.	Talatan-Mafara	Sudan	1.33 ± 0.09
21.	Gusau	Sudan	1.35 ± 0.07
22.	Sokoto	Sudan	1.80 ± 0.38
Mean Bulk Density Guinea			1.40±0.17gcm^{-3}
Mean Bulk Density Sahel			1.25±0.17gcm^{-3}
Mean Bulk Density Sudan			1.43±0.19gcm^{-3}

It was observed that while soils from the sites within the Guinea savannah were heavier within the range of 1.25 to 1.6 gcm^{-3} those of the Sudan and Sahel were lighter and notably that of Maiduguri (Sahel savannah) was as low as 1.25gcm^{-3}. This accounts for the noticeable continuous haze of Sahara dust particles blown in the form of aerosols within the Sudan and Sahel savannah belts.

4.4 Elemental Abundances in Savannah Soils

The following listings (Table 4.5) are the mean values of elements determined in the Nigerian Savannah soils.

Table 4.5 Elemental abundances in Nigerian Savannah soils units in ppm or as otherwise stated.

Elements	Savannah		
	Sahel	Sudan	Guinea
Al%	3.72±0.2	2.77±3.18	4.05±1.9
Ba	201±6.7	257.59±150	240.13±122.85
Br	BDL	2.01±1.76	1.9±1.1
Ca	BDL	BDL	1.4±0.0
Ce	60±3.7	51.09±9.9	43.61±11.25
Cl	267.4±40.1	384.7±151.94	195.2±80.73
Co	14.22±3.0	14.47±7.48	21.28±2.8
Cr	34±4.0	21.67±7.2	21.97±5.06
Cs	0.74±0.1	1.29±0.9	0.86±0.1
Cu	BDL	BDL	BDL
Dy	5.88±0.9	8.5±8.0	4.33±1.48
Eu	0.96±0.2	1.24±1.3	1.38±1.0
Fe%	1.20±0.1	2.03±2.9	2.446±1.5
Gd	BDL	BDL	BDL
Hf	24.96±3.0	22.44±3.4	26.08±6.72
K%	2.69±0.1	1.37±0.9	2.0±1.0
La	47.99±6.0	61.04±9.6	44.38±17.8
Lu	0.61±0.1	0.42±0.27	0.51±0.18
Mg%	0.28±0.0	0.24±0.16	0.32±0.09
Mn	BDL	203.61±149.14	233.61±176.6
Na%	0.48±0.1	0.14±0.1	0.56±0.7
Rb	47.6±6.0	36.33±3.2	42.72±10.5
Sb	0.52±0.1	0.75±0.1	0.8±0.1
Sc	3.85±0.1	6.3±7.4	6.09±2.3
Sm	7.92±1.1	8.27±11.7	7.36±3.1
Sr	BDL	BDL	BDL
Ta	1.03±0.1	1.3±0.6	1.07±0.46
Tb	BDL	BDL	BDL
Th	4.74±0.1	10.46±4.75	9.36±5.5
Ti%	0.45±0.1	0.81±0.7	0.44±0.2
V	BDL	19.22±7.9	43.54±23.3
Yb	BDL	3.97±3.1	3.35±3.3

BDL=below detection Limit

The total data sets of elements obtained for all the sampled sites within the three savannahs were subjected to cluster analysis

4.5 Cluster Analysis of data sets

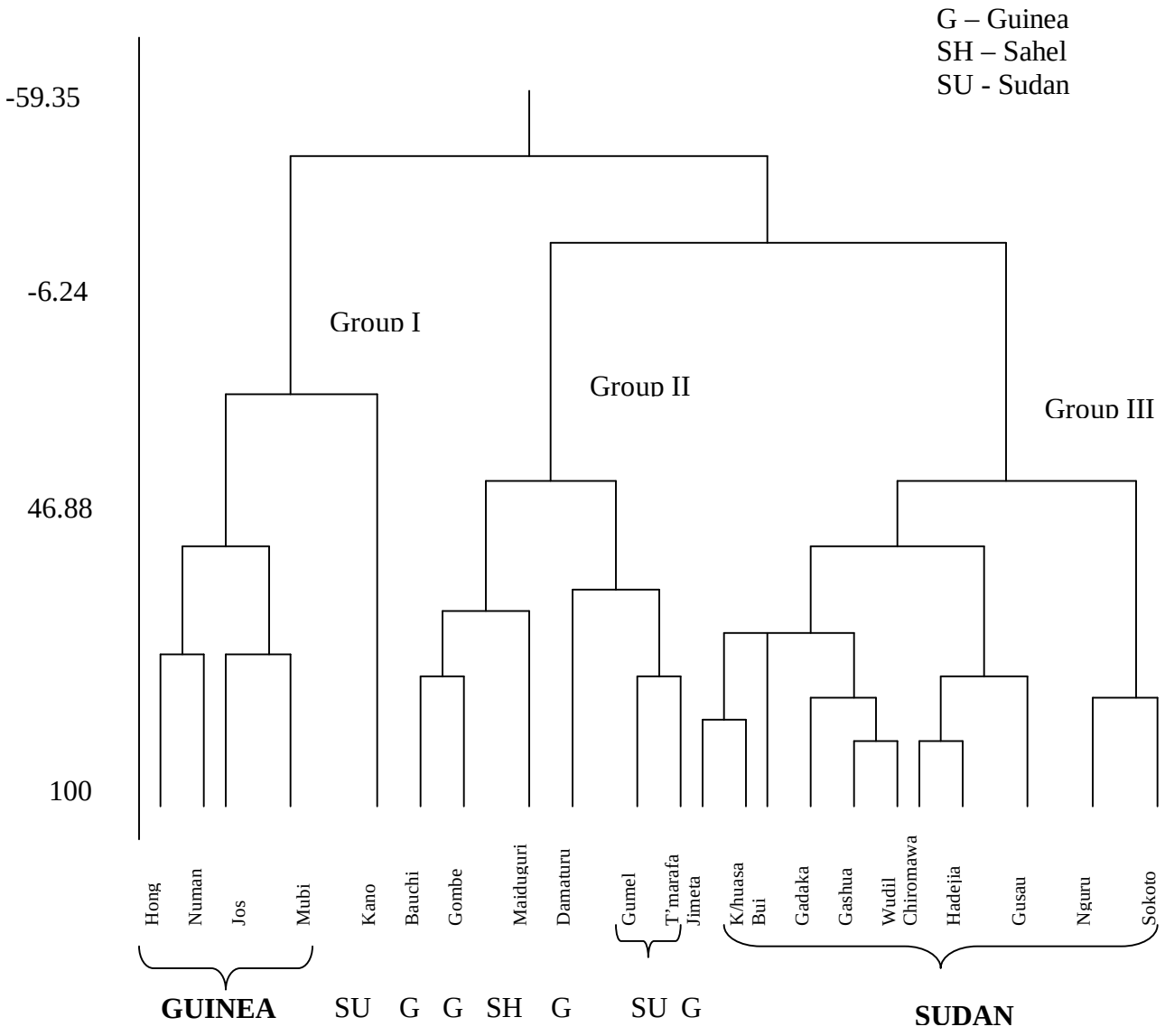
The total number of element concentrations determined in this work is 616 of which 484 were extracted after obtaining their respective means and standard deviations.

. Finally the elemental abundances for all the soil samples were examined using cluster techniques. Tree diagrams called dendrograms obtained from cluster techniques highlighted the similarity existing between elements determined for the various soils studied from the three savannah belts (Guinea, Sudan, and Sahel).

4.5.1 Cluster Dendrograms

Data evaluation resulting in specifying WARD METHOD in the cluster procedure yielded two dendrograms Fig 4.2 and 4.3 as outputs for all the soil samples analyzed.

Three major clusters could be seen from Fig 4.2. At a dissimilarity coefficient of less than 46. 88, five sites (Hong, Numan, Kano Jos, and Mubi) clustered to form one group. Six soil samples sites (Bauchi, Gombe, Maiduguri, Damaturu, Gumel, and Talatan-Mafara) formed a second group and the third group (Jimeta, Kafin Hausa, Biu Gadaka, Gashua, Wudil, Chiromawa, Hadejia, Gusau, Nguru, and Sokoto). From the cluster we see that sites of group I and group III are samples from the Guinea savannah and Sudan savannah respectively.



KEY

SU = SUDAN G = GUINEA SH = SAHEL

Fig. 4.2 Dendrograms showing the clusters of elemental abundances for different Nigerian Savannah soil sites

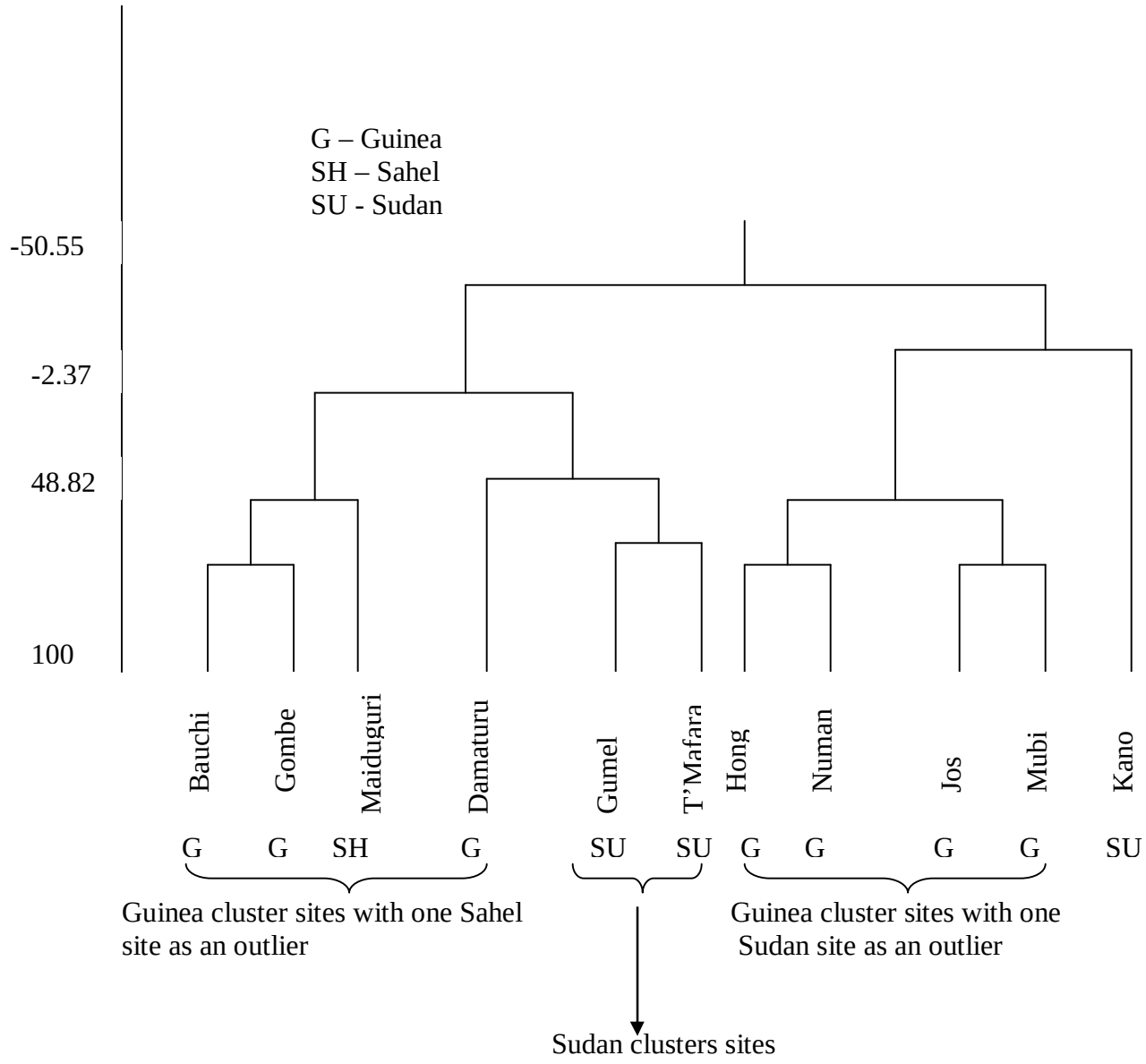


Fig. 4.3 Dendrograms of cluster out-put for Groups I and II only

Table 4.6(a) Soil cluster groupings according to sample site elemental abundances GROUP I

Sampled sites (Towns)	Savannah Groups
Hong	Guinea
Numan	Guinea
Jos	Guinea
Mubi	Guinea
Kano	Sudan

Table 4.6(b) Soil cluster groupings according to sample site elemental abundances GROUP II

Sampled sites (Towns)	Savannah Groups
Bauchi	Guinea
Gombe	Guinea
Maiduguri	Sahel
Damaturu	Guinea
Gumel	Sudan
Talatan-Mafara	Sudan

One success in the result of this clustering procedure is that in the **GROUP III** cluster groups all the samples form the **Sudan savannah** sites clustered together with the exception of Jimeta as an outlier. Outliers show disproportionate effect in multivariate analysis and do not tend to cluster at some levels with their sub-groups (Ewa, 2003). An almost similar grouping occurred in **GROUP I** where all the four samples from the **Guinea Savannah** with Kano as an outlier. In GROUP II cluster group there were mixed clusters of sites from the entire savannah. This could be explained in terms of the fact that the concentrations of the elements were largely dissimilar. The Cluster analysis

therefore is a convincing tool that makes us conclude that the sampling and analysis yielded true reflections and conclusions on the element content of Sudan, Guinea and Sahel soils

Table 4.6(c) Soil cluster groupings according to sample site elemental abundances GROUP III

Sampled sites (Towns)	Savannah Groups
Jimeta	Guinea
Kafin Hausa	Sudan
Biu	Sudan
Gadaka	Sudan
Gashua	Sudan
Wudil	Sudan
Chiromawa	Sudan
Hadejia	Sudan
Gusau	Sudan
Nguru	Sudan
Sokoto	Sudan

The input data also revealed that the concentrations of the elements determined for Maiduguri are grossly different from samples of Sudan and Guinea. This it proves how successful cluster methods could be in segregating data which are dissimilar as shown in this study.

At a coefficient of about 75.34 six sites (Jimeta, Kafin-Hausa, Gashua, Wudil Chiromawa, Hadejia) clustered similar to the sites (Hong, Numan, Jos, Mubi) showing that although they are from different savannah belts yet they have some similarities.

An attempt was made to re-investigate the clustering tendencies (Fig4. 2,) of only group I and group II of (Fig4.3.). Again two classes emerged. First group sites (Bauchi, Gombe, Maiduguri, Damaturu, Gumel, Talatan-Mafara) and the second group sites (Hong, Numan, Jos, Mubi) with Kano now as an outlier sample from Sudan savannah belt. From this segregation, it becomes very obvious that the other samples from different savannah belt have quite different characteristics.

Thus cluster analysis of the elemental concentrations of all the soil sample analyzed confirms that certain soils have close similarities and are dissimilar to others. The result of this analysis is therefore a true indication that the elemental content of soils from different savannah zones (Sudan, Guinea, and Sahel) is different.

4.6 Essential Elements

There are about ninety or more elements found in plants, but only twenty – one elements take part in the growth and development of plants.

The 16 essential elements are Carbon, Oxygen, Hydrogen, Nitrogen, Calcium, potassium, magnesium, phosphorus, Sulphur, Chlorine, Iron, Boron, Manganese, Zinc, copper, and Molybdenum. The elements Cobalt, Nickel, Silicon, Sodium and Vanadium are also needed by some plants.

Trace elements concentrations determined from the three Nigerian Savannah belts, show that the guinea Savannah are highly enriched in essential elements such as calcium, Potassium, Manganese, Magnesium and Iron. The Sudan belt is rich in Chlorine, Iron, and Manganese and the Sahel is rich in Potassium, Chlorine, and Magnesium as shown in Table 4.7.

The average values of magnesium from the three Savannah belts are close to each other.

Table 4.7 Essential Elements Determined from the Nigerian Savannah belts (Average concentration in ppm)

Elements	Sahel	Sudan	Guinea
Ca	BDL	BDL	14
Cl	267.4	384.7	195.2
Fe	1.2	2.03	2.46
K	2.67	1.37	1.97
Mg	0.28	0.24	0.32
Mn	BDL	203.61	322.61

The essential elements determined were plotted as bar charts in Fig.4.4. It was observed that the Guinea is rich in some essential elements determined in this work. The Guinea savannah consists of a large land mass of soils within Nigeria where intensive agricultural activities are carried out. The bar charts for the soils plotted confirm that the essential soil elements needed for agricultural cultivation of plants and food crops were identified in these savannah zones. The Guinea savannah showed highly relative enrichments for Fe, Mg, Mn and Ca (Fig. 4.4) which are basic plant requirements as compared with the Sudan and Sahel savannahs. From this work it appears that the Sahel savannah soils are deficient in Ca and Mn.

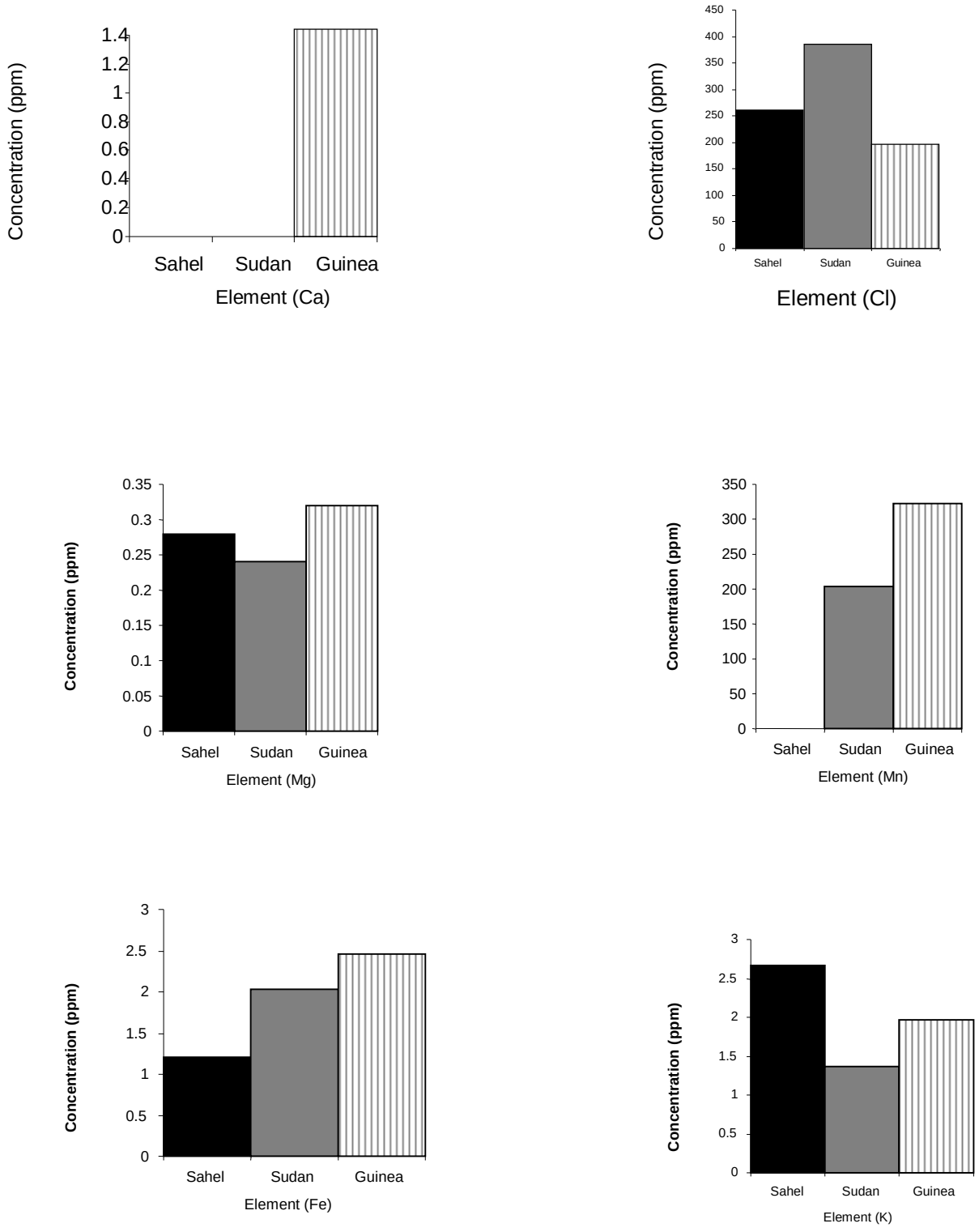


Fig. 4.4 Bar charts of the essential elements determined in Nigerian Savannah soils

4.7 Quality Control of data

Element concentrations of the analyzed soil were also compared with their respective average concentrations in the standard reference materials (NIST 1633b) as is commonly done by other workers (Ewa, 2003, and Ewa, et al, 1992, Oladipo 1987). For each element the data on soil sample were analyzed and tested statistically by determining their means and standard deviation as shown in Table 4.8. Our results show that the analyses for most of the elements were better than 5%

Table 4.8 Quality Control data for NIST1633b,.Concerntration is given in ppm or as otherwise stated.

Elements	This work	NIST1633b
Al (%)	14.76±1.0	15.05
Ba	390±20.9	709
Br	3.57±1.0	2.9
Ce	185.9±3.0	190
Co	162.8±3.9	±50
Cr	149.1±5.2	198.2
Cs	8.23±3.7	11
Dy	9.82±6.7	17
Eu	3.48±1.3	4.1
Fe (%)	7.28±1.9	7.78
Hf	6.75±2.4	6.8
K (%)	1.9±0.2	1.95
La	84.2±1.2	94
Lu	1.07±0.3	1.2
Mg (%)	0.23±0.0	0.482
Mn	135.4±1.8	131.8
Na (%)	0.235±0.09	0.201
Sb	3.6±0.00	6
Sc	37.12±1.2	41
Sm	19.47±4.4	20
Ta	1.24±0.9	1.8
Th	21.65±3.3	25.7
Ti (%)	0.33±0.4	0.791
Yb	8.86±0.8	7.6

CHAPTER FIVE

SUMMARY AND CONCLUSIONS

5.1 Summary

This research result shows relatively uniform soil colour characteristics of the savannah profile with a mottled sequence below a depth of 27cm. The soil horizons are dominated by sub-angular blocky structures, separated from each other by various layers that range from rare-quartz gravels to dominant fine textures of sand.

Soil bulk density measurements revealed that the Sahel soils were generally lighter when compared to those from the Sudan and Guinea soil zone. This explains why they are easily transported as aerosols during the hammattan period Conductivity studies revealed that soils of the arid zones (Sahel) had higher values when compared with the Guinea and Sudan soils. Soils of the Guinea savannah generally had acidic pH values 5.4±0.3

NAA was used to determine the trace element abundance in the Nigerian savannah belts. Elements determined from the three Nigerian Savannah belts are (Al, Ba, Br, Ca, Ce, Co, Cs, Dy, Eu, Fe, Hf, K, La, Lu, Mg, Mn, Na, Rb, Sb, Sc, Sm, Ta, Th, Ti, V, and Yb). The Sahel savannah is rich in essential elements in the order (K, Mg, Cl, Mn, Fe) while Guinea is in the order Ca, Fe, Mg, Mn, K, Cl) and Sudan (Cl, Fe, Mn, Mg, K).

The large data of elements obtained from the soil samples were subjected to cluster analysis. Cluster techniques have been successfully used in presenting a rapid visualization of the diversity in the grouping of soil sample of Nigerian savannah belts.

The results indicate segregation by the soil from Guinea and Sudan savannah respectively. The following soil data clustering conclusions were drawn from this work.

(1) Sudan and Guinea soils were stable in clustering together. The stability of the clustering has been tested and confirmed by two dendrograms (Figs 4.2 and 4.3) depicting three major groupings of Sudan, Guinea and Sahel savannah soils respectively.

(2) All the major soil sites for the Sudan soils (Kafin Hausa, Biu, Gadaka, Gashua, Wudil, Chiromawa, Hadejia, Gusau, Nguru , Sokoto) clustered together indicating that these soils have the same soil element characteristics. Equally the Guinea savannah soil sites (Hong, Numan, Jos, and Mubi) clustered within the same group with a few outliers. This result shows the effectiveness of the clustering techniques and should be used as a basis for re-affirming group consistency

(3) Finally clustering of Nigerian soils discriminates each soil along their savannah groupings confirming that the analytical data of the elements are in good agreement.

5.2 Conclusion

In conclusion therefore, soil element data and their physical parameters were obtained for the three savannah (Guinea, Sudan, and Sahel) zones in Nigeria, tested for group homogeneity of elemental content and found to be consistent using cluster methods. Data reported in this work will serve as base-line information on trace element levels in Nigerian savannah belts. As an extension of the work, the data will be useful as preliminary investigation results for the purpose of monitoring trace

element levels around Nigerian savannah belts. This in future will assist in the geochemical mapping of the Northern Nigeria savannah region

5.3.1 Recommendations.

The following recommendations are made to the federal government through the University authority.

(1) The plant meant for the production of liquid nitrogen should be replaced. To enhance the production of the liquid nitrogen, because luck of the liquid nitrogen is one of the major problems affecting research activities in the Center for Energy Research and Training (CERT).

(2) The government should support the research through financing it from time to time in order to monitor trace element levels around Nigeria savannah belts.

(3) Study of the entire savannah belts should be carried out using a grid point system in order to obtain a geochemical mapping of the Northern Nigeria savannah region

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