CHARACTERIZATION AND CLASSIFICATION OF MAJOR IRISH POTATO GROWING SOILS ON THE JOS PLATEAU

BY

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DECLARATION

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.

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The above declaration is affirmed.

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CERTIFICATION

This thesis entitled "CHARACTERIZATION AND CLASSIFICATION OF MAJOR IRISH POTATO GROWING SOILS ON THE JOS PLATEAU" by AKINWA OLABANJI ANDREW meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to the most High God, through whose grace I successfully completed the work.

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ABSTRACT

The major soils used in growing Irish potato on the Jos Plateau, were studied. The soils fall within three geologic groupings namely : soils on Newer basalts, soils on granites and soils on unconsolidated deposits overlying granites. The soils were selected from three Local Government Areas of Plateau State which together constitute about 78% the land area of the major potato growing areas of Jos Plateau and about 65% the entire area of the Plateau.

The soils occur in an environment with a dry season of about 5 months. The vegetation is the northern Guinea Savanna type and has been specifically described as Montane vegetation.

The soils are deep, well drained or imperfectly drained. Those formed on Newer Basalts are generally clayey, those on granites sandy and those on unconsolidated deposits are sandy or clayey. An ochric epipedon is common in the soils, the soils are also high in silt. The uppermost (Ap or Au1) horizons of the soils are generally deficient in clay. The soils have yellowish brown, dark grayish brown or dark reddish brown surface horizons while the subsurface horizons are light gray, yellowish brown or red. The soils have weak subangular blocky structure or moderate angular blocky structure commonly for the surface horizons, while the subsurface horizons have moderate or strong angular blocky structure.

The soils are low in organic matter. They have low, moderate or high cation exchange capacity but most fall in the moderate CEC categories with the soils on Newer basalts having higher values. The soils on Newer basalts are also higher in exchangable cations and some other nutrient elements, as compared to those on granites or unconsolidated deposits, but all the soils are generally low in nutrient elments.

The soils have been classified as Acrisols and Ultisols or Alfisol in the FAO/UNESCO Soil Map of the World legend(1974) and the USDA(1975) System respectively. A land suitability classification for Irish potato, has also been carried out for the soils. All the soils are suitable for potato but those on basalts are better potato soils than those on unconsolidated deposits and grain

A soil improvement package for potato production aimed principally at minimising or correcting the effects of unfavourable environmental factors, based on the results of investigations conducted on the soils and careful observations, has also been included in the study as follows:

(A) Package aimed at minimising the impacts of unfavourable environmental factors
  - (i) Mulching
  - (ii) Avoidance of steep land for potato cultivation
  - (iii) Minimum tillage
  - (iv) Contour ploughing
  - (v) Crop rotation
  - (vi) Occasional tests.

(B) Corrective measures
  - (i) Liming
  - (ii) Fertilizer application
  - (iii) Avoidance of acid - forming fertilizers
  - (iv) Split - application of fertilizers.

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1. INTRODUCTION

Soil characterization and classification are indispensable to sustained optimum crop production. This all-important role of soil characterization and classification, becomes more obvious now with the increased pressure on the land in a bid to meet the food requirements of the world's teeming population. Soil characterization for example, serves to highlight or focus on the status of a soil as regards important soil parameters or characteristics such as texture, organic matter content, cation exchange capacity and acidity conditions amongst others, all of which have direct bearing on the suitability or otherwise of a soil for crop production. Soil characterization therefore makes the identification of both suitable and unsuitable soils for crop production possible and helps in highlighting what could be done to improve the soils for increased crop production.

Soil classification on the other hand, enhances the recognition of similar or identical soils located in different places, thus facilitating the transfer of knowledge acquired elsewhere, to other places. It also conveys to the Soil Scientist, an immediate impression of what a soil is like, thereby enabling him or her, to picture what prospects the soil holds for crop production, this is particularly so for a classification name which coins with it, certain salient features of the soil. It also aids in the process of inventorying the soils of an area.

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The Jos Plateau occupies about 8,600 Km^2 in an area situated within Longitudes 8^{o} 22' and 9^{o} 30'E and Latitudes 8^{o} 30'N and 10^{o} 10'N (Hill, 1978). Its boundary is marked for the most part by a steep fall to the surrounding plains, which is only more gradual in the East.

Irish Potato is a popular and promising crop grown on the Jos Plateau and it has high nutritional, commercial and industrial values. The crop is grown mainly in five zones on the Plateau, namely : Jos, Barakin-Ladi, Mangu, Pankshin and Bassa Local Government Areas of Plateau State.

The study area (Jos, Barakin-Ladi and Mangu Local Government Areas), falls right in the heart of the Jos Plateau and constitutes about 78% of the total land area of the major potato producing zones of the Plateau. This accounts for about 81% of the estimated total land area under potato production in the major potato producing zones, as at the year 1986 (Ifenkwe, 1987).

Characterization and classification of the potato growing soils of the Jos Plateau as earlier highlighted, will facilitate the production of the crop. Only very few soil studies conducted on the Jos Plateau, have been interpreted for the potato crop and such interpretations have been generalised, merely indicating the mapping units that could sustain the production of certain crops including potato. As crops have their ideal sets of soil requirements, a soil or soil mapping unit, will not hold exactly the same prospects for a number of crops, therefore, only a soil study specifically interpreted for the potato crop, using

the ideal set of soil requirements for the crop as the basis and coming up with gradations in land suitability for the crop, is of utmost importance to the production of the crop. Such an approach is particularly necessary, considering the high economic importance attached to potato production on the Jos Plateau and it will guide farmers in site selection for the production of the crop.

Even though a number of soil studies have been conducted on the Jos Plateau, much more still have to be done, for a better understanding of the soils and their consequent optimum utilization; moreso, as only relatively few of such studies are comprehensive enough, for far reaching Land Use Policies. A study of major soils on the Plateau for specified objectives or generalised purposes for example, will not only generate information in the context of the set goals, but will in addition generate more information about the soils studied themselves and also update soil information on the Plateau in general.

Again, greater efforts are still needed on the proper identity of the soils of the Jos Plateau, in terms of brecise identification names which convey clear, first-hand information on the soils; terms such as lateritic or ferruginous that have been used to describe the soils in some cases, are too generalised to be of much use. Also, attempts at classifying the soils of the Plateau under recognised classification systems, have been few up to date. The objectives of this study are therefore to :

(i) generate more comprehensive information on the soils of the Jos Plateau thereby enhancing their better

understanding and utilization, (ii) classify them using internationally recognised systems thus enhancing their identity and understanding world-wide, (iii) serve as an addition to the yet few comprehensive soil studies conducted on the Jos Plateau, (iv) determine their suitability for the Irish potato crop and suggest what could be done to make them support and sustain the production of the crop at higher yields.

The soils are classified according to the USDA Soil Taxonomy (Soil Survey Staff, 1975) guided with the up to date supplements or modifications in the classification system; and the FAO/UNESCO Soil map of the world legend (1974), as they are presently the two systems mainly used in Nigeria.

2. LITERATURE REVIEW

2.1 Soil characterization, classification and crop production.

Soil characterization and classification play a major role in profitable, crop production ventures and meaningful feasibility studies for crop production which will be of wide acceptence and application, must incorporate them.

Soil characterization may be defined as the determination of important soil parameters or characteristics such as texture, cation exchange capacity, organic carbon, total nitrogen, available phosphorus, and pH (soil reaction), amongst others; all of which jointly dictate largely, the success or failure of any crop production venture. Each of the characteristics influences plant growth in specific ways. For example, at low soil pH, some legumes cannot nodulate, availablity of phosphorus is impaired because of fixation by iron and Aluminium as oxides and hydroxides; the intake of some nutrient elements by the crop plant is supressed, an example in this respect is calcium. Also, when a soil has a clay or clay loam texture, water-logging condition is common, especially during the rains and the crop dies or perform poorly because of poor soil aeration. Such a soil too is difficult to work. Furthermore, when the cation exchange capacity of a soil is low, such a soil holds little amounts of nutrients for crops and the crops would not do well unless the

situation is corrected by the addition of chemical fertilizers or organic manures. In the Zaire valley, a soil low in organic matter, has a low reserve of nutrient elements especially nitrogen, phosphorus and sulphur. Its ability to sustain good crop yields is therefore limited.

Land capability or suitability classification, which makes possible the judicious use of agricultural land, depends largely on soil characterization. Recommendations made to keep the soil in good form or will ensure continuous and high crop yields at the completion of most soil studies, are directed largely at improving soil characteristics such as pH, available phosphorus, total nitrogen, exchangeable cations and organic matter amongst others, to desirable levels.

Soil classification may be defined as the "allocation of a soil into the unit that best incorporates the range in characteristics of the soil amongst a number of individual units or natural bodies (soils); enabling one to determine the kind and range of soil properties that characterize and denote each of such soil units and the allocation of soils to the unit" (Brady, 1974). The history of soil classification is almost as old as man himself. From the time man first began cultivating his own crops, he felt differences in the productive capacity of soils and classified them, if only in terms of "good" and "bad" for his purposes (Brady, 1974).

Three kinds of concepts are characterized by the history of soil classification : (i) soils as a habitat for crops, (ii) soils as a superficial mantle of weathered rock and

(iii) Soils as natural bodies (Idoga, 1985). Soil classification based on the concept of soils as a habitat for crops, is the oldest because of its relation to practical agriculture (Bregy, 1974). The early Egyptian and Roman Civilizations for example, noticed differences in soils as media for plant growth and such recognition persists even today, as soils are described as good "cotton", "corn" or "wheat" soils.

It was after geology had become a scientific discipline of its own, that the second concept of soils as unconsolidated mantle of weathered rocks came into limelight (Buol et al., 1973; Idoga, 1985). Two basic principles employed in classification under this concept were the geology of soils and the lithologic composition of the parent materials of the soils and terms such as glacial, lluvial and colluvial soils were freely used (Bregy, 1974). Some of the terms persist to date in soil classification literatures.

The classification of soils based on the concept that soils are natural bodies was initiated by Dokuchaev (Bregy, 1974) and this not only constitutes the most scientifically oriented approach amongst its contemporaries, but formed the basic foundations for the present classification systems (Buol et al., 1973; Idoga, 1985). Under the concept proposed by Dokuchaev (Bregy, 1974) that soils are natural bodies subject to classification by rules, the classification were primarily based on factors of soil formation and other soil properties. Dokuchaev's concept was later modified due to some limitations, chief among which was its strong genetic bias. Emphasis is

now on morphogenetic characteristics of soils rather than on genetic factors, in present day classification systems. Attention is now on both the characteristics or features which the soils exhibit on the field and the processes which resulted in the characteristics observed.

Soil classification serves to give both an immediate insight into the identity of a soil and invariably, the detailed, unmistakable identity of the soil, in terms of its salient features. It thereby highlights on the prospects the soil holds for crop production, as the classification name of a soil conveys to the soil scientist, some of the important features of the soil in the first instance. When for example, a soil is described as Typiic Haplustalf, it implies at the first sight that the soil is an Alfisol, a common soil in the tropical environment, it may be yellowish ot reddish in colour generally and quite rich in Iron oxides. A careful look into the full list of characteristics of a Typic Haplustalf and other information at the higher classification levels of the soil, gives the complete identity of the soil.

Soil classification thus facilitates the recognition of similar soils and enhances the transfer of knowledge or research results acquired elsewhere to other places of similar setting and soil properties.

2.2 Previous Soil Studies on the Jos Plateau

Several soil studies have been undertaken on the Jos Plateau by different workers. The study by Tomlinson (1965) of soils of Northern Nigeria, included those of the Jos

Plateau. The Institute for Agricultural Research (I.A.R.) of the Ahmadu Bello University, Zaria, conducted the survey of a "Proposed Irrigation Scheme of Ta Hoss" in 1960. The same Institute undertook the Bokkos Land Use Scheme Survey in 1961 and a Reconniassance Study of Soil Erosion Problems on the Plateau in 1964. Recently too (1986), the Institute conducted a detailed survey of the Jos International Breweries Farm at Zalaki near Jos.

Klinkenberg (1968), led a soil survey team to study a Rice Irrigation Scheme at Panyam. The Land Resources Division of the Overseas Development Agency, United Kingdom, has conducted a reconnaisance survey of the soils of the Jos Plateau, (Hill; 1978). The Federal Department of Agricultural Land Resources has also conducted a reconnaissance survey of Plateau State (Okoye, 1985), (the main seat of the Jos Plateau) and in the report of the survey, some of the soils of the Jos Plateau were classified as Oxic Haplustalf (Ferric Luvisol), Andic Eutropept (Ferralic Cambisol) Oxic Haplustalf (Ferric Acrisol) and Arenic Haplustalf (Orthic Luvisol).

Ojanuga and Awujoola (1981), characterised and classified some soils of the Jos Plateau, Employing fresh roads cuts, gravel pits and man-made trenches along three major sites radiating from Jos. Some of the soils studied were classified as (Orthic Acrisol (Typic Haplustalf), Chromic Luvisol (Udic Rhodustalf) and Chromic Cambisol (Typic Eutropept). The classification names with asterika are said to be tentative by the authors.

Also, Ugwu (1985), undertook a study of "The properties, Classification and Geomorphic Relationships of some soils of Jos Plateau". Some of the soils involved in the study were classified as Ultic Haplustalf (Eutric Nitosol), Acuic Ustifluvent (Dystric Fluvisol), Typic Paleustult (Ferric Acrisol) and Andic Ustic Humitrepept (Dystric Cambisol).

The soil classifications done in the previous soil studies conducted on the Jos Plateau as just highlighted, have shown that the soils encountered thus far on the Plateau, are Alfisols, Ultisols, Entisols and Inceptisols, in the USDA(1975) soil classification system or Luvisols and Acrisols, in the FAO/UNESCO (1974) soil classification system.

The predominant parent materials of the soils of the Plateau, are deep, unconsolidated deposits derived from weathered granites, Basement Complex rocks and older Basalts (Hill, 1978). These materials have been modified by mild lateritisation, resulting in pronounced mottling. In places, concretionary gravels derived from the erosion of lateritic ironpan have been spread over the surface of the unconsolidated deposits. Elsewhere, the soils are developed on Newer Basalts, on granites and their detritus, or on lateritic ironpan.

The genesis of the soils of the Plateau suggests that one suitable way of studing the soils, is on the basis of the geology of the area, as the parent materials are intricately linked to the geology. Ojanuga and Awujoola (1981), used this approach in their soil study of the Plateau.

As earlier mentioned, fine loamy material thought by Macleod et al. (1971), to be aeolian, affects the surface horizons of the soils. Poor drainage may affect any of the parent materials, but due to the marked seasonal rainfall, the water table fluctuates. The sandy surface horizons of many of the soils drain rapidly, particularly where underlain by gravelly material (Hill, 1978).

Most of the soils on the Jos Plateau have a very poor nutrient status. The cation exchange capacity of the most commonly occuring soils is reported to be less than 8 meq/ 100 g of soil except for the soils on Basalt (Hill, 1978). Soil pH is always less than 6 and frequently less than 5. The lower pH levels limit the growth of common arable crops like Maize, Sorghum, Yam, Millet and Groundnuts, (Hill, 1978). At the low pH of most of the soils, there will be little phosphorus available for plant growth and this will be an additional limitation to the crops mentioned.

2.3 Production of the Irish Potato Crop

The Irish potato is a cool weather loving plant, as it has over the years been grown and adapted to temperate climates. Its cultivation in the tropics is restricted to the high altitude areas where the temperature is sufficiently low especially night temperatures which is very important in tuber initiation.

Since the introduction of potato into the Jos Plateau by the European Tin Miners in the early 1940s its production has increased steadily. Today, potato production has

expanded to other high altitude areas such as the Mambilla Plateau, Biu Plateau and Obudu hills. During the cool harmattan months, its growth can also be sustained in the low altitude areas around Kano, Sokoto, Borno, Kaduna and Bauchi States of Nigeria (Ifenkwe, 1987).

2.3.1 Expansion of potato production

The first attempt to expand the production of potato in Nigeria was during the second World war 1935-45. The colonial Government of Nigeria attempted to meet the food needs of its expatriate soldiers in West Africa by growing potato (Williams, 1962; Ifenkwe, 1987). Most of today's local varieties are remnants of those early introductions (Suchomel, 1967; Ifenkwe, 1987).

In the present day Nigeria, potato is no longer an expatriate or whiteman's food, it has been integrated into the Nigerian food list either as a vegetable in the more distant locations from the production centres or as a staple food in the major producing zones. Table 1 shows the increases in potato production during the last four decades.

Table 1. Potato production in Nigeria (1940-86)

Year	1940	1944	1954	1975-76	1977	1980-86
Marketable production (tonnes/yr)	180	1,732	1,800	48,000	50,000	100,000

Source : Ifenkwe, 1987

Potato production is still on the increase and increasingly more land is being used for its production. In the Jos Plateau, which presently accounts for well over 80% of the total production in Nigeria (Ifenkwe, 1987), most of the land previously used for the production of 'Acha' (Digiteria exilis), a traditional cereal crop, is now being used for potato production. The reasons for the phenomenal increase according to Ifenkwe (1987), are :

(a) Potato is regarded as a cash crop which fetches the producer a high income relative to other vegetables especially during the dry season when prices are high due to lower production.

(b) During the rainy season, it is harvested quite early (80-90 days from planting) relative to other root crops such as yam and cassava and therefore acts as a good substitute for these other root crops which do not appear in the market until later in the year.

(c) The fact that it can be grown at least twice a year makes it a very attractive crop to grow a factor which is very important in areas where land is limiting (this is now becoming the case in parts of the study area).

2.3.2 Land area under potato production

The land area under potato production has also steadily increased during the past forty years from a mere 300 ha in 1954 to well over 10,000 ha in 1976

(Obigbesan, 1976; Ifenkwe, 1987). During the last decade, the area under potato production has more than doubled and it is presently estimated that in the Jos Plateau alone, about 20,000 ha of land is cultivated to potato either alone or in combination with maize or other cereal crops and legumes such as sorghum, millet and cowpea (Ifenkwe, 1987).

In the Jos Plateau, the land under potato production is located in five main Local Government Areas. Table 2 shows the land areas of the Local Government Areas and the estimated areas under potato production as well as the estimated potential areas for future expansion especially with improvement in irrigation facilities.

Table 2. Land areas of major potato producing zones on the Jos Plateau as at 1986

Locai Govt. Area	Total land area (ha)	Estimated land area under potato production (ha)	Estimated potential area for potato production (ha)
Pankshin	23,338.4	2,33.4	3,500
Mangu	361,933	7,238.7	54,290
Barakin Ladi	195,661	5,869.8	39,132.2
Jos	169,504	3,390.1	16,950.4
Bassa	177,577	3,551.5	17,757.7

Source : Ifenkwe, 1987

2.3.3 General characteristics of potato soils

Irish potato can be grown successfully on both organic and mineral soils provided the soils have sufficient depth. The soil texture can be fine sand, gravelly soils and clay loams. An ideal potato soil however, should be deep and well drained and have silt loam or sandy loam texture in addition to being slightly acid. Soils meeting the started criteria can store large amounts of water without becoming saturated or muddy. They are easy to work and could be very productive with good management. Heavy soils such as clay loams and clays make harvesting difficult and the crop is left unattractiviely dirty.

2.3.4 Nutritional value

The potato contains high quality protein and substantial amounts of essential vitamins, minerals, and trace elements (Shideler, 1984).

Protein content of potato is equal to yam and is almost twice that of sweet potato and cassava. Moreover, on a cooked basis, the potato compares with other major staples, such as boiled rice and cereals cooked as porridges.

The average amount of potato protein required for maintenance of nitrogen balance in adults is similar to the amount in an egg, and is less than that required by many other foods including beef, tuna, fish, wheat flour, soy-bean, rice, corn and beans.

Studies also show that infants and small children can consume up to 80% of their nitrogen requirements as potato (Shideler, 1984). The quality of potato dietary nitrogen

for feeding humans is high. Even a small quantity (100 grams) of boilded potato supplies up to 13% of FAO/WHO recommended daily allowance of protein for children and up to 7% of the adult allowance (Shideler, 1984).

The potato has a well-balanced protein-to-calorie ratio. If one eats enough potato to supply a significant amount of energy, a significant quantity of protein will also be provided.

Potatoes are a good source of ascorbic acid (Vitamin C) and some B Vitamins, especially thiamine, niacine and Vitamin BC (Shideler, 1984). Consumed as a staple on a regular basis, potatoes provide more Vitamin C than citrus fruits, which tend to be eaten less frequently. Among staples, potato is perhaps the richest source of total niacine. Minerals and trace elements in the potato provide a moderate source of iron, a good source of phosphorus and magnesium, and a rich source of potassium; its low sodium content is useful in salt-free diets (Shideler, 1984).

2.3.5 Manures and fertilizers

Potato crops benefit from organic manures such as Farm Yard Manure and Slurry, not only because of the nutrient value (often ignored by farmers), but also, because of its beneficial effects on soil structure and moisture retention in a dry season (Lockhart and Wiseman, 1982). It can be liberally applied when available - usually 30-60 tonne/ha of Farm Yard Manure or Slurry equivalent. It could be ploughed in or applied to hand-planted crops.

Liberal dressings of fertilizers may be applied to potato crops as any surplus will benefit the crops following. Fertilizers are either broadcast during cultivation or more efficiently, placed in the ridges either by planters or manually.

The most profitable rates depend on numerous factors such as climate, soil type and state of fertility, previous cropping, variety, method of application, etc., so expert advice can sometimes be helpful especially regarding the need for magnesium and trace elements (Lockhart and Wiseman, 1982).

Too much nitrogen applied to the seed-bed usually delays tuber developmement and so can reduce yields in some seasons. Nitrogen and potash increase yield by increasing tuber size; phosphate increases the number of tubers (Lockhart and Wiseman, 1982). Plate 1 shows potato tubers on display by the road side in the project area.

2.3.6 Uses

Potatoes are used mainly for human consumption, but some are at times fed to livestock, for example, during a glut year in the United Kingdom (Lockhart and Wisemand, 1982). In several EEC countries, some of the crop is used for producing starch, alcohol, etc.

Potatoes are eaten as boiled or baked, chips, crisps, etc, and in the United Kingdom, an increasing proportion of the crop (about 20%) is processed as crisps, frozen chips, dehydrated instant mash, and canned "new" potatoes.



Plate 1: Potato tubers on display by the road side in the study area.

3. PHYSICAL ENVIRONMENT OF STUDY AREA

3.1 Location

The Jos Plateau is a well defined highland area, standing shoulder-high above its surroundings. According to Hill & Rachara (1973); and Ugwu (1983), it is bounded by the Benue Piedmont and Makurdi and Ibi Plains to the South, Bauchi and Gongola Plains to the East; the Kishi hills complex, Zala Plains, Kano Plains and parts of Kaduna Plains (Samaneka - Zaria area), to the North; and by the Kaduna Plains and the Jema'a Platform to the North-west, West and South-west respectively.

The study area (Jos, Barakin-Ladi and Bangu Local Government Areas), falls right in the heart of the Jos Plateau, covering over half of the entire area of the Plateau and shares basically all features of the Plateau.

Figure 1 presents the location map of the Jos Plateau while figure 2 presents the location map of the study area on the Plateau, showing the location of the soil bottle pits.

3.2 Geology and Geomorphology

Figure 3 shows the geology of the Jos Plateau. The geology of the Jos Plateau has been described by Macleod et al., (1971); and Hill (1978). It consists of gneisses, migmatites and granites generally known as Pre-Cambrian Basement Complex rocks. Medium to coarse grained granites (Younger Granites), have been intruded into the Basement Complex, forming a series of ring complexes thought to be of Jurassic age (Jacobson et al., 1958).

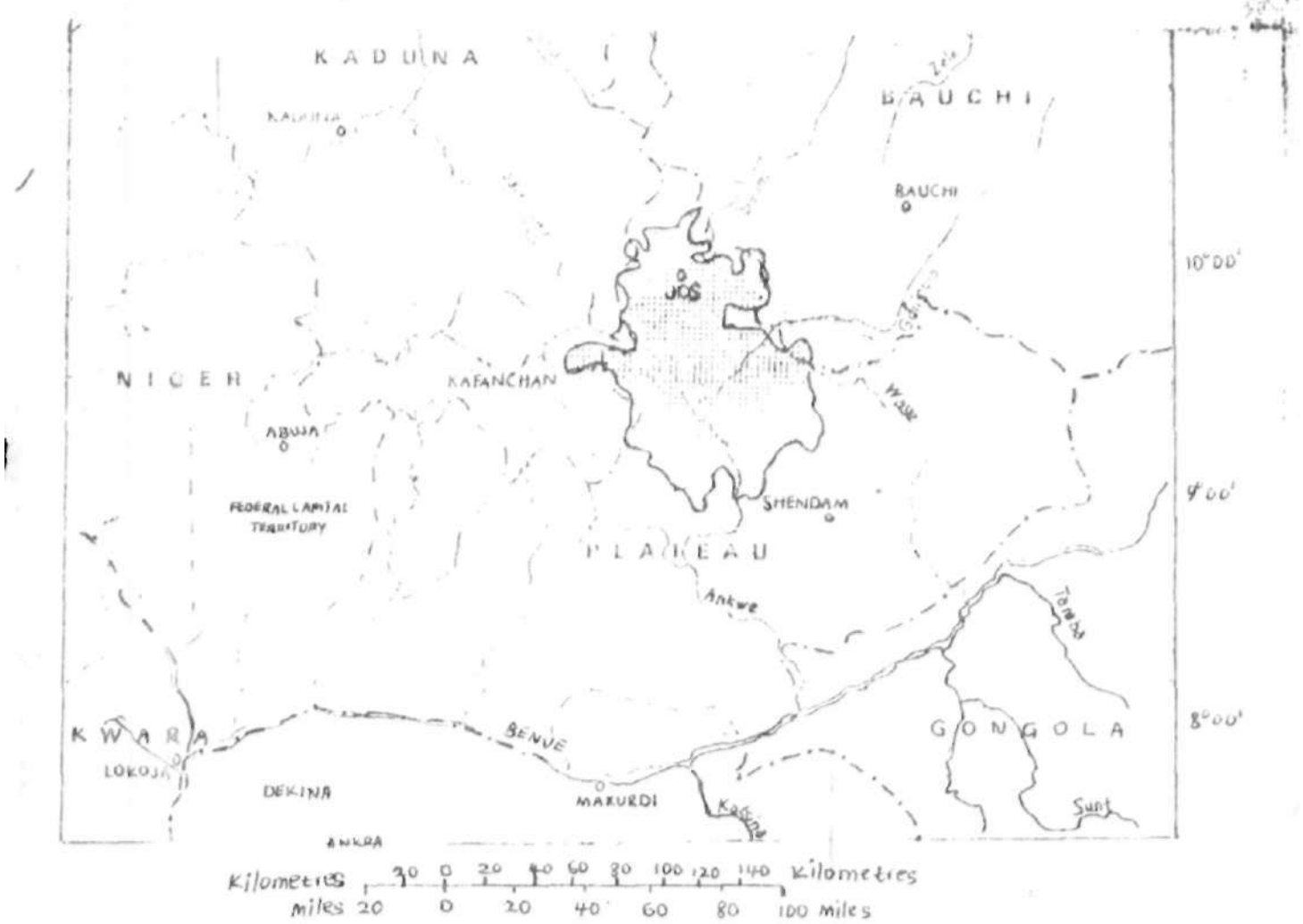


Fig. 1: Location Map of the Jos Plateau (Adapted from Hill, 1978).

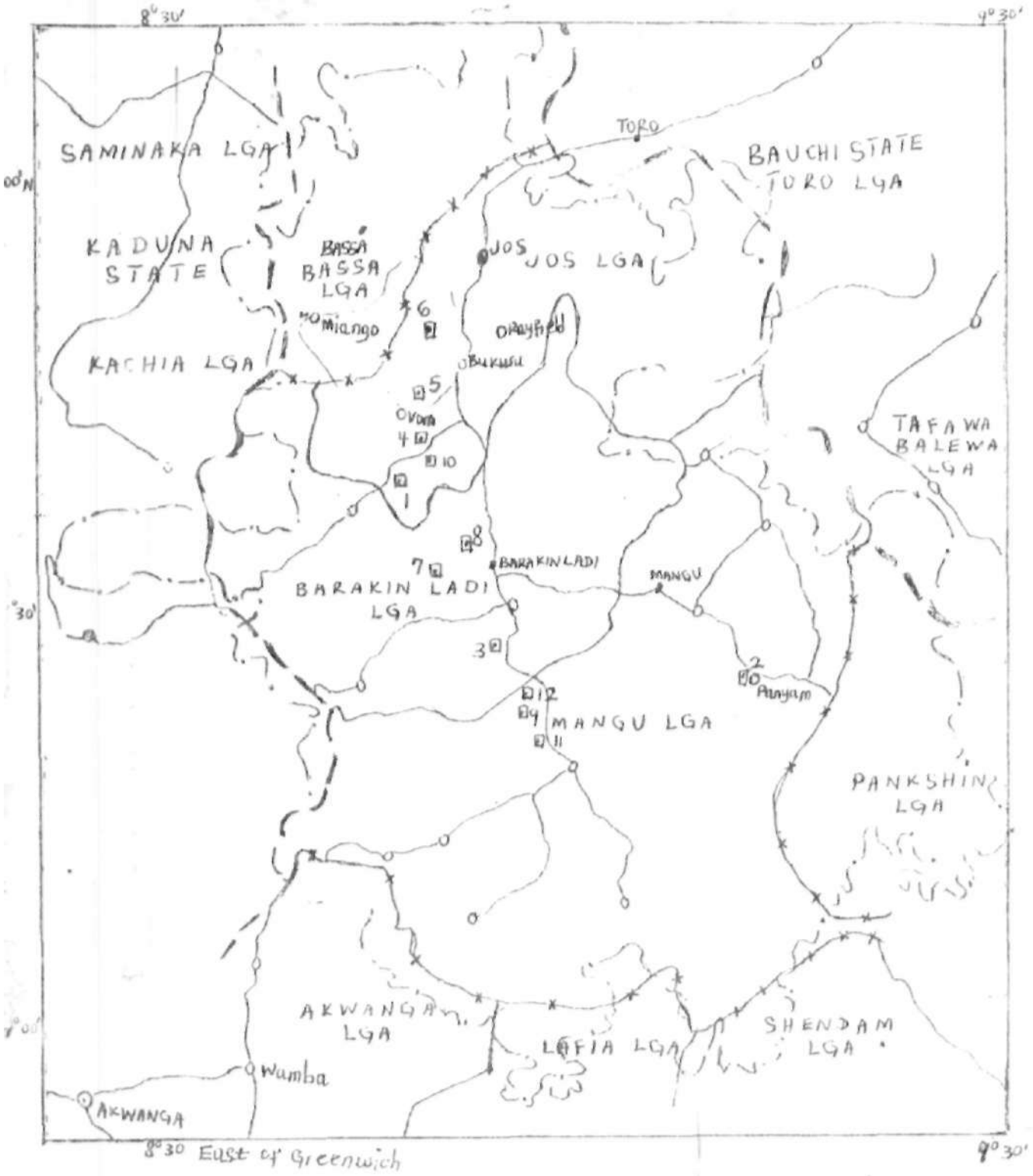


Fig.2: Location map of the study area, showing the sites of the profile pits (Adapted from Hill, 1978)

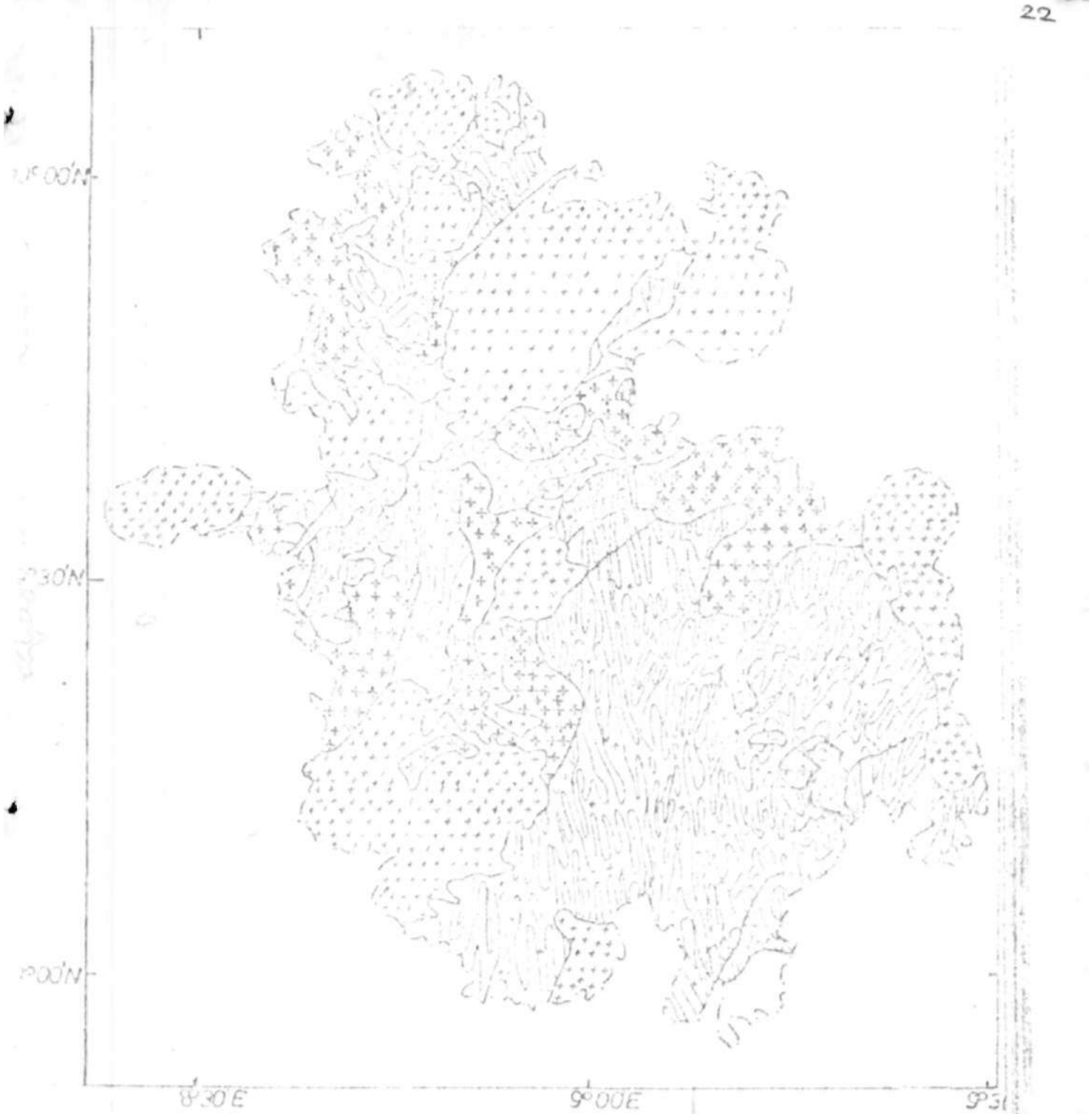


Fig.3: The Geology of the Jos Plateau (Source: Hill and Rackham, 1973).

The Plateau has been affected by volcanic activities from Tertiary to recent times Macleod et al. (1971), have distinguished (a) Lateritised Older Basalts (b) Unlateritised Older Basalts, generally associated with (a), and (c) Newer Basalts that are typically large flows that can be traced to reasonably well preserved cones.

Erosion of the Lateritised Older Basalts has led to the formation of a secondary ironpan and deep unconsolidated deposits on the valley side slopes. During the Pleistocene, several phases of erosion and deposition seem to have taken place and a number of different deposits, the Rayfield, Bokkos and Bisichi deposits, have been recognised by Hill and Rackham (1974). A fine, yellowish loamy material, has in more recent times been deposited over much of the Plateau (Hill, 1978) and has been suggested as aeolian in origin (Macleod et al; 1971).

Ugwu (1983), has given an in depth discussion of the geomorphology of the Jos Plateau. According to him, the Plateau is an erosional relic which assumed its present form in Cretaceous times, when the sedimentary rocks of the Benue valley were deposited (Grove, 1952). He went on to say that the view is supported by the argument of Moss (1968), that in West Africa, the ubiquity of the Late Cainozoic Post-African elements is seriously challenged only in the vicinity of the Jos Plateau where remnants of the Jurassic Gondwana and the Cretaceous Pos-Gondwana elements exist in association with a subjacent development of the Cainozoic African surface. Pugh and King (1952), have also referred to the remnants of the Gondwana

Landscape, which govern the aspect of Jos Plateau area at about 1220 m or more, mainly south and south-east from Jos, where it has been preserved on the relatively 'Younger Granites'.

Furthermore, King (Hill and Rackham, 1973) implied that the earliest planation surface, the Gondwana surface, is represented only by the highest parts of the Younger Granites hills, as he referred to remnants at 1760 meters. He, therefore, suggested a Post-Gondwana date for the main Plateau surface which Thorp (1967), has assigned to a planation surface developed on the Jos-Bukuru complex at 1280-1370 metres and which as recently observed by Hill and Rackham (1973), is now mainly represented by hill summits.

According to Ugwu (1983), a chronological order for the development of the Jos Plateau during the Tertiary and Quaternary periods following the preservation of the Gondwana and Post-Gondwana surfaces, has been suggested by Hill and Racham (1973). Many of the developments are due to alternations between wet and dry climates. First, there was a late Tertiary erosion resulting in the accumulation of the pre-Older Basalt alluvium. The Older Basalts were then extruded over this alluvium during the pliocene. A period of lateritisation associated with a climate of alternating wet and dry seasons then followed. This is suggested to have taken place during the early Quaternary age and resulted in the production of Lateritised Older Basalts. Another period of intense erosion, "probably under arid conditons", then followed. This resulted in the

dissection of the Lateritised Older Basalts with the formation of mesas and scarps. This erosion also produced great quantity of debris which formed thick unconsolidated deposits referred to as the Ray field and Bokkos deposits.

The Newer Basalts were then extruded and it has been suggested that another period of erosion followed which cut valleys into the Rayfield and Bokkos deposits. The valleys are believed to have been filled by another group of deposits, the Bisichi deposits, in which true alluvial deposits alternace with materials believed to have originated from mass movement.

In addition to the generally, gently undulating surface of the Jos Plateau observed by Macleod et al., (1971), hills, mountains and dissected terrain have been identified by Hill and Rackham (1973), in addition to the undulating plains. The hills and mountains are predominantly formed of the resistant Younger granites, the dissected terrain, mainly of granites and other Basement Complex rocks and the undulating plains, of migmatites, granite and granite-gneiss, Lateritised Older Basalts and Newer Basalts.

3.3 Relief and Drainage

Most of the Plateau surface lies between 1050-1370 m. Lower lying areas within the Plateau are usually associated with migmatites whilst the Newer Basalt flows give flat to gently undulating terrian (Hill, 1978). Over much of the rest of the Plateau, the underlying rock is obscured

by unconsolidated material and in detail the relief is controlled by the ironpan.

The drainage of the Jos Plateau is radial. The watersheds of the three major river systems of Nigeria originate from the Jos Plateau. The Delimi river drains to Chad, the Gongola river drains north east wards before swinging to the Benue; the Wase, Shemankar, Ankwe and Mada rivers drain directly to the Benue, whilst the Kaduna river drains to the Niger (Hill, 1978).

3.4 Climate

Only Jos has full climatological data, published by the Nigerian Meteorological Service, but less comprehensive records are maintained for other towns in the area.

3.4.1 Rainfall

The rainfall data for Jos is contained in Table 3. Rainfall is highest in the South West corner of the Jos Plateau, the mean annual rainfall being about 1,600 mm. The rainfall decreases gradually north east wards and the mean annual rainfall in Jos is about 1,400 mm. Higher rainfall may occur locally around the Shere Hills. The rains start in April and end in October; only little rain falls during the rest of the year (Hill, 1978).

Kowal and Knabe (1972), defined areas thought to have similar temperature, rainfall and evapotranspiration regimes. The areas are shown as polygons, constructed around synoptic climatic stations in Northern Nigeria. The length of the rainy period for the polygons (Jos and Bauchi) on the Jos Plateau is 190 and 140 days respectively.

Table 3. Meteorological data for Jos

Observation	Jan	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct	Nov.	Dec.	Total Annual or monthly mean	Years of record
Rainfall (mm)	2.0	2.3	24.1	94.7	190.8	228.1	323.9	281.4	208.5	42.7	3.1	1.5	1403.	50
Evapotranspiration (mm)	117	122	145	122	114	101.3	84.6	78.5	94.5	115.8	122	114	1331	34
Air Temp (°C)	20.5	22.5	24.5	24.5	24	23.5	21	21.5	22	22	21.5	19.5	22.3	10
Sunshine (hrs)	9.5	9.2	7.9	6.8	6.5	6.6	4.9	4.5	5.9	7.4	9.7	9.1	7.3	10
Relative Humidity (%)	17	17	23	47	67	73	80	80	71	53	22	18	47	10

In the Jos polygon, the rainy period starts between the 1st and 10th of April and ends between the 11th and 20th of October while in the Bauchi polygon, it starts between the 1st and 10th of May and ends between the 1st and 10th of October. During the rainy period, crops are unlikely to suffer moisture stress long enough to affect yield significantly, so it can be considered as the safe growing period. The study area is in the Jos polygon.

Benoist (1975), has however, shown that as the starting date of the rainy period may vary, the probabilities of the rainy period starting on the dates shown are only 50 and 30% for Jos and Bauchi.

3.4.2 Temperature

Maximum temperatures range from 23.5-30.9°C and 28.4-34.9°C for Jos and Bauchi polygons respectively during the rainy season, while the minimum temperatures range from 19.6 – 22.8°C and 26.6–28.5 °C for the polygons during the same season. Table 3 earlier referred to, contains Temperature data for Jos. The highest temperatures occur in March and April when the mean monthly temperatures reach 24.5°C. Mean monthly temperatures drop to 19.5°C in December which coincides with the harmattan period.

3.4.3 Relative Humidity

The Relative Humidity data for Jos is contained in table 3. The Relative Humidity (%) is lowest in January and February when the value for each month is 17% and reaches the peak in July and August with the value at 80% for each month.

The relative humidity is directly linked with the trend in rainfall; it is lower for the period January to April during which the rainfall is low, while it is highest for the period May to September when the rainfall is equally high; for the period October to December, during which the rainfall is low again, the relative humidity is also low.

3.4.4 Pattern of radiation

According to Kowal and Knabe (1972), the pattern of radiation on the Jos Plateau equates with the pattern of rainfall with the largest amount of solar radiation being received during the rainy season. There is a general drop in the amount of radiation from October to February. Peak intensities of radiation are attained around mid-day and the highest values are recorded in the rainy season, even-though actual number of hours of mean daily sunshine are higher in the dry period of October to March, as shown in Table 3. The lowest peaks are recorded during the harmattan period. This can be attributed to the bright clouds which reflect radiation during the rainy season and the hazy and dusty harmattan clouds which reduce effective radiation during the harmmatan.

The mean annual global radiation for Jos, calculated from the sunshine hours on the basis of ten-day periods for each month, has been recorded as 436 cal, cm^{-2} $year^{-1}$, by Kowal and Knabe (1972). The net radiation is about 154.1 cal. cm^{-2} day^{-1}, while the mean daily sunshine hours is 7.3. The mean daily global radiation in the Jos polygon

is 301-424 cal cm^{-2} day^{-1} while that in the Bauchi polygon is 349-488 cal cm^{-2} day^{-1}, during the rainy period. The mean daily actual sunshine hours in the Jos polygon range from 3.71-7.20 hours while the values range from 4.86-4.88 hours in the Bauchi polygon, also during the rainy period (Hill, 1978).

3.4.5 Evapotranspiration

Evapotranspiration is a good indicator of the depletion of soil water. It depends on temperature, relative humidity and wind. As contained in Table 3, the lower the relative humidity, the higher the evapotranspiration. Evapotranspiration is consequently at its highest values during the dry season (October to April) when the relative humiditty attains the lowest values.

Based on the rainfall data in Table 3, the annual rainfall (1403 mm) on the Plateau, is a bit in excess of annual potential evapotranspiration (1331 mm). During the dry season (October to April), evapotranspiration is higher than rainfall and a water deficit could normally be expected in the soil during the period, while during the rains (May to September), there is some water surplus in the soil. Based on the evapotranspiration data for Jos, as contained in Table 3, the mean monthly figures for the Jos Plateau range from 78.5 mm to 145 mm, with an average of 110.9 mm.

3.5 Vegetation

Figure 4 shows the vegetation complexes of the Jos Plateau. The vegetation of the Jos Plateau reflects interaction with climate, soil and the activities of man.

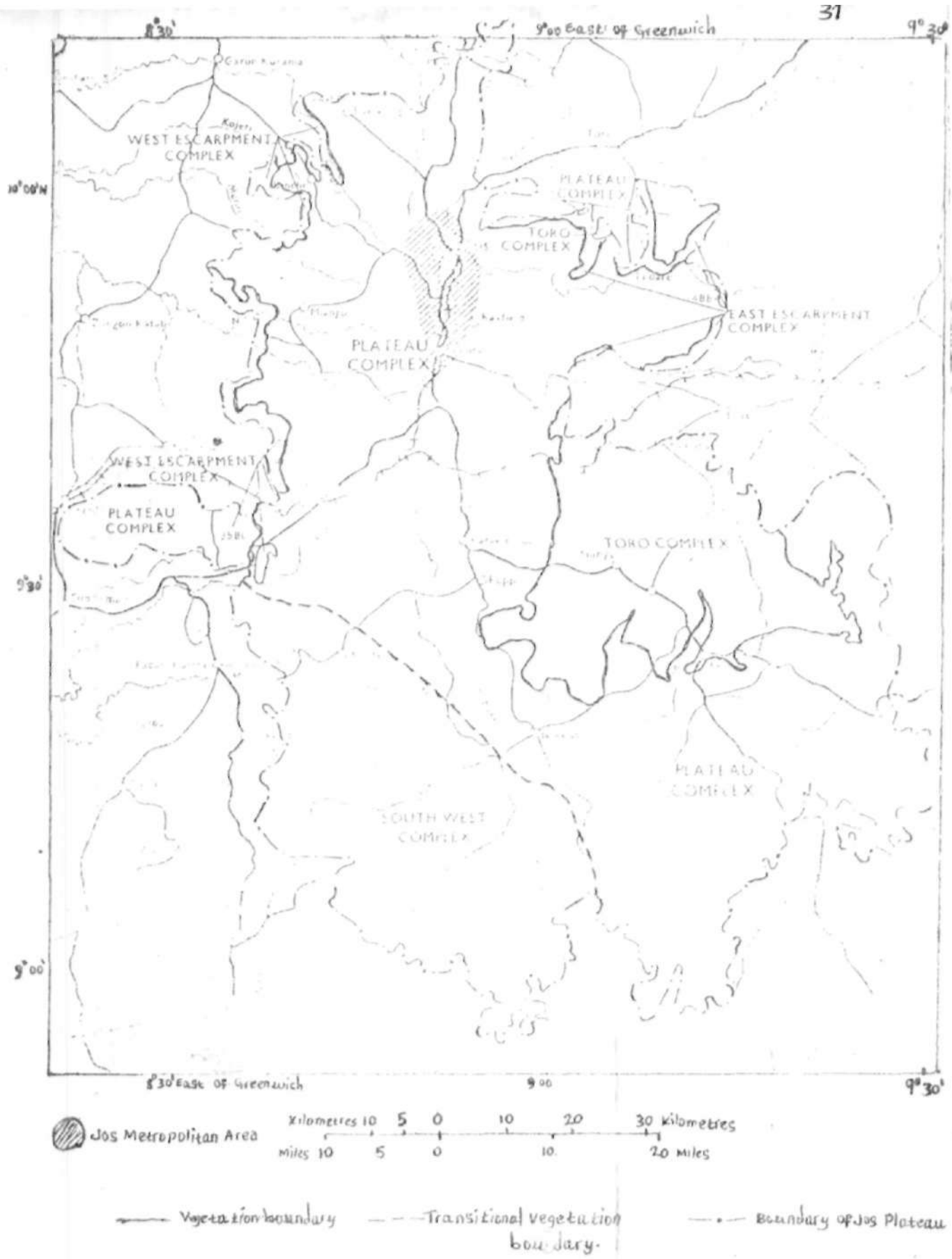


Fig. 4: The vegetation complexes of the Jos Plateau (Adapted from from Hill, 1988)

Little of the original vegetation remains due to prolonged cultivation and present day vegetation is mainly short duration fallow (Hill, 1978).

Alford & Tuley (1974) and Hill (1978), have described the vegetation as consisting of six complexes which broadly reflect climatic changes. The complexes provide a frame-work within which soil-vegetation relationships can be considered.

3.5.1 The Plateau Complex

This occurs over the central port of the Plateau with mean annual rainfall of 1,270-1,524 mm. Andropogon pseudapricus grassland and Terminalia syzygium shrubland predomina[illegible] in this complex. Rocky areas carry a Fiscus/ Euphorbia shrubland. On the shallow soils on ironpan, there is a sparse grassland in which species of Loudetia, Ctenium Microchola and Sporobolus predominate. Hyparrhenia rufa occurs in more poorly drained sites, whilst on the basalt derived soils species of Paspalum and Brachiaria are found.

A larger part of the study area and rightly too, the entire Plateau, falls within this vegetational complex.

3.5.2 The South West Complex

The vegetational complex occurs in the south-western part of the Plateau, with a mean annual rainfall of 1,524-2,030 mm. Adenodolichos shrubland predominates, with a riparian woodland where species of Phoenix and Syzygium occur together with Cyathea dregei.

3.5.3 The West Escarpment Complex

For this type of vegetation, conditions are more typical of the Southern Guinea zone. Mean annual rainfall is lower than in the South-West Complex. Here, we have Anogeissus/Vitex woodland, Riparian woodland and Adenodolichos shrubland also occur.

3.5.4 The East Escarpment Complex

In this vegetational type, Isoberlinia/Monotes shrubland or woodland predominates. Adenodolichos occurs together with the riparian woodland found in the South West Complex.

3.5.5 The Toro Complex

This type of vegetation occurs mainly on the Mangu Plains where the Plateau surface slopes gently down to the East. Mean annual rainfall is lower than on the Plateau Complex. Much of the vegetation is similar to the Plateau complex. There is a Combretum sericeum shrubland, while in areas of intense cultivation, we have Parkia / Daniella parkland.

3.5.6 The Alluvial Complex

Here, Phoenix/Syzygium guineense riparian woodland predominate.

3.6 Present Land use

3.6.1 Density and distribution of cultivation

In terms of density of cultivation, there are areas with 60% or more cultivation, 59-35% cultivation, 34-10% cultivation and areas with less than 10% cultivation (Hill,1978).

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Areas with 60% or more cultivation are areas of intensive land use with little spare land. There is considerable pressure on the land owing to population pressure. These areas are considered unsuitable for large mechanized farming projects because of problems associated with land tenure and the displacement of population. A significant part of the study area falls in this category. Amongst such areas are those around Jos, Vom, Ta Hoss and Barakin-Ladi.

Areas with 59-35% cultivation are areas where for the existing farming system, there is a balance between population and available land. Some land around Bokkos in the Study Area, falls in this class. Extensive, unused land, suitable for grazing, mechanised farming and resettlement schemes often abound on such land, provided other factors are favourable.

Areas with 34-10% cultivation are those with either a high proportion of land unsuitable for arable crop or there is unused land. Only a little portion of the study area falls in this class.

Areas with less than 10% cultivation are of low population density with little pressure on the land and there is usually ample grazing land especially in the wet season. Space is available for mechanised farming and resettlement schemes provided other factors are favourable. The study area has very little land falling in this class. Only the extensive areas of land on the hills and mountains around the edges of the Plateau, have less than 10% cultivation.

In terms of distribution of cultivation, much of the surface of the Plateau is intensively cultivated, the heaviest cultivation desnity being concentrated on the basalt flows at Vom, Miango, Riyom and Panyam. Another area of dense cultivation occurs north east of Mangu.

3.6.2 Present farming systems

The Agriculture of the Jos Plateau has been described by Gosden (1978); and Hill (1978); it is typified by rainfed upland farming, with small farms cultivated by hand. The staple food grain, acha (Digitaria exiles), is the main food crop and the farming system has been defined as the Acha system.

Acha is usually followed by transplanted long season bulrus millet (dauro) some finger millet (tamba) and sorghum. Maize is popular in the southern part of the Plateau. Sweet potatoes, cocoyams and increasingly yams, are grown for food. The sale of surplus food crops fetch some cash. Vegetables grown in wet areas including gully bottoms or with simple irrigation during the dry season, constitute a valuable source of income. Irish potatoes and maize are frequently grown for sale in the South and the practice is becoming increasingly popular.

Cultivation by hand is still the popular practice but the use of Tractor hire services for land preparation is on the increase and there is isolated use of draught animals. Acha is usually planted on the flat but dauro, tamba, Irish Potatoes and maize are all grown on ridges. Yams, cocoyams and sweet potatoes are usually grown on large ridges but cocoyams are also grown on large raised beds.

In most intensively cultivated areas such as Riyom, Ta-Hoss, Vom, Miango and Mba, cultivation is continuous or for long periods. Fallows do not exceed two years and cropping is continuous. Fallows of about 4 to 5 years follow about 4 years cropping, in less intensively cultivated areas. Maintenance of fertility is by combined use of short fallows, cattle manure and fertilizer, when available.

A large number of cattle is kept all the year round on the Jos Plateau and most of the cattle belong to nomadic or semi-nomadic Fulani but some farmers own a few animals which are usually Fulani breeds but th ere are some Muturu cattle. In the dry season, many of the Fulani herds move to the floodplains of the Benue River and its tributaries.

There are minor variations within the main farming system due to ethnic, climatic or physical differences. Distinctions can be recognised between below-subsistence areas and areas with surplus food or cash crops. In the below-subsistence areas, in the northern part of the Jos Plateau, represented by villages such as Bomo/Katanye and Laminga/Forbor, farm incomes have to be supplemented by outside employment, frequently in the tin mining industry. The low production of these areas may be due to intensive cultivation over a long period, of soils that have an inherently low fertility. As there has been little use of fertilizer, the soils have become degraded.

In subsistence areas, farming supports the family but a little surplus is available for sale. This type of farming occurs South of the below-subsistence areas from

Miango to Gindiri and places such as Gwaram/Rim, Ta-Hoss and Chemso fall in the category. Much of the land is cultivated in this places. The poor inherent fertility of most of the soils shows that production is low. The short fallows and only limited use of fertilizers indicate that there is little chance of improving the fertility status.

3.6.3 Rangeland

The Jos Plateau has special advantages for cattle production : it has a higher rainfall than the surrounding plains and it is tse-tsefly free throughout the year. Opencast mining activities seriously reduce the area available for pasture and rangeland production.

3.6.4 Forestry

Forestry activities on the Jos Plateau has been described by Howard (1976) and Hill (1978). As trees and shrubs have been removed by shifting cultivation and browsing cattle, most of the undulating surface is virtually treeless. Most of the forest reserves have been sited on the dissected country bounding the Plateau on the West and South; there is a limited number of forest reserves on the Plateau surface (about six), due to the shortage of land. There are also communal Forest Areas usually planted to Eucalyptus, which are small areas of land set aside by the Local Authority to grow forest produce for the community. There are also Mines Reclamation Areas planted to Eucalyptus by the Mines Land Reclamation Unit. In addition, there are

plantations commonly planted to Eucalypts. There is also the tradition on the Plateau, of preserving trees of economic importance and such are usually found in the villages, often among rocks. Khaya grandifolia and Canarium schweinfurthii are common species.

3.6.5 Mining

Open cast tin mining has disturbed a large area of land on the Jos Plateau, about 316 km^2 (Hill, 1978). Legislation was introduced in 1945, requiring at least 70% reclamation by the mining company before a lease can be relinquished. A number of leases relinquished before 1945 still require reclamation. A large area of land also remains unreclaimed because the mining companies are unwilling to relinquish the leases even though they are not being worked at present; because there are residual deposits of tin that may be economic to work if the price of tin increases.

The Minesland Reclamation Unit (MLRU) was set up to reclaim leases relinquished before 1945 and in conjuction with the Forestry Department, rehabilitate all reclaimed mining land by planting with Eucalyptus. As the MLRU suffered lack of staff and equipment, large areas of land abound that have neither been reclaimed nor planted. Plate 2 shows left over heaps of soil excavated during the exploitation of tin, in the study area.

Howard (1975) and Hill (1978), have shown that the Policy of levelling the mining spoil with heavy equipment, leads to compaction and a reduced growth of the Eucalyptus.



Plate 2: Left over mounds from mining activities in the study area.

Also, the excavations form reservoirs for water which is at present mainly used by the mining companies themselves. Some of the reservoirs provide irrigation water for the growing of vegetables during the dry season. One unfortunate aspect of the reservoirs is that a number of lives have been lost in them by drowning, during fishing or swimming.

3.7 Erosion

The special erosion problems on the Jos Plateau, has been reported by Jones (1975). He identified and mapped approximately 7,250 km of gully representing a volume of 100 million tons of soil lost. The gullying is due to the high natural soil erodibility, tin mining, overgrazing and cultivation methods. Two prominent gullies in the study area are the Heipang gully and the Kuru gully. Sheet erosion too, is severe over much of the Plateau.

4. MATERIALS AND METHODS

4.1 Field Studies

Field studies involved the selection of major soils that support the Potato crop, from three major potato growing areas (Jos, Barkin-Ladi and Mangu Local Government Areas of Plateau State) on the Jos Plateau, based on the three major geologic soil groupings on the Plateau namely: soils on Newer Basalts, soils on Granites and on unconsolidated deposits overlying granites. The unconsolidated deposits consist largely of the fragments and fine materials derived from the common rock types on the Plateau such as granites, basalts and migmatites amongst others.

A familiarization tour of the study area was first undertaken, followed by augering of the soils to confirm the homogeneity of soils developed within some geologic setting, in the study area. The soils were selected using the auger points information obtained, coupled with other relevant information such as physical presence of the potato crop or its remains on the field, frequent displays of potato tubers by the road side in an area; physiography, vegetation and rock type.

4.2 Laboratory Studies

4.2.1 Particle Size distribution analysis

Particle size distribution was determined in accordance with the method by Day (1965); whereby the gravel contents (%) were determined by direct sieving and weighing; the sand, silt and clay were determined using the Bouyoucos hydrometer, with sodium hexametaphosphate (calgon) employed as the dispersing agent. Progressive time intervals were used to determine the sizes and amounts of the setting particles. The sand fraction was collected, washed, dried and sieved for separation into the coarse and fine sand fractions.

4.2.2 Soil Reaction

Soil pH both in water and 0.05M calcium chloride, were determined in 1:1 soil: liquid pastes, in accordance with the procedure by McLean (1982), using a Kent 7065 model combined glass electrode pH meter.

4.2.3 Exchange acidity

Exchange acidity was determined in accordance with the method described by Thomas (1982). Ten grams of the sample was extracted with 100ml of 1MKCl in a plastic bottle, by shaking the soil suspension for one hour in an end to end reciprocating shaker. The

suspension was filtered into a 250 ml conical flask, 5 drops of phenolphthalein indicator were added and the solution titrated against 0.025N NaOH. A drop of 0.05N HCl was added to bring the solution to the colorless condition. 10 ml of NaF solution was added, 5 drops of phenolphthalein indicator were added and the solution was titrated against 0.05N HCl to the end point. Exchangeable Aluminium and Hydrogen were calculated from the blank and titre values obtained and other relevant parameters.

4.2.4 Organic carbon

Organic carbon was determined by the Walkley-Black method following the procedure described by Hesse (1971). One gram of each soil sample was used. The organic matter was oxidized using Potassium dichromate ($K_2Cr_2O_7$) and employing concentrated sulphuric acid (H_2SO_4) to generate heat to raise the temperature and hasten the reaction. [illegible] Ferrous ammonium sulphate titration [illegible] with Barium diphenylamine [illegible] sulphonate indicator, was used to determine the excess dichromate not consumed in the oxidation. The organic carbon oxidized was calculated from the amount of dichromate reduced in the oxidation.

4.2.5 Total nitrogen

The total percentage nitrogen was determined by the micro Kjeldahl method, following the procedure described by Bremmer (1965), whereby the nitrogen in the sample is

converted to ammonium (NH_4^+) by digestion with concentrated H_2SO_4 and Kjeldahl catalyst mixture. The ammonium nitrogen is determined from the amount of ammonia liberated by distilling the digest with alkali and titration of the distillate.

Two grams of the finely ground soil were used, 100ml of the distillate collected and titrated with 0.025N H_2SO_4 using Bromocresol green-methyl red mixed indicator, to determine the amount of NH_3 liberated. Total nitrogen was obtained by using the blank and titre values obtained.

4.2.6 Available phosphorus

Available phosphorus was determined by the Melich II Method, 5g of the soil sample was weighed into a centrifuge tube, 35ml of extracting solution was added and the tube covered with a rubber stopper and shaken for 2 minutes in a shaker. Two drops of HCl were added and the soil suspension was centrifuged for 15 minutes after which 10ml of the clear solution was pipetted into a 250ml flask and 10ml of ascorbic acid solution was added. The flask was then made to mark with distilled water. Phosphorus in the solution was determined with a Spectrophotometer

4.2.7 Exchangeable cations

Exchangeable cations were determined following the procedure described by Thomas (1982). Two grams each, of the soil samples were weighed into a plastic shaking bottle, 50ml of 1N NH_4 OAc (pH7) were added, the bottles covered and shaken for one hour in an end-to-end shaker. The soil suspension was filtered and clear liqiud collected in a 50ml flat bottomed flask made to mark. Calcium and magnesium in the solution were determined from a Perkin-Elmer 290B Atomic Absorption Spectrophotometer while sodium and potessuim were determined using an EEL model A flame photometer.

4.2.8 Cation exchange capacity

Cation exchange capacity was determined in accordance with the principles discussed by Chapman (1965), whereby the exchange complex is saturated with ammonia, using neutral ammonia acetate. The ammonium absorbed is determined by distillation and titration processes.

Ten grams each, of the soil samples were saturated with ammonia and excess ammonium was leached off the ammonium saturated samples using 100ml each of methanol. The samples and the filter papers were transferred into Kjeldahi flasks, 300ml of distilled water, 10ml of 10% acidified NaCl2, 5 drops of anti-foam mixture, 1g of granular zinc and 30ml of 1N NaOH each, were added respectively. The flasks were connected to the distillation apparatus and 200ml each, of the contents were distilled into 50ml of 4% H_3BO_3 and the distillate

titrated with 0,2NHCl using Bromocresol green-methyl red indicator.

4.2.9 Base saturation

Base saturation percentages for the soils were determined by dividing the total exchangeable bases (Ca, Mg, K, Na) of the soils, by the cation exchange capacity of the soils (meq/100g soil) and multiplying the results by 100.

5. RESULTS AND DISCUSSION

5.1 Soil Morphological Characteristics

The soils formed on basalts, granite or colluvial unconsolidated deposits of varying compositions; are deep, well drained or imperfectly drained, commonly having varying amounts of gravels, iron concretions or plinthite in some horizons. A 'Stone line' is often encountered in the soils. The 'Stone line' separates the deposited fine colluvial material from the saprolite over which it has been deposited. Hill and Rackham (1973); Ojanuga and Awujoola (1981); and Ugwu (1983), had earlier reported 'stone line' in soils of the Jos Plateau.

The colours of the surface horizons of the soils range from yellowish brown (10YR 5/4) or drak yellowish brown (10YR 4/4) to dark reddish brown (5YR 3/3) while the subsurface horizons are red (2.5YR 4/8), dark reddish brown (5YR 3/4) or light yellowish brown (10YR 6/4). Colours are for the moist soil unless otherwise stated.

The soils have weak, medium subangular blocky, moderate, medium angular blocky or strong medium or coarse angular blocky structure.

The surface horizons are sandy loam to clay loam in texture while the subsurface horizons are sandy clay loam to clay in texture.

The morphological characteristics of the soils in the various geological formations, are discussed in deails as follows:

5.1.1 Soils on Newer basalts

The soils occur on gently or moderately sloping terrains with many boulders of basalt scattered all over the surface. The land area is often quite extensive especially in the Ta-Hoss area. The soils are deep and well drained. Weathered fragments of basaltic rocks were observed in the profiles. In the Panyam area where weathering has reached a more advanced stage, basaltic remnats occur only as tiny, soft, dark particles whereas in the Ta-Hoss area where weathering is at a relatively less advanced stage, the remnants occur as hard, coarse, fragments. Basaltic fragments or particles tend to increase farther down the profiles, due perhaps to reduced rate of weathering intensity. The surface horizons of the soils are dark reddish brown (5YR 3/3) and the subsurface horizons are strong brown (7.5YR 4/6), dark reddish brown (5YR 3/4) or red (2.5YR 4/8) in colour. The soils have moderate, medium or strong, coarse angular blocky structure and the surface horizons are sandy loam to clay loam in texture while the subsurface horizons are loam to clay in texture. An ochric epipedon and an argillic horizon , are common in the soils.

Two profiles which typify the soils on Newer basalts, are described below; clours, as already mentioned, are for the moist soil.

Profile J-PL-1

Location	: About 1KM away from Riyom, on the Jos - Akwanga road and about 130 metres from the road on the Left Hand Side of the road.
Parent material	: Basalt.
Physiography	: Gently undulating land.
Topography	: 3% slope.
Slope position	: Mid slope.
Drainage	: Well drained.
Erosion	: Slight to moderate sheet erosion.
Surface Characteristics	: Basalt boulders are common on the soil surface.
Vegetation/Land use	: Northern Guinea Savanna (Montane vegetation), cultivated to potato, millet, acha.
Depth to water table	: Not encountered, but more than 186cm.

Horizon	Depth (cm)	Description
Ap	0-36	Dark reddish brown (5YR 3/4) sandy clay loam; moderate, coarse angular blocky structure; hard (dry), firm (moist), sticky and plastic (wet); common, coarse pores and many medium and fine pores; common coarse roots; many medium and fine roots; pH 5.4 diffuse smooth boundary.
Bt1	36-62	Yellowish red (5YR 4/6) clay; moderate to strong coarse angular blocky structure, hard(dry), firm (moist), sticky and slightly plastic (wet); moderate clay skins on peds, many medium and fine pores, many medium and fine roots; pH 5.1, diffuse smooth boundary.
Bt2	62-130	Dark reddish brown (5YR 3/4) clay; moderate, coarse angular blocky structure; hard (dry), firm (moist) slightly sticky (wet), moderate clay skins on peds, many medium and fine pores, many medium and fine roots, pH 5.3 diffuse smooth boundary.

BC	130-186	Dark reddish brown (5YR 3/4) clay loam, moderate, coarse angular blocky structure, hard (dry), firm (moist), sticky and slightly plastic (wet), coarse, angular black basalt fragments, many medium and fine pores, many medium and fine roots, pH 5.4.

Profile J-PL-2

Location : About 1KM to the Panyam Motor Park, on the right hand side of the Mangu-Panyam road and about 60 metres from the road.

Parent material : Basalt.

Physiography : Gently undulating land.

Topography : 4% slope.

Slope position : Middle slope.

Drainage : Well drained.

Erosion : Slight to severe sheet erosion.

Surface Characteristics : Many Basalt boulders scattered on the soil surface.

Vegetation/Land use : Northern Guinea Savanna (montane vegetation), cultivated to potato, maize, beans, sweet potato,

Depth to water table : Not uncountered but greater than 162cm depth.

Horizon	Depth (cm)	Description
Ap	0-22	Dark reddish brown (5YR 3/3) loam; strong, coarse angular blocky structure; hard (dry), firm (moist), sticky and plastic (wet); common, coarse pores and many medium and fine pores; common, coarse roots; many medium and fine roots; pH 5.8, diffuse wavy boundary.

Bt1	22-56	Dark brown (7.5YR 3/4) clay loam; strong, coarse angular blocky structure; hard (dry), firm (moist), sticky and plastic (wet); moderate clay skins on peds, many medium and fine pores; many medium and fine roots; pH 5.5, diffuse smooth boundary.
Bt2	56 -100	Strong brown (7.5YR 4/6) clay, strong, coarse angular blocky structure; hard, firm, sticky and plastic; moderate clay skins on peds, many medium and fine pores; many medium and fine roots; pH 5.6; diffuse smooth boundary.
Bt3	100-162	Yellowish red (5YR 4/6) clay; strong, coarse angular blocky structure; hard (dry), firm (moist), sticky and plastic (wet); tiny, soft, black particles of decaying basalt, many medium and fine pores, many medium and fine roots; pH 5.9.

Plate 3 shows the occurrence of boulders of basalt at the site of the profile J-PL-2. Farmers have gathered the basalt into heaps and ridges to pave way for cultivation. Plate 4 shows the profile J-Pl-2 itself.

5.1.2 Soils on Granites

The soils occur on gentle slopes or undulating land with slopes of 1 - 4%. The land is extensive or moderately extensive. The soils are deep and well drained. Outcrops of granites abound in the area. The soils are formed on weathered granites. Often, there is a thin veneer of fine colluvium deposited over an underlying saprolitic parent material and it is separated from the saprolitic material by a thin stone line. Ojanuga and Awujoola (1981), reported the thickness of the fine colluvial material as less than one metre. They also reported the occurrence of the stone line at a depth of between 30cm and 60cm in the soils of the granitic areas they studied on the Jos Plateau. In profile J-PL-3 formed on granite in the study area, the stone line was encountered at the depth of 23cm, which means that the stone line could be found at a shallower depth than that reported by Ojanuga and Awujoola (1981). The stone line consists of round, medium and coarse gravels



Plate 3: Boulders of basalt at the site of soil profile J - PL-2, formed on ...wer basalt.

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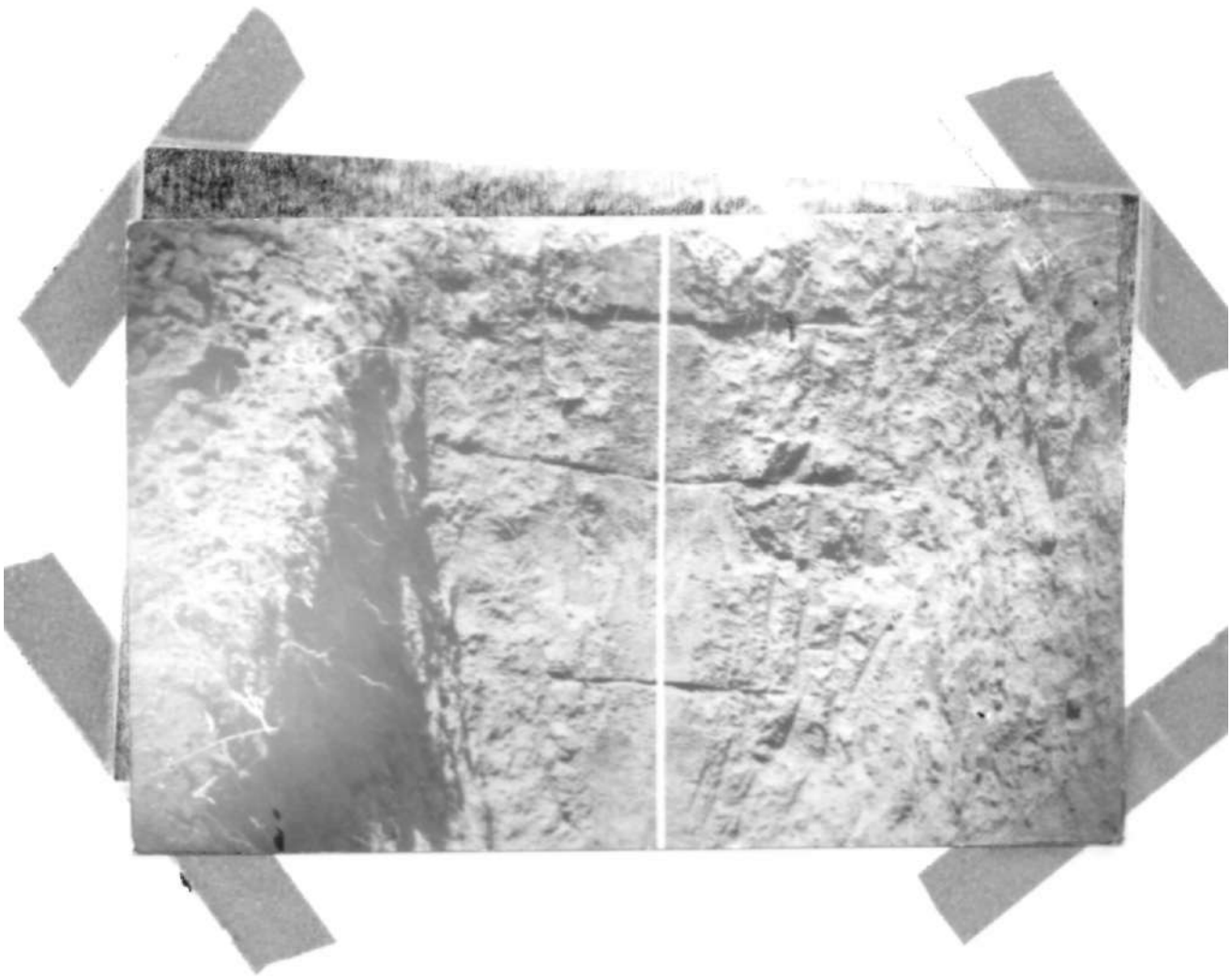


Plate 4: Soil profile J - Pl-2, formed on newer basalt in the study area.

and it is 8cm thick. The stone line is an indication of lithologic discontinuity and also that water deposition played a role in the formation of the soil.

The surface horizons are strong brown (7.5YR 4/6) or red (2.5YR 4/8). The soils have yellowish red (5YR 5/8), reddish gray (10YR 5/1) or brownish yellow (10YR 6/6) mottles; plinthite is a common occurrence in the soils. They have weak to moderate, medium subangular blocky structure or moderate to strong, medium angular blocky structure. The surface horizons are sandy loam or sandy clay loam in texture and the subsurface horizons range from sandy loam to clay in texture.

Three profiles, (two on Younger granites and the other on Older granite), which typify the soils on Granites are described as follows:

Profile J-PL-3 (on Younger granite)

Location : About 19KM to Bokkos on the right hand side of the Barakin-Ladi/ Bokkos road and about 50 metres from the road.

Parent material : Fine colluvium over saprolite from granite gneiss.

Topography : 2 % Slope.

Slope position : Upper slope.

Drainage : Well drained.

Erosion : Moderate sheet erosion.

Surface characteristics : Land is non-stony, but there are nearby granitic rock outcrops.

Vegetation/Land use : Northern Guinea Savanna, cultivated to potato, maize, acha.

Depth to water table : Not encountered, but more than 164cm depth.

Horizon	Depth (cm)	Description
Ap	0-11	Yellowish brown (10YR 5/4) sandy loam with many fine distinct yellowish red (5YR5/8) mottles, strong, medium, angular blocky structure; hard (dry), firm (moist), sticky and plastic (wet); many medium and fine pores; many medium and fine roots; pH 4.6; diffuse smooth boundary.
AB	11-23	Dark yellowish brown (10YR 4/4) sandy loam; moderate, medium angular blocky structure; hard (dry), firm (moist), sticky and plastic (wet); many medium and fine roots; pH 4.6; diffuse smoooth boundary.

AB	23-31	A layer of round gravels - "Stone line".
2Bt1	31-39	Yellowish brown (10YR 5/8) sandy clay loam with many, coarse, distinct red (2.5YR 4/6) mottles; moderate, medium subangular blocky structure; hard (dry), firm (moist), clay skins, gravelly, common, coarse pores, many medium and fine pores, many medium and fine roots; pH 5.2; diffuse, smooth boundary.
2Bt2	39-93	Yellowish brown (10YR 5/4) sandy loam with prominent dark red (2.5YR 3/6) mottles; moderate, medium, angular blocky structure, hard (dry), firm (moist), sticky and plastic (wet); gravelly, many coarse, medium and fine pores, many fine and medium roots, pH 5.2 diffuse smooth boundary.
2BC	93-160	Red (2.5YR 4/6) sandy loam with common, coarse, faint red (10YR 5/2) mottles; moderate, medium angular blocky structure, hard (dry), firm (moist), sticky and

		plastic (wet); many fine and medium pores, pH 5.0, diffuse smooth boundary.
2C	160-164	Strong brown (7.5YR 4/6) clay, with many coarse prominent reddish gray (10R 5/1) mottles; strong, medium angular blocky structure, hard (dry), firm (moist), sticky and plastic (wet); many fine pores, pH 5.1.

Profile J-PL-6 (On older granites)

Location	:	About 0.6KM after the Jos Wild Life park, on the left hand side of the road and about 30 metres from the road.
Parent material	:	Older granite.
Physiography	:	Undulating land with close by outcrops of granite.
Topography	:	4% Slope
Slope position	:	Middle slope.
Drainage	:	Well drained.
Erosion	:	Moderate to severe sheet erosion.
Surface Characteristics	:	Non-stony land.
Vegetation/Land use	:	Northern Guinea Savanna cultivated to potato and acha.
Depth to water table	:	Not encountered but greater than 173cm depth.

Horizon	Depth (cm)	Description
Ap	0-16	Dark yellowish brown (10YR 4/4) sandy clay loam; weak, fine subangular blocky structure; slightly hard (dry), firm (moist), sticky and slightly plastic (wet); common coarse pores and many medium fine roots, pH 5.0, diffuse smooth boundary.

Bt	16-60	Strong brown (7.5YR 5/6) sandy clay loam with common, coarse, distinct red (2.5YR 4/6) mottles; moderate, medium, angular blocky structures; hard (dry), firm (moist), sticky and plastic (wet); thin clay skins on peds, common coarse pores and many medium and fine pores; common coarse roots and many medium and fine roots, pH 5.1, diffuse smooth boundary.
Cu1	60-92	Red (2.5YR 4/6) sandy clay loam, with many coarse, distinct yellowish red (5YR 5/8) mottles; moderate, medium angular blocky structure, hard (dry), firm (moist), sticky and plastic (wet), gravelly, few coarse pores and many medium and fine pores; few coarse roots and many medium and fine roots, pH 4.8 diffuse smooth boundary.
Cu2	92-173	Red (2.5YR 4/6) sandy clay loam, with many coarse distinct brownish yellow (10YR 6/6) mottles; moderate, medium angular blocky structure, hard (dry), firm (moist), sticky and moderately plastic (wet); many medium and fine pores, many medium and fine

Profile J-Pl-4 (On younger granite)

Location : About 120 metres to the Kaduna Vom - Vom Christian Hospital - Miango junction and about 80 metres from the road on the right hand side of the Barakin Ladi/Miango road.

Parent material : Colluvium from younger granite over younger granite.

Physiography : Undulating land with nearby granitic outcrops/hills.

Drainage : Well to imperfectly drained.

Erosion : Moderate to severe sheet erosion.

Surface Characteristics : Nil.

Vegetation/Land use : Northern Guinea Savanna cultivated to potato, maize and acha.

Depth to water table : Not encountered but more than 191cm depth.

Horizon	Depth (cm)	Description
Ap	0-8	Yellowish brown (10YR 5/4) loam; moderate, medium angular blocky structure, hard (dry), firm (moist), sticky and plastic (wet); common coarse

		Pores, very many medium and fine pores, very many medium and fine roots, pH 4.0, gradual smooth boundary.
A2	8-17	Yellowish brown (10YR 5/6) clay loam, moderate, medium angular blocky structure, hard (dry), firm (moist) sticky and plastic (wet); very many medium and fine pores, very many medium and fine roots, pH 4.0, gradual smooth boundary.
AB	17 - 39	Yellowish brown (10YR 5/6) clay loam, with many course, prominent light gray (10YR 7/1) mottles; moderate, medium angular block structure; hard (drY), firm (moist), sticky and plastic (wet); many medium and fine pores. few medium and fine roots, pH 3.8, diffuse smooth boundary.
Bt1	39 - 75	Light gray (10YR 7/1) clay loam with many coarse, distinct red (2.5YR 4/8) mottles; strong, medium angular blocky structure, hard (dry), firm (moist), sticky and plastic (wet); thin clay skins on peds, many medium and fine pores, pH 4.7, diffuse smooth boundary.

Bt2	75-104	Light yellowish brown (10YR 6/4) loam, with many coarse distinct red (2.5YR 4/8) mottles; strong medium angular blocky structure; hard (dry), firm (moist), sticky and plastic (wet); thin clay skins on peds, common, medium pores, and many fine pores, pH 4.7, diffuse smooth boundary.
BC	104-125	Light yellowish brown (10YR 6/4) loam, with many coarse, distinct red (10R 4/8) mottles; strong, medium angular blocky structure, very hard (dry) very firm (moist) sticky and plastic (wet) iron concretions, common medium pores, many fine pores, pH 5.7, diffuse, smooth boundary.
C1	125-156	Light yellowish brown (10YR 6/4) loam, with many coarse distinct, red(10R 4/8) mottles, strong, medium angular blocky structure; very hard (dry) very firm (moist) sticky and plastic (wet); iron concretions, common medium pores, many fine pores, pH 5.9, diffuse, smooth boundary.

156–191 Light gray (10YR 7/1) clay loam, with many coarse, distinct red (2.5YR 4/8) mottles; strong coarse angular blocky structure, very hard (dry), very firm (moist), sticky and plastic (wet); iron concretions, common, medium pores, many fine pores, pH 6.2.

5.1.3 Soils on unconsolidated deposits overlying granites

The soils occur on gently undulating or undulating landscape. They are the most common types of soil in the area. The soils are deep, well drained to imperfectly drained. The surface horizons are generally well drained while the subsurface horizons may be well drained or imperfectly drained. The soils formed on the Rayfield Deposits around Barakin-Ladi are well drained while those on the Bokkos deposits around Bokkos, are well to imperfectly drained. The soils are developed on unconsolidated deposits which vary in composition. The deposits overlie either younger granites or older granites, but most of the deposits overlie older granites. Granites account for a significant proportion of the components of the soils as shown by their moderate to high sand and quartz contents. The deposits around Barakin-Ladi, as already mentioned, come under what have been popularly referred to as the Rayfield deposits while those around Bokkos have been referred to as the Bokkos deposits (Hill and Racham, 1973; Ugwu, 1983).

The surface horizons of the soils are brown (10YR 5/3), dark yellowish brown (10YR 4/6) or yellowish brown (10YR 5/4), while the subsurface horizons are brownish yellow (10YR 6/6), pale yellow (5Y 7/3) red (2.5YR 4/6)

or light gray (10YR 7/2). The soils have light gray (5Y 7/2), dark yellowish brown (10YR 4/6) or yellowish red (5YR 4/6) mottles. They have significant amount of plinthite.

The structure of the soils ranges from weak, medium, subangular blocky structure to moderate, medium subangular or angular blocky structure or strong, coarse angular blocky structure.

The texture of the surface horizons varies from loamy sand to clay loam while the subsurface horizons have sandy clay loam, clay loam or clay texture. An ochric epipedon and an argillic horizon, are common features of the soils. Three representative profiles (one formed on the Rayfield deposits and two on the Bokkos deposits), are described as follows:

Profile J-PL-8 (Formed on Rayfield deposits)

Location	:	About 1KM from Barakin-Ladi low cost houses and about 80 metres from the road on the right hand side of the low cost - Fulani Village road.
Parent material	:	Rayfield deposits.
Physiography	:	Gently undulating land, bounded by far away hills.
Topography	:	2% slope.

Slope position : Middle slope.

Drainage : Well drained.

Erosion : Moderate sheet erosion.

Surface Characteristics : A few stones around.

Vegetation/Land use : Northern Guinea Savanna, vul ivated to potato, maize.

Depth to water table : Not encountered but more than 180cm depth.

Horizon	Depth (cm)	Description
Ap	0-11	Yellowish brown (10YR 5/4) sandy loam, moderate, medium angular blocky structure, hard (dry), firm (moist), slightly sticky and plastic (wet); many medium and fine pores, many medium and fine roots, pH 5.9, diffuse smooth boundary.
Bt1	11-50	Yellowish brown (10YR 5/4) sandy clay loam with common coarse distinct red (2.5YR 4/6) mottles; moderate, medium angular blocky structure, hard (dry), firm (moist), slightly sticky and plastic (wet), thin clay skins on peds and in pores, many medium and fine pores, many medium and fine roots; pH 5.0, diffuse smooth boundary.

Bt2	50-90	Yellowish brown (10YR 5/4) sandy clay loam with many coarse prominent yellowish red (5YR 4/6) mottles; moderate medium subangular blocky structure, hard (dry), firm (moist), slightly sticky (wet), clay skins on peds and in pores, many medium and fine pores, common, medium and fine roots; pH 4.4, diffuse smooth boundary.
Bt3	90-123	Light gray (5YR 7/2) sandy clay loam with many coarse prominent yellowish red (5YR 4/6) mottles; moderate subangular blocky structure, hard (dry), firm (moist), sticky and plastic (wet), thin clay skins on peds, many medium and fine pores, common medium and fine roots, pH 5.1, diffuse smooth boundary.
Cu1	123-155	Red (2.5YR 4/6) sandy loam with many coarse prominent light gray (5Y 7/2) mottles; moderate, medium angular blocky structure, hard (dry), firm (moist) sticky and plastic (wet); many medium and fine pores, pH 6.9, diffuse smooth boundary.

Cu2	155-180	Yellowish red (5YR 4/6) sandy loam with many coarse prominent light gray (5Y 7/2) mottles; moderate, medium angular blocky structure, hard (dry), firm (moist), sticky (wet); gravelly, many medium and fine pores, pH 6.7.

Profile J-PL-11 (On Bokkos deposits)

Location : About 9KM to Bokkos and about 200 metres from the road on the right hand side of the Barakin-Ladi/Bokkos road.

Parent material : Unconsolidated Bokkos deposits.

Physiography : Gently undulating open land, bounded by far away hills.

Topography : 4% slope.

Slope position : Middle slope.

Erosion : Mild to severe sheet erosion.

Drainage : Well to imperfectly drained.

Vegetation : Northern Guinea Savanna, cultivated to maize and sweet potato.

Depth to water table : Water encountered at the depth of 50cm (Pit was sunk in September during the rains).

Horizon	Depth (cm)	Description
Ap	0-15	Yellowish brown (10YR 5/3) loam with few, fine distinct strong brown (7.5YR 4/6) mottles; moderate, medium angular blocky structure, hard (dry), firm (moist), slightly sticky and plastic (wet), many coarse, medium

		coarse, medium and fine pores, many coarse, medium and fine roots, pH 6.2, diffuse smooth boundary.
Bt1	15-38	Yellowish brown (10YR 5/4) clay loam with few, fine distinct yellowish (5YR 6/8) mottles, strong angular blocky structure, hard (dry), firm (moist), slightly sticky and plastic (wet), many coarse, medium and fine pores, many coarse, medium and fine roots, pH 5.5, diffuse smooth boundary.
Bt2	38-57	Light brownish gray (2.5Y 6/4) sandy clay loam with many coarse distinct yellowish brown (10YR 5/6) mottles; strong angular blocky structure, hard (dry), firm (moist), sticky and plastic (wet), gravelly, many medium and fine pores, many medium and fine roots, pH 5.6, diffuse smooth boundary.
BCt	57-81	Light gray (5Y 7/3) sandy clay loam with many coarse distinct dark yellowish brown (10YR 4/6) mottles, moderate angular blocky structure, hard (dry), firm (moist) sticky and plastic (wet), gravelly, many medium and fine pores, many medium and fine roots, pH 5.7, diffuse smooth boundary.

81-130 Light gray (5Y 7/3) sandy clay loam with many coarse, distinct dark yellowish brown (10YR 4/6) mottles, strong angular blocky structure, hard (dry), firm (moist), moderately sticky and plastic (wet), gravelly, many coarse, medium and fine pores, many medium and fine roots, pH 5.9

Profile J-PL-12 (On Bokkos deposits)

Location: : About 12KM to Bokkos on the Barakin-Ladi/Bokkos road and about 300 metres from the road, on the right hand side of the road.

Parent material : Unconsolidated Bokkos deposits.

Physiography : Undulating land.

Topography : 5% slope.

Slope position : Middle slope.

Drainage : Well to imperfectly drained.

Erosion : Mild to severe sheet erosion.

Vegetation : Northern Guinea Savanna (Montane vegetation) cultivated to maize, potato.

Depth to water table : Water table encountered at the depth of 74cm (Pit was sunk in September during the rainy season).

Horizon	Depth (cm)	Description
Ap	0-18	Dark grayish brown (10YR 4/2) loam, moderate, medium angular blocky structure, hard (dry), firm (moist) sticky and plastic (wet); common coarse pores and many medium and fine

		pores, common coarse roots and many medium and fine roots, pH 6.4, diffuse smooth boundary.
Bt1	18-39	Yellowish brown (10YR 5/6) clay loam, with common coarse prominent yellowish red (5YR 4/6) mottles; moderate, medium angular blocky structure, hard (dry), firm (moist), sticky and plastic (wet); clay skins on peds and pore linings, slightly gravelly, many medium and fine pores, many medium and fine roots, pH 5.6, diffuse smooth boundary.
Bt2	39-70	Yellowish brown (10YR 5/6) clay loam with common, coarse, prominent yellowish red (5YR 4/6) mottles; moderate, medium angular blocky structure, hard (dry), firm (moist), sticky and plastic (wet); thin clay skins on peds and in pores, slightly gravelly, man y medium and fine pores, many medium and fine roots, pH 5.7, diffuse smooth boundary.
BC	70-94	Light brownish gray (2.5Y 6/2) sandy clay loam with common, coarse, distinct strong brown (7.5YR 5/6) mottles; strong medium angular blocky structure,

very hard (dry), firm (moist), sticky and plastic (wet); gravelly, many coarse, medium and fine pores, common, medium roots, pH 5.8, diffuse smooth boundary.

94-135 Light gray (10YR 7/2) sandy clay loam with common, coarse, prominent brownish yellow (10YR 6/8) mottles; strong, coarse, angular blocky structure, very hard (dry), firm (moist), sticky and plastic (wet), gravelly, many coarse, medium and fine pores, common medium roots, pH 6.0.

5.2 Physical and Chemical Characteristics

5.2.1 Particle Size distribution

Table 4 contains the data on the particle size distribution of representative profiles, for the various soils. The surface horizons of the soils have a texture which ranges from sandy loam to sandy clay loam while the subsoils have sandy clay loam, clay loam or clay textures.

The soils contain varying amounts of coarse fragments. The co se fragments of the horizons range from 1.9 to 38.9%, the average being 16%. The soils developed on granites have relatively constant and low amounts of coarse fragments in their Ap horizons and the upper transitional horizons, but the B and C horizons have many to abundant coarse fragments. The stone line and gravel layer too, are high in coarse fragments. Ojanuga and Awujoola (1981), have reported high amounts of coarse fragments in the gravel layer, stone line or C horizons of the soils of the Jos Plateau. A similar observation was made by (Ugwu, 1983) who also worked on some soils of the Jos Plateau. Ojanuga and Awujoola (1981), attributed the concentration of coarse fragments in the gravel layer or stone line to erosional processes, in other words, the coarse fragments have been deposited partly by moving water; the washing away of fine soils materials by moving water, leaving

Table 4: Particle Size distribution for representative profiles of the soils

Horizon	Depth	Gravel 2000um	Sand			Silt 50-2um	Clay <2um	Textural Class (USDA)
			CS 2000-250um	FS 250-50um	TS 2000-50um			
	cm	% of whole soil	% of 2000um soil					
			Soils on Newer Basalts					
Profile J-PL-1								
Ap	0-36	7.0	4.2	49.8	54	14	32	SCL
Bt1	36-62	6.8	1.5	28.5	30	18	52	C
Bt2	62-130	18.0	5.3	34.7	40	16	44	C
BC	130-186	19.2	3.3	36.7	40	18	42	CL
Profile J--PL-2								
Ap	0-22	6.7	6	38	44	36	20	L
Bt1	22-56	6.6	3.6	32.4	36	28	36	CL
Bt2	56-100	16.7	5.8	32.2	38	20	42	C
Bt3	100-162	17.3	3	35	38	22	40	C

Table 4 (Contd.)

Horizon	Depth	Gravel 2000um	Sand CS 2000-250um	Sand FS 250-50um	Sand TS 2000-50um	Silt 50-2um	Clay <2um	Textural Class (USDA)
	cm	% of whole soil	% of 2000um soil					
			Soils on Granites					
Profile J-PL-3								
Ap	0-11	1.9	35.8	28.2	64	24	12	SL
AB	11-23	12.7	24.6	33.4	58	32	10	SL
	23-31	Stone line	-	-	-	-	-	-
Bt1	31-39	12.1	22.4	31.6	54	18	28	SCL
Bt2	39-93	10.0	32	32	64	18	18	SL
BC	93-160	16.4	25	39	64	20	16	SL
C	160-164	18.7	2.4	37.6	40	10	50	C
Profile J-PL-4								
Ap	0-8	6.2	9	29	38	38	24	L
AB	8-17	7.4	7	31	38	34	28	CL
Bt1	17-39	15	5	31	36	30	34	CL
Bt2	39-75	20.7	4	34	38	30	32	CL
BC1	75-104	15.3	9	33	42	34	24	L
BC2	104-125	20.4	15	27	42	36	22	L
CB	125-156	17.4	15	33	48	28	24	L
C	156-191	13.8	11	33	44	28	28	CL

Table 4 (Contd.)

Horizon	Depth	Gravel 2000um	Sand CS 2000-250um	Sand FS 250-50um	Sand TS 2000-50um	Silt 50-2um	Clay <2um	Textural Class (USDA)
	cm	% of whole soil	% of 2000UM soil					
Soils on Granites (contd).								
Profile J-PL-6								
Ap	0-16	3.8	27	33	60	20	20	SL
Bt	16-60	2.2	15	43	58	12	30	SCL
Cu1	60-92	26.6	21	39	60	18	22	SCL
CU2	92-173	24.3	20	46	66	12	22	SCL
Soils on unconsolidated deposits overlying granites								
Profile J-PL-8								
Ap	0-11	10.7	32	30	62	28	10	SL
Bt1	11-50	8.9	19	29	48	22	30	SCL
Bt2	50-90	3.7	14	36	50	22	28	SCL
Bt3	90-123	18.7	17.0	33	50	22	28	SCL
Cu1	123-155	16.1	31	33	64	20	16	SL
Cu2	155-180	19.9	39	25	64	18	18	SL

Table 4(Contd.)

Horizon	Depth	Gravel	Sand			Silt	Clay	Textural Class
			CS	FS	TS			
		2000um	2000-250um	250-50um	2000-50um	50-2um	<2um	(USDA)
	cm	% of whole soil	% of 2000um soil					
Soils on unconsolidated deposits overlying granites (contd.)								
Profile J-PL-11								
Ap	0-15	20	16	34	50	30	20	L
Bt1	15-38	31.6	12	32	44	28	28	CL
Bt2	38-57	22	16	34	50	24	26	SCL
BC	57-81	33.5	19	33	52	24	24	SCL
C	81-130	37.8	20	30	50	22	28	SCL
Profile J-PL-12								
Ap	0-18	22	14	30	44	30	26	L
Bt1	18-39	34.2	10	32	42	22	36	CL
Bt2	39-70	23.3	11	27	38	20	42	C
BC	70-94	35.1	22	32	54	18	28	SCL
C	94-135	38.9	20	32	52	24	24	SCL

behind the coarse materials, is also a contributory factor. The concentration of the coarse fragments in the C horizons has been attributed to decreasing intensity of weathering processes with depth.

The soils on basalt show the same trend in the distribution of coarse fragments within their profiles like those on granites; the Ap, AB and Bt1 horizons have few and relatively constant amounts of coarse fragments while the lower Bt horizons down to the C horizons have many or abundant coarse fragments. The decrease in the intensity of weathering down the profiles, just as has been observed by Ojanuga and Awujoola (1981) serves to explain the many or abundant coarse fragments in the lower B and C horizons of the soils. However, the observation by Ojanuga and Awujoola (1981) that the well developed soils formed in basaltic parent materials almost have no coarse fragments or have few coarse fragments, is at variance with the observation in this study whereby the soils formed on basalt have few to abundant coarse fragments.

For the soils on unconsolidated deposits, there is no specific trend in the distribution of the coarse fragments within the Ap, AB and Bt horizons of soils, but the last few horizons of the soils are generally higher in coarse fragments than the overlying horizons.

The lack of a specific trend in the content of coarse fragments of the Ap to Bt1 horizons of the soils, might be attributed to the fact that the soils formed on unconsolidated deposits, which vary in contents and the horizons of the soils could normally vary in composition, depending on which materials were deposited within any one section of the soil. The higher contents of coarse fragments (made up of quartz and concretions) in the lower Bt to C horizons, can also be attributed to decreasing intensity of weathering down the profile. The lowest horizon down the profile, which directly overlies the bedrock, may be part of the previously weathered bedrock. Profiles J-PL-8 and J-PL-11 serve to illustrate the observed trend in coarse fragments contents, within the profiles of the soils formed on unconsolidated deposits.

Sand accounts for between 30 to 82% of the fine earth fraction ($< 2mm$) of the surface horizons of the soils and between 38 to 78%, for the subsurface horizons. The dominance of the fine earth fraction of most soils of the Jos Plateau by sand has earlier been reported by Ugwu (1983) and this study has confirmed that observation.

For some of the soils, the surface horizons are higher in sand, examples are profiles J-PL-1 and J-PL-2, while the subsurface horizons are lower in sand.

However, for some other soils, the surface horizons are less in sand content while the subsurface horizons are higher in sand. Examples in this regard are profiles J-PL-4 and J-PL-8. The argillic Bt horizons as shown in Profiles J-PL-2, J-PL-3 and Profile J-PL-12, for example, are however low in sand content. The concentration of sand in the surface horizons of some of the soils may be due to deposition of sand by wind (especially fine sand) or by running water. The washing away of fine soil materials by moving water, leaving behind the coarse materials, may be another reason Esu (1982) has attributed the relatively higher fine sand in the upper horizons of some of the soils he studied in the Kaduna area of Nigeria, to the aeolian source of the soil parent material of the upper layers of the soils, and the colluvial or saprolitic origin of the lower subsoil horizons. The surface horizons of the soils of the present study have been influenced by aeolian fine loamy material (Macleod et al., 1971). The soils too have lower subsoil horizons which are colluvial or saprolitic in origin. The concentration of sand in the subsurface horizons of some soils may be due to the deposition of the sand by water long ago, especially in the case of soils formed on unconsolidated deposits as represented by profiles J-PL-8 and J-PL-12. It may also

be due to the parent material effect (for those formed on, or largely formed on granitic materials) as quartz, an important component of granite, is a major component of sand. The soils on granites and unconsolidated deposits are higher in sand than those on basalts; this is due to the parent material effect.

Silt accounts for between 12 to 38% of the fine earth fraction of the surface horizons of the soils and between 10 to 36% for the subsurface horizons. The soils are generally high in silt. The high silt contents of the soils serves to differentiate them from the soils of the humid tropical lowlands of southwest Nigeria (Wessel, 1965; Ojanuga, 1969, 1981). The high silt contents of the soils on the other hand, make them similar to the soils of Kaduna area studied by Esu (1982).

The silt content decreases down the profile for some of the soils; profiles J-PL-8 and J-PL-11 are examples in this respect. Esu (1982), reported a decreasing trend with soil depth, in the silt content of some of the soils he studied. The higher contents of silt in the upper horizons of the soils may be attributed to the aeolian, fine loessial material received by their surface horizons. Also, as has been advanced by Esu (1982), fine colluvial sediments received by the soils from upper slope positions, could contribute to the higher silt contents of the surface horizons. For others however, no

regular trend in the silt content down the profile was observed.

The soils on basalts are higher in silt than those on granites and unconsolidated deposits. Ojanuga and Awujoola (1981), reported higher silt contents for soils of basaltic parent materials than those of granitic parent materials on the Jos Plateau. The higher silt contents of the soils on basalts, may be due to the finer nature of the components particles of basalt when compared to granite.

Clay accounts for between 6 to 52% of the fine earth fraction of the surface horizons of the soils and between 16 to 50% for the subsurface horizons. The soils formed on basalts are higher in clay compared to those on granites or unconsolidated deposits. Examples of soils on basalts are profiles J-PL-1 and J-PL-2. The soils on unconsolidated deposits are intermediate in clay, between those on basalts and granites. The clay content does not follow any regular trend down the profile, but the clay content is constantly high for the B horizons. This means there was an eluviation of clay from the A horizons and the subsequent deposition of the clay in the B horizons, in the process of soil development. There are clay skins on peds and in pores.

5.2.2 Soil reaction

Table 5 shows the pH values for representative profiles of the soils studied. The soils are generally acid in reaction, as determined both in water and 0.01M $CaCl_2$. They have pH values ranging from 3.8 to 6.9. The acid nature of the soils can be attributed to heavy orographic (relief) rainfall experienced on the Jos Plateau, leading to leaching. The use of acid forming fertilizers such as Urea and Ammonium sulphate, could also be a contributory factor. The urine of cattle reared on some of the land when left fallow, could also contribute to the low pH of the soils, especially in the surface horizons.

For most of the soils, there is no definite trend in the pH values down the profile but for some of the soils, for example the profile J-PL-4, the pH increases down the profile. This may be due to the leaching of basic cations from overlying horizons and thus deposition in the underlying horizons. Also, down the profiles, there is a general increase in the clay content especially within the B horizons, this serves to retard water percolation thereby checking on leaching and consequently, an increase in pH down the profiles. Again, the parent materials of the soils may be rich in basic ions such as calcium, magnesium and potassium, the weathering of the parent materials releases the basic ions. As one

Table 5. Some Chemical Characteristics of representative profiles of the Soils

Horizon	Depth	pH H_2O	pH $CaCl_2$	Exch. Acidity Al^{3+}	Exch. Acidity H^+	Organic C	Total N	Avail. P	Exch. Cations Ca	Mg	K	Na	CEC NH_4OAc	Base Sat.
	cm			meq/100g soil		%	%	ppm	meq/100 g of Soil					%
Soils on Newer Basalts														
Profile J-PL-1														
Ap	0-36	5.4	5.2	0.18	0.10	1.4	0.10	6.3	2.12	1.93	0.15	0.02	18	23
Bt1	36-62	5.1	5.0	0.20	0.0	1.0	0.07	2.6	1.56	1.09	0.04	0.07	18	15
Bt2	62-130	5.3	4.9	0.20	0.0	0.8	0.07	0.3	1.87	1.03	0.05	0.07	18	17
Bc	130-186	5.4	5.0	0.10	0.0	0.8	0.04	4.2	2.00	1.07	0.04	0.01	11	27
Profile J-PL-2														
Ap	0-22	5.8	5.5	0.10	0.10	1.3	0.08	6.3	3.31	3.21	0.21	0.07	21	33
Bt1	22-36	5.5	5.3	0.20	0.10	0.8	0.13	6.9	3.43	3.04	0.16	0.07	20	34
Bt2	36-100	5.6	5.1	0.10	0.0	0.6	0.04	8.3	2.87	3.37	0.17	0.07	25	25
Bt3	100-162	5.9	5.2	0.10	0.0	0.5	0.05	5.9	3.37	4.07	1.00	0.13	20	42

Table 4 (cont'd)

Horizon	Depth	pH		Exch. Acidity		Organic	Total	Avail.	Exch. Cations				C.E.C.	Base Sat.
		H_2O	Soul	Al^{3+}	H^+	C	N	P	Ca	Mg	K	Na		
	cm			meq/100g soil		%	%	ppm	meq/100 g of soil					%
Soils on Granite														
Granville d-Fi-3														
Ap	0-11	4.6	3.6	0.18	0.27	1.2	0.08	5.9	3.75	1.20	0.35	0.11	16	19
AB	11-23	4.6	3.7	1.25	0.15	1.7	0.12	2.7	1.06	0.20	0.05	0.07	18	8
	23-31	-	-	-	-	-	-	-	-	-	-	-	-	-
Bt1	31-39	5.2	4.5	0.20	0.20	0.9	0.06	1.6	2.12	0.12	0.05	0.07	20	12
Bt2	39-93	5.2	4.5	0.10	0.0	0.6	0.04	1.9	2.00	0.17	0.03	0.09	13	18
BC	93-160	5.0	4.7	0.10	0.0	0.3	0.01	2.0	2.25	0.28	0.03	0.09	17	12
C	160-164	5.1	4.7	0.20	0.0	0.4	0.01	1.4	1.85	0.41	0.01	0.07	21	10
Granville d-Fi-4														
Ap	0-8	4.0	3.1	0.78	0.10	1.0	0.08	5.9	2.12	0.91	0.24	0.09	15	23
AB	8-17	4.0	3.3	1.20	0.05	0.3	0.08	3.9	1.30	0.91	0.16	0.08	15	24
Bt1	17-39	3.4	3.3	2.95	0.05	0.7	0.05	2.4	1.25	0.40	0.12	0.07	16	14
Bt2	39-75	4.7	3.7	3.35	0.58	0.5	0.05	2.0	1.15	0.41	0.13	0.07	25	7
BC1	75-104	4.7	4.2	2.50	0.08	0.4	0.03	1.4	0.84	0.29	0.15	0.07	13	11
BC2	104-125	5.7	4.0	1.98	0.05	0.3	0.02	1.9	1.02	0.29	0.15	0.07	15	11
CB	125-156	5.5	4.3	1.98	0.02	0.03	0.02	1.4	1.31	0.41	0.21	0.06	17	12
C	156-191	5.2	4.3	2.20	0.10	0.03	0.02	2.5	1.54	0.49	0.22	0.13	18	14

Table 5 (contd)

Horizon	Depth	pH H_2O	pH $CaCl_2$	Exch. acidity Al^{3+}	Exch. acidity H^+	Organic C	Total N	Avail. P	Exch. Cations Ca	Mg	K	Na	CEC NH_4OAc	Base Sat.
	cm			meq/100g soil		%	%	ppm	meq/100 g of soil					%
Soils on Granites (contd)														
Profile J-PL-6														
Ap	0-16	5.0	5.1	0.30	0.10	0.8	0.07	20.1	3.81	1.0	0.22	0.03	13	28
Bt	16-60	5.1	3.7	2.00	0.20	0.1	0.03	5.1	0.81	0.38	0.24	0.02	16	8
Ba1	60-92	5.3	3.9	0.40	0.10	0.0	0.03	1.4	0.56	0.08	0.16	0.01	14	6
Ba2	92-173	5.0	4.3	0.00	0.00	0.0	0.02	0.9	1.62	0.06	0.11	0.02	13	5
Soils on unconsolidated deposits overlying granites														
Profile J-PL-9														
Ap	0-11	5.3	4.7	0.30	0.13	1.9	0.14	4.3	0.84	0.51	0.13	0.09	15	23
Bt1	11-50	5.0	4.0	0.53	0.17	0.6	0.05	1.6	0.40	1.08	0.16	0.07	17	23
Bt3	80-90	5.1	4.9	0.35	0.18	0.4	0.04	1.3	0.44	1.19	0.21	0.09	18	25
Bt3	90-123	5.1	4.6	0.50	0.03	0.3	0.03	2.5	0.56	1.13	0.14	0.11	17	17
Ba1	123-155		5.3	0.13	0.05	0.4	0.02	1.4	0.31	1.05	0.17	0.10	8	57
Ba2	155-180	5.7	5.0	0.10	0.05	0.3	0.02	2.8	0.81	0.93	0.14	0.09	13	32

Table 5 (contd)

Horizon	Depth	pH H_2O	pH $CaCl_2$	Exch. Acidity Al^{3+}	Exch. Acidity H^+	Organic C	Total N	Avail. P	Exch. Cations Ca	Mg	K	Na	CEC NH_4OAc	Base Sat.
	cm			meq/100g soil		%	%	ppm	meq/100 g of soil					%
Soils on unconsolidated deposits overlying granites (contd)														
Profile J-PL-11														
Ap	0-15	6.2	5.1	0.90	0.0	1.5	0.12	4.9	2.12	0.66	0.07	0.05	15	20
Bt1	15-38	5.5	5.0	2.70	0.0	1.1	0.11	2.0	1.60	0.28	0.05	0.05	16	12
Bt2	38-57	5.6	5.1	1.40	0.20	0.8	0.08	2.8	1.19	0.20	0.06	0.08	19	8
BC	57-81	5.7	5.4	1.10	0.0	0.6	0.07	3.2	1.25	0.20	0.05	0.08	18	9
C	81-130	5.9	5.4	1.30	0.0	0.7	0.06	3.5	1.19	0.21	0.05	0.07	17	9
Profile J-PL-12														
Ap	0-18	6.4	5.4	0.40	0.0	1.4	0.12	1.9	2.50	1.26	0.06	0.03	19	21
Bt1	18-39	5.6	5.1	0.30	0.0	1.1	0.10	14.5	2.68	1.23	0.06	0.09	17	24
Bt2	39-70	5.7	5.1	0.20	0.0	0.7	0.10	2.6	3.18	1.50	0.06	0.08	16	29
BC	70-94	5.8	5.4	0.10	0.0	0.5	0.05	4.2	3.24	2.02	0.06	0.09	16	34
C	94-135	6.0	5.5	0.10	0.0	0.5	0.06	1.2	3.56	2.26	0.08	0.09	17	35

progresses down the profile, the effects of the parent material becomes more pronounced. Ugwu (1983) has advanced this explanation for the observed increase in pH down the profiles of some soils formed on basalt, on the Jos Plateau.

The increase in pH down the profiles of some of the soils may also be due to the accumulation of acid products in the surface horizons; as observed by Hubert and Hass (1940) in some low-lying citrus soils of California. As earlier indicated, some of such products could originate from acid forming fertilizers. As cattle grazing is common in the area, the urine passed out by the animals could also be another source of such products.

The soils generally will benefit from liming, for better crop production. Under the strongly acid nature of the soils, leguminous plants in particular, would not perform well, because they would not be able to nodulate (Alva, 1987).

The pH in 0.01M $CaCl_2$ is generally lower than in water, but follows same trend as that in water generally, the difference between the two sets of pH values (Δ pH) range from -0.1 to -1.0 indicating that the soil colloid possess a net negative surface charge. For some, both values are the same indicating lack of çation or *anion* exchange or zero point of charge.

5.2.3 Exchange acidity

Table 5 contains the exchange acidity values for representative soils within the different geologic formations.

The exchange acidity of the soils ranges from 0.10 to 3.83 meq/100g soil for the horizons with the average value for the horizons being 0.99 meq/100g soil. Exchangeable Aluminium accounts for the greater proportion of the exchange acidity of the soils, the values ranging from 0.10 to 3.25meq/100g soil for the horizons and the average for the horizons is 0.9 meq/100g soil. Exchangeable hydrogen ranges from 0.0 to 0.58meq/100g soil for the horizons with the average value for the horizons being 0.09meq/100g soil.

For most of the soils, the exchange acidity decreases down the profile, profiles (J-PL-8 and J-PL-12) formed on unconsolidated deposits, are examples in this regard. This is partly due to reduced weathering down the profile and the deposition of leached bases in underlying horizons from the overlying horizons and also due to the effect of bases recently released from the weathering parent materials, the influence of which becomes more pronounced down the soil profile; the bases minimize exchange acidity.

For some of the soils, the exchange acidity increases for a while down the profile, then decreases and thereafter remains relatively constant. Profile (J-PL-4) formed

on granite is an example in this respect. This can be attributed to variations in factors such as leaching, deposition of basic elements, parent material and differential rates of weathering down the profiles of the soils.

For the profile (J - PL - 5) formed on granite, the exchange acidity increases down the profile. This may be due partly to the deposition of Aluminium and hydrogen ions leached from surface horizons in the underlying horizons.

Liming [illegible] soils will serve to reduce the exchange acidity [illegible] soils support crop growth. Liming of the soils to (pH 6.1 - 6.5) will reduce the exchange acidity to a desirable level.

5.2.4 Organic carbon

Table 5 shows the percent organic carbon content for representative profiles of the soils. The organic carbon contents of the soils are low. The values range from 0.0% to 2% and the average for the horizons is 0.7%. This compares adequately with the range of between 0.2% and 2% reported by (Ugwu, 1983) who also worked on some soils of the Jos Plateau. The low organic carbon contents of the soils implies that they are low in organic matter.

The low organic matter content of the soils may be attributable partly to the rapid decomposition of organic matter characteristic of tropical environments and partly due to bush burning and the non-incorporation of crop residues into the soil after harvesting. Another reason for the low organic matter contents of the soils as advanced by Singh and Balasubramanian (1977) and (Ugwu, 1983), is that the native level of organic matter in Savanna soils is quite low because of the prevailing high temperature and relatively low rainfall, both of which result in sparse vegetative cover.

Fine textured soils as typified by profiles J-PL-1 and J-PL-2, are generally higher in organic carbon than the coarse-textured soils as typified by profile J-PL-4 and J-PL-6. This agrees with the earlier findings by Ugwu (1983) that the top horizons of the imperfectly drained soils he studied on the Jos Plateau, (fine-textured

soils), are higher in organic carbon than those of the well drained soils (with coarser texture.) Though the comparison in the study was centered on the surface soil horizons of the soils, the present study has revealed that the higher values of organic carbon of the imperfectly drained soils over those of the well drained soils also hold true over the entire depth of the profiles.

The low organic matter content of the soils implies that they hold little reserves of nutrient elements for crop use, except where they are rich in minerals, such as montmorillonite, micas or feldspars. The water holding capacities of the soils too, will be low.

The organic carbon contents of the soils generally decrease down the profile. One reason for this is that the upper horizons receive more organic residues than the lower horizons in the profile.

5.2.5 Total Nitrogen

The soils are low or very low in total nitrogen. They range from 0.01% to 0.14% in total nitrogen content and the average for the horizons is 0.06%.

There is a positive correlation between organic carbon and Total Nitrogen, for the soils, that is, soils relatively high in organic carbon are also high in Nitrogen and vice versa. Profile J-PL-1 for example, is higher in

organic carbon and also higher in total Nitrogen, the correlation coefficient between organic carbon and total Nitrogen for the soil is 0.91. Profile J-PL-4 is low in organic carbon, in the same way, it is low in total Nitrogen, the correlation coefficient between organic carbon and total Nitrogen for the soil is 0.93.

The reason for the observed positive correlation between Nitrogen and organic carbon, is that organic matter is a reservoir of many nutrient elements including Nitrogen and the mineralisation of the organic matter releases the nutrient elements.

Like organic carbon, total Nitrogen decreases down the profiles of the soils. An example in this regard is profile J-PL-4. This can be explained from the fact that organic matter which is a reservoir of Nitrogen, decreases down the soil profile, because the surface horizons of soils normally receive more organic matter than the subsurface horizons. Another reason that may be advanced for the decrease in Nitrogen down the profile, is the receipts by surface horizons of nitrogenous fertilizers such as Urea and Calcium Ammonium Nitrate (CAN).

Table 5 contains the total Nitrogen data for representative profiles of soils in the different geologic formations.

5.2.6 Available Phosphorus

The available phosphorus data for representative profiles of the soils are presented in Table 5

The soils are very low in available phosphorus, the average for the horizons being 3.5ppm. The available phosphorus ranges from 0.3ppm to 20.1ppm.

The very low available phosphorus of the soils may be explained partly by the low organic matter content of the soils. Organic matter is a reservoir of phosphorus and other nutrient elements, therefore when the organic matter content of the soil is low, the available phosphorus will normally be low. Again, the very strongly acid reaction of the soils implies that phosphorus will be fixed in the soil, under such conditions. Again, the soils are cropped on a continuous basis with little or no time of fallow and quite often, fertilizers are not applied, therefore, the phosphorus is depleted.

There is generally no uniform trend in the amounts of available phosphorus down the profiles of the soils.

Profile J-PL-2 on newer basalt, is uniformly higher in available Phosphorus through its entire depth, when compared to the other profiles studied. This may be partly due to the higher organic matter content of the soil when compared to many of the other soils and partly to the higher pH values of the soil. As pH increases from extremely acid (4.5) up to moderately acid (5.6 - 6.0) Phosphorus becomes more available because it is less fixed.

5.2.7 Exchangeable cations

The exchangeable calcium of the soils is low, it ranges from 0.42 to 4.5meq/100g soil. The average for the horizons is 2.12meq/100g soil. The exchangeable Magnesium is low or moderate but it is generally low. It ranges from 0.06 to 4.07 meq/100g soil and the average for the horizons is 0.94meq/100g soil. The exchangeable Potassium is very low or low but generally low. It ranges from 0.01 to 1.0meq/100g soil. Exchangeable sodium is very low, it ranges from 0.01 to 0.13meq/100g soil, for the horizons and the average is 0.06meq/100g soil. However, the soils will be able to supply the cations needs of potato for one or two cropping seasons, judging from the low critical levels of the elements for many arable crops.

The generally low exchangeable cations of the soils may be attributed to leaching which is favoured by the heavy relief rainfall received on the Jos Plateau. The

situation is worse for those of the soils which are sandy, because increased leaching is enhanced. This is demonstrated by the profile J-PL-3 which is very sandy and consequently, have particularly low exchangeable cations.

Another reason that may be advanced for the low exchangeable cations of the soils, is that they are in most cases cropped on a continuous basis with little or no time of fallow allowed, during which the soils could have built up the nutrient elements; also, quite often, the soils are used in this way without the application of manures and fertilizers, to help replace what is removed by crops.

Exchangeable cations increase down the profiles of some of the soils, for example, profiles J-PL-8 and J-PL-12. This may be due to the removal of cations from the upper horizons and the subsequent deposition in the underlying horizons, during leaching. It may also be due partly to the less intensity of weathering on the parent materials down the profile and the parent materials still have within them cations which are being released into the environment, as they weather. The removal of cations by plants, from the upper horizons, may be another reason for the increase in cations down the profiles; the withdrawal of cations by plants roots become less and less down the profile because the density of roots become less and less.

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However, for some of the soils, the exchangeable cations decrease down the profiles; this may be due to the fact that organic matter contributes a significant amount of the exchangeable cations of such soils and as organic matter decreases down the profile, the exchangeable cations also decrease. For other soils however, no uniform trend in the amounts of exchangeable cations down the profile was recorded.

Judging from the low exchangeable cations of the soils they will benefit from application of fertilizers such as Calcium Ammonium Nitrate, Super-phosphorous and N.P.K. or manures such as Farm Yard Manure. Data on the exchangeable cations of representative profiles of the soils are contained in Table 5

5.2.3 Cation exchange capacity

The cation exchange capacity for the horizons of the soils range from 8.0 to 25.0 meq/100g soil and the average is 17meq/100g soil. Most of the soils have moderate CEC values. The moderate CEC of the soils can be attributed to the usual richness of the parent materials (basalts and granites mainly) in primary minerals such as feldspars and micas which weather to form secondary minerals such as montmorillonite and vermiculite, which

have high surface areas over which cation exchange activities can take place. Remnants of weathering basalt were still visible in the profiles J-PL-1 and J-PL-2 formed on basalt. The near-temperate climate of the Jos Plateau should facilitate the formation of expansible minerals such as montmorillonite and vermiculite.

The CEC increases down the profiles of the soils generally, attaining peak values in the B horizons, then decreases and remaining relatively constant thereafter. This is well exemplified by profiles J-PL-4, J-PL-6 and J-PL-11. This can be attributed to the increase in clay down the soil profile, with the highest clay accumulation usually occuring in the B horizons. The clay fraction of the soil contains most of the secondary minerals such as montmorillonite and vermiculite; the higher amounts of the minerals in the B horizons farther down the soil profile, serve to explain partly their higher CEC values.

The higher CEC values of some C horizons right at the base of the soil profile, over those immediately overlying them, as exemplified by profiles J-PL-3, J-PL-9 and J-PL-12, may be due to the higher clay content of the horizons or their higher content of expansible minerals, over those of the overlying horizons.

The likelihood of the presence of expansible minerals in soils of the Jos Plateau, has been indicated by (Ugwu (1983) based on the observation that profiles relatively high in clay, are also high in CEC/100g of clay. It is believed that the near-temperate climate of the Jos Plateau, should enhance the formation of such minerals. Recently, (Ogunsola, 1985), has reported the presence of expansible clay minerals in soils of the Jos Plateau, Nigeria.

the presence of expansible minerals, in soils of the Plateau. The first explanation is most likely the case for profiles J-PL-3 and J-PL-4, while the second explanation seems to be the case for the profile J-Pl-12 where the horizon at the base of the profile, has less clay then the overlying horizon.

For some of the soils, the CEC increases down the profile for a while, but decreases for the last horizon at the base of profile. This also can be attributed to the usual increase in clay down the soil profile, the increase attaining its peak usually in the B horizons and thereafter decreases. The higher clay contents of the overlying horizons thus contribute to their higher CEC values, as clay is the main seat of secondary clay minerals in the soil. For some soils however, there is no uniform trend in the distribution of CEC values down the profile.

The generally moderate CEC of the soils may be attributed partly to their igneous parent materials which are rich in minerals like feldspars, and micas which weather to form expansible secondary minerals. Surface horizons could also have the benefit of organic matter which could increase the cation exchange capacity significantly. The cation exchange capacity of humus is about two times that of montmorillonite and as much as twenty five times that of kaolinite, (Brady, 1974).

Furthermore, quite a number of the soils are high in clay, the clay fraction of soils is higher in minerals than the silt or sand fraction and improves the cation

exchange capacity of soils. This fact is supported by the higher CEC values of soils that are higher in clay such as profiles J-II-1 and J-II-2.

Based on the CEC values, the soils on basalts hold better prospects for crop production because they can retain and supply plant nutrients better than the soils on granites or on unconsolidated deposits.

5.2.9 Base saturation

The Base saturation percentages for the soils are very low or low, the average value for the horizons is Table 5 contains the Base saturation data for representative profiles of the soils.

The low Base saturation percentages of the soils can be explained partly from the heavy rains received on the Plateau; this encourages leaching of the bases. Also, the continuous cropping of the soils with no replacement of the nutrients removed, with the exception of fertilizers or manures, partly explains the low Base saturation of the soils. The sandy texture of most of the soils, too, enhances leaching of the bases, contributing further to the low Base saturation of the soils.

The surface horizons of some of the soils are higher in Base saturation than the underlying horizons; this is due to the influence of organic matter which is higher in the surface horizons, because the surface horizons receive more organic residues. Soil profiles J-II-4 and J-II-11 serve to illustrate this effect.

The soils which have higher clay contents are also higher in Base saturation. Examples are the profiles J-PL-8 and J-PL-2. This is due partly to the higher mineral contents of the soils and partly due to reduced leaching which is enhanced by their heavier texture. Ugwu (1983), has observed that the poorly or imperfectly drained soils of the Jos Plateau embraced in his study, are higher in Base saturation than the well drained soils. He attributed the differences to the differences in levels of leaching experienced by the two classes of soils.

The very low Base saturation of the soils implies that they are low in the basic elements such as calcium and potassium, and partly explains why the soils are strongly acid in reaction. The low levels of basic elements in the soils must be supplemented by addition through fertilizers or organic manures for any profitable crop production ventures using the soils.

6. SOIL CLASSIFICATION

The soils have been classified according to the criteria of the USDA Soil Taxonomy, (Soil Survey Staff, 1975) and the FAO/UNESCO soil map of the world legend (1974).

6.1 Classification according to Soil Taxonomy

The soils studied have been classified under the Order of Ultisols and AltiSols as follow:

6.1.1 Soils on Newer basalt

Profile J-PL-1 and J-PL-2

The soils have an argillic horizon, they have a base saturation by NH_4OAc (pH 7.0) of less than 50% which is equivalent to less than 35 percent by sum of cations within 1.61 m of the surface of the soil they have an isohyperthermic temperature regime; they have no oxic horizon, no spodic horizon they therefore come within the Order of Ultisols.

The soils have an ustic moisture regime, they have less than 0.9 percent organic carbon in the upper 15 cm of the argillic horizon exclusive of an Ap horizon, the soils therefore fall within the sub-order of Ustults.

The soils have no fragipan, they have an epipedon that has a color value, moist less than 4 in all parts, they have no plinthite that forms a continuous phase or constitutes more than half the matrix in any subhorizon in the upper 1.25 m of the soil, they have a clay distribution with depth such that the percentage of clay

decreases from its maximum amount by greater than 20 percent of the maximum within 1.5 m of the soil surface, and the layer in which the percentage of clay is less than the maximum does not have evidences of clay eluviation in the form of skeletans on ped surfaces; the soils also have an argillic horizon that has 10 percent or more weatherable minerals in the 20-to 200-micron fraction of its upper 50 cm; the soils are therefore classified in the Great-group of Rhodustults.

The soils have an argillic horizon that is continuous vertically and horizontally, the texture is finer than loamy fine sand in some part of the argillic horizon and the soils have no lithic contact within 50 cm of the soil surface, they are therefore classified as Typic Rhodustults

6.1.2 Soils on granites

Profile J-PL-3

The soil has an argillic horizon, it has a base saturation (by sum of cations) of < 35 percent within 1.56 m of the surface of the soil, it has an isohyperthermic termperature regime; it has no oxic horizon, within 30 cm it therefore comes within the Order of Ultisols.

The soil has a hue redder than Aquults, it has an ustic moisture regime, it has less than 0.9 percent organic carbon in the upper 15 cm of the argillic horizon exclusive of an Ap horizon; the soil is classified as an Ustult.

The soil has an argillic horizon that in its upper 50 cm has less than 10 percent weatherable minerals in the 20 to 200-micron fraction and a clay distribution such that

the layer in which the percentage of clay is less than the maximum within 1.5 m of the soil surface, has skeletans; also, the soil has no plinthite that forms a continuous phase or constitutes more than half the matrix in any subhorizon with 1,25 m of the soil surface and it has no fragipan; the soil is classified further as a Paleustult.

The soil has a continuous argillic horizon uninterrupted by ledges of bedrock, no lithic contact within 50 cm of the mineral soil surface, it has a texture finer than loamy fine sand in some part of the argillic horizon and the argillic horizon has no lamellae; the soil is not artificially drained in the upper 75 cm of the soil and in the upper 12.5 cm of the argillic horizon, no petroferric contact within 1m of the soil surface; it has some horizons within 1.5 m of the soil surface that have 5 percent plinthite by volume, it has CEC 24 meq per 100 g clay (by NH_4OAc) and it has no epipedon as thick as 50 cm which has a particle-size class that is sandy throughout; it is therefore classified as Plinthic Paleustult.

Profile J-PL-6

The soil has an argillic horizon, it has a base saturation (by sum of cations) of < 35 percent within 1.4 m of the surface of the soil it has an isohyperthermic temperature regime, it has no oxic horizon, no spodic horizon and no plinthite that forms a continuous phase within 30 cm of the surface; the soil is classified as an Ultisol therefore.

The soil has a redder hue than Aquults, it has an ustic moisture regime, it has less than 0.9 percent organic carbon in the upper 15 cm of the argillic horizon exclusive of an Ap horizon, the soil is further classified as an Ustult.

The soil has no fragipan, no plinthite that forms a continuous phase or constitutes more than half the matrix in any subhorizon within 1.25 m of the soil surface, it has a color $\frac{\text{value moist}}{\text{chroma}}$ of 4 in the epipedon; it also has a clay distribution with depth such that the percentage of clay decreases from its maximum amount by 20 percent of that maximum within 105 m of the soil surface, and the layer in which the percentage of clay is less than the maximum has no evidences of clay eluviation in the form of skeletans on ped surfaces. It also has an argillic horizon that has 10 percent or more weatherable minerals in the 20 to 200-micron fraction of its upper 50 cm, the soil is therefore an Haplustult.

The soil has a continuous argillic horizon uninterrupted by ledges of bedrock, no lithic contact within 50 cm of the mineral soil surface, it has a texture finer than loamy fine sand in some part of the argillic horizon and the argillic horizon has no lamellae, it is not artificailly drained in its upper 75 cm and the upper 12.5 cm of the argillic horizon; it has a hue redder than 10 YR in most parts of the upper 75 cm of the soil that have a color value, moist of 4 or more with mottles of high chroma within the depth and the hue becomes redder with depth within 1m of the soil surfoae; the soil has no

petroferric contact within 1m of the surface, it has some horizons within 1.5 m of the soil surface that has ≥ 5 percent plinthite by volume, it has CEC > 24 meq per 100 g clay (by NH_4OAC), it has no epipedon as thick as 50 cm with particle size class that is sandy throughout; the soil is therefore classified as a Plinthic Haplustult.

Profile J-PL-4

The soil has an argillic horizon. The argillic horizon has base saturation (by sum of cations) less than 35% within a depth of 1.42 m from the surface. The soil has neither a spodic nor an oxic horizon; therefore it comes within the order of Ultisols.

The soil is saturated with water at some time of year, it has prominent mottles and also, an isohyperthermic soil temperature regime and chroma moist of 1 in the matrix of the argillic horizon; the soil thus comes within the sub-order of Aquults.

The soil has no plinthite that forms a continuous phase or constitutes more than half the matrix of any sub-horizon within 1.25m of the soil surface; it has isohyperthermic temperature regime and a clay distribution such that the percentage of clay decreases from its maximum by 20 percent or more of the maximum within a depth of 1.5m from the soil surface and the horizon in which the clay content is less than the maximum has ca cracktans. Also, the soil does not have an abrupt textural change.

at the upper boundary of the argillic horizon; also, the soil has no fragipan, it is therefore classified as a Tropaquult.

The soil has an Ap horizon that has a color value, moist of 4, it has plinthite that constitutes 5 percent or more of the matrix of some sub-horizons within 1.5m of the soil surface and the soil has some subhorizons that have a dominant chroma of 3 or more within 75 cm of the soil surface, the soil is thus given the subgroup name of Aeric Plinthic Tropaquult

6.1.3 Soils on unconsolidated deposits overlying granite

Profile J-H-8

The soil has an argillic horizon, a hue in some part of the argillic horizon that is 5YR or yellower, a colour value moist, of 4 or more and a base saturation by sum of cations of more than 35 percent at a depth of 1.36m below the upper boundary of the argillic horizon. It has an ustic moisture regime, an mollic epipedon, no spodic horizon overlying an argillic horizon, no oxic horizon overlying an argillic horizon and no plinthite that forms a continous phase within 30cm of the surface; the soil is there classified in the Order of Alfisols.

The soil has an isohyperthermic temperature regime, chroma too high for Aqualfs, no aquic moisture regime or artificia/drainage; the soil is classified in the Sub-Order of Ustalfs.

The soil has no duripan within 1m of the soil surface, no natric horizon, no plinthite that forms a continuous phase or constitutes more than half the matrix within any subhorizon of the argillic within 1.25m of the soil surface; no lithic or paralithic contact within 1.5m of the surface. It has a clay distribution such that the layer in which the percentage of clay decreases by as much as 20 percent of the maximum throughout a depth of 1.5m from the soil surface has evidences of clay eluviation (clay skins in some pores, steep rise in clay content of underlying). The soil has many coarse mottles that have a hue of 7.5YR or redder and chroma more than 5 in the argillic horizon; the soil is therefore classified in the <u>great-group of paleustalfs</u>.

The soil has no mottles that have chroma of 2 or less within 75cm of the soil surface, it has a texture finer than loamy fine sand in some subhorizon within 50cm of the soil surface, it has no cracks at some period in most years that are 1cm or more wide at a depth of 50cm, that are at least 30cm long in some part, and that extend upward to the surface or to the base of an Ap horizon, it has more than 5 percent plinthite by volume in some subhorizon within a depth of 1.5m of the soil surface, it has no calcic horizon or soft, powdery secondary lime within a depth of 1.25cm, has no argillic horizon that has base saturation (by sum of cations) of 75 percent or more in some part, no natrocalcic horizon that has its upper boundary within 1.5m of the soil

surface, CEC of 24 or more meq per 100g clay (by NH_4OAC) and an argillic horizon that has a colour hue of 5YR or yellower in some part; the soil is therefore classified as Plinthic Ultic Haleustalf

Profile J-PL-11 and J-PL-12

The soils have an argillic horizon. The argillic horizon has base saturation (by sum of cations) less than 35% within a depth of 1.43m and 1.40m from the surface respectively. The soils therefore come within the order of Ultisols.

The soils are saturated with water at some time of year, they haveea dominant hue of 2.5Y or 5Y in the matrix of the argillic horizon and prminent mottles and also an isohyperthermic soil temperature regime; the soils thus fall in the sub-order of Aquults.

The soils have no plinthite that forms a continuous phase or constitutes more than half the matrix of any isothermic temperature regime, they have a clay distribution such that the percentage of clay decreases from its maximum by 20 percent ormore of the maximum within a depth of 1.5m from the soil surface and the horizon in which the clay content is less than the maximum has few skeletons. Also, the soils have ten "percent or more weatherable minerals in the 20-to 200-micron fraction in the upper 50cm of the argillic horizon and do not have an abrupt textural change at the upper boundary of the argillic horizon; also, the soils have no fragipan, the soils are therefore classified as Tropaquults.

The soils have an Ap horizon that has a clour value, moist of them have planthite that constitutes 5 percent or more of the matrix of some subhorizons within 1.5cm of the soil surface and the soils have some subhorizons that have a dominant chroma of 3 or more within 75cm of the soil surface, the soils are thus given the subgroup name of Aeric Plinthic Tropaculfts.

6.2.1 Soils on Newer basalts

Profiles J-PL-1 and J-PL-2

The soils have an argillic B horizon which has a base saturation of less than 50 percent (by NH_4OAc) within 125cm of the surface; they lack a mollic A horizon, they lack an albic E horizon overlying a slowly permeable horizon, they laxk the distribution pattern of the clay and the toncing which are diagnostic for the planosols, Nitosols and Pouzoluvisals respectively; they also lack an aridic moisture regime; the soils are therefore classified as Acrisls.

The soils have an ochric A horizon; they lack ferric properties, they also lack plinthite within 125cm of the surface and they lack hydromorphic properties within 50cm of the surface; they are classified as Orthic Acrisols.

6.2.2 Soils on granites

Profiles J-PL-3, J-PL-4 and J-PL-6

The soils have an argillic B horizon which has a base saturation of less than 50 percent (by NH_4OAC) within 125cm of the surface; they lack a mollic A horizon, they

lack an albic E horizon, they lack the distribution pattern of the clay and the tonguing which are diagnostic for the planosols, Nitosols and podzoluvisols respectively; they also lack an aridic moisture regime; they are classified as Acrisols.

The soils have plinthite within 125cm of the surface, they are classified further as Plinthic Acrisols.

6.2.3 Soils on unconsolidated deposits overlying granites

Profiles J-PL-8, J-PL-11 and J-PL-12

The soils have an argillic B horizon which has a base saturation of less than 50 percent (by NH_4OAc) within 125 cm of the surface; they lack a mollic A horizon, they lack an albic E horizon, they lack the distribution pattern of the clay and the tonguing which are diagnostic for the planosols, Nitosols and podzoluvisols respectively; they also lack an aridic moisture regime; they are classified as Acrisols.

The soils have plinthite within 125 cm of the surface, they are classified further as Plinthic Acrisols.

Table 6. Summary of soil classification

Geologic grouping of soil/soil profile	Soil Taxonomy	FAO/UNESCO
On newer basalts		
Profile J-PL-1	Typic Rhodustult	Orthic Acrisol
Profile J-PL-2	Typic Rhodustult	Orthic Acrisol
On granites		
Profile J-PL-3	Plinthic Paleustult	Plinthic Acrisol
Profile J-PL-4	Aeric Plinthic Tropaquult	Plinthic Acrisol
Profile J-PL-6	Plinthic Haplustult	Plinthic Acrisol
On unconsolidated deposits overlying granites		
Profile J-PL-8	Plinthic Udic Paleustalf	Plinthic Acrisol
Profile J-PL-11	Aeric Plinthic Tropaquult	Plinthic Acrisol
Profile J-PL-12	Aeric Plinthic Tropaquult	Plinthic Acrisol

7. LAND SUITABILITY CLASSIFICATION FOR IRISH POTATO PRODUCTION

In classifying the different types of land involved in this study as regards their suitability for potato, the classification will be based on the status of the soils as regards the ranges in physical soil requirements for potato, starting from the ideal through the moderately suitable to the unsuitable set of soil requirements for the crop; with adequate attention paid to the nutrient status of soils.

As a reminder, an ideal potato soil is deep, well drained silt loam or sandy loam in texture and it is slightly acid. However, potato will still perform adequately well in soils having the texture of fine sand or clay loam, it also tolerates gravelly soils.

7.1 Potato land suitability classification system used

The land suitability classification will be done following the suitability classes for potato, as spelt out in the table 7.

Yield data, obtained from plots located within the various suitability classes, of land using improved potato varietes and fertiliser type and level 40kg N(Urea), 40kg P_2O_5(SUPA), 20kg K_2O/ Ha, (mixed) as recommended by the National Root Crop Research institute (Irish Potato Programme) Kuru, Jos, have also been included in the suitability classes.

TABLE 7: AGRO-CLIMATE BASED LAND CLASSIFICATION CRITERIA FOR IRISH POTATO PRODUCTION ON THE JOS PLATEAU.

Land qualities	Suitability Classes				
	Class I (Ideal Potato land)	Class II (Highly suit. pot. land)	Class III (mod. suit. pot. land)	Class IV (more. suit pot. land)	Class V (unsuitable potato la
Drainage	Well drained	Well or well to imperfectly drained	Imperfectly drained	Imperfectly or poorly drained	poor drai or excess vely drai
Depth	150cm	150cm	150cm	150cm or more	50cm o 50cm
Texture (Surfaces soil)	Sil or SL	SL - L	L or SCL	CL or C	Coarse S SC or C
(Subsoil)	L - CL	L - CL	CL - C	C	SC or C
Water holding capacity	Good	Good	Good or High	High or very high	Low, Hig or very high
Slope	1 - 2%	2 - 3%	2 - 3%	4 - 6%	6%
Stoniness	Non - Stony 1% soil Surface is covered with stones	A-bit stony (1-2% Surface is covered with stones)	A bit stony (1-2% of the soil surface is covered with stones.	Stony (about 10% the soil surface is civered with stones).	very stony (stones cover o 20% the soil su ce)
Rock out crops	None or few	Few	Few	Common	Many

TABLE 7 (CONTD).

Land qualities	Suitability Classes				
	Class I	Class II	Class III	Class IV	Class V
Land area	20 Ha,	15 Ha, or more	15 Ha, or more	2 - 5 Ha	2 Ha.
Nutrient Status (Upper 50cm of soil) Ex,cations	Ca Mg K Na 5.0 2.6 0.3 0.05	Ca Mg K Na 2.0-1.0-0.15-0.03 5.0 2.6 0.3 0.05	Ca Mg K Na 1.5-0.5-0.15 0.015 2.0 1.0 0.25 0.03	Ca Mg K Na 0.5-0.3-0.05-0.005 1,5 0.5 0.15 0.015	Ca Mg All ∠va stipula for cla IV
	Meq/100g soil/or more	Meq/100g Soil.	Meq/100g Soil	Meq/100g Soil	
CEC	8,0 meq/100g soil or more	6-8meq/100g Soil	4.0-60 meq/100g soil	3-4 meq/100g soil	∠3 meq/ soil
Bas. Sat. Tot,N	0,09% or more	0.05-0.09%	0.03-0.05%	0.015-0.03%	∠0.01
Avail,P	5ppm or more	3.5-5.0ppm	2.0-3.5ppm	1.4-2.0ppm	∠1.4p
Org.C.	2% Or More	1-2.0%	0.5-1.0%	0.3-0.5%	∠0.3%
pH	5,8-6.5	5.1 - 6.0	4.5 - 5.5	4.5 - 5.5	∠4.5
Yield	11.0 Tonne/Ha or more, with no addition of fertilizers and under the farmer's condition	11 Tonne/Ha or more with the application of fertilizers and under the farmer's condition	6.0 - 9.0 Tonne/ Ha, with the application of fertilizers and under the farmer's condition	3 - 5 Tonne Ha with the application of fertilizers and under the farmer's condition	∠1.0 T /Ha with applic tion fertil zers, der th farme condi

7.2 Land suitability classes of the soils

Soils studied are given suitability classes for potato production as follow:

7.2.1 Soils on newer basalts

The soils are well drained, deep, have the texture of loam, sandy clay loam, clay loam or clay; they have good water holding capacity, land is gently undulating or undulating, stony, there are a few rock outcrops, land is moderately extensive; the soils are low or moderate in nutrient elements, they are very strongly or strongly acid in reaction, yield of 10.8 Tonne/Ha. with application of 40kg N(Urea), 40kg P_2O_5(SUPA) and 20kg (K_2O)/Ha of mixed fertilizer. The land is therefore classified as a class II (Highly suitable) potato land.

7.2.2 Soils on granites.

The soils are well drained, deep, have the texture of sandy loam or sandy clay loam, They have good water holding capacity, land is gently undulating or undulating, non-stony, there are a few rock outcrops, land is extensive or moderately extensive; the soils are very low or low in nutrient elements, they are very strongly acid in reaction. Yield of 8.6 Tonne/Ha with the application of 40kg N (Urea) 40kg P_2O_5 (SUPA) and 20kg (K_2O) /Ha of mixed fertilizer. The land is classified as a class III (moderately suitable) for potato land.

7.2.3 Soils on unconsolidated deposits overlying granites

The soils are well drained or imperfectly drained, deep, they have texture ranging from loamy sand, sandy loam, loam to clay loam, sandy clay loam or clay. Land is gently undulating or undulating few or no stones, few or

no rock outcrops, land is extensive, soils are very low, low or moderate in nutrient elements, they are extremely acid, very strongly acid or strongly acid in reaction. Yield of 8. 4 Tonne/Ha with the application of 40kgN(Urea), 40kgP_2O_5(SUPA)and 20kg (K_2O) /Ha of mixed fertilizer. The land is classified as a class III (moderately suitable potato land.

TABLE 8: POTATO YIELDS (TONNE/HA) FROM PLOTS ON WHICH SOIL PROFILE PITS WERE LOCATED; WITH THE APPLICATION OF 40KG N (UREA) 40KG P_2O_5 (SUPA), 20KG K_2O L HA., UNDER THE FARMER'S CONDITIONS

SOIL TYPES /PROFILE PITS	YIELDS	SUITABILITY CLASSES
Soils on newer basalts		
Profile J-PL-1	10.7	II
Profile J-PL-2	10.5	II
Soils on granites		
Profile J-PL-3	8.6	III
Profile J-PL-4	8.4	III
Profile J-PL-6	8.3	III
Soils on unconsolidated deposits overlying granites		
Profile J-PL-8	8.7	III
Profile J-PL-11	8.5	III
Profile J-PL-12	8.4	III

7.2.4 The category of soils that support most of the potato grown in the study area.

In both Mangu and Barakin-Ladi Local Government Areas, the soils developed on unconsolidated deposits overlying granites, constitute the greater proportions of the total land areas; the soils accounting for about 60% (about 217,159.8ha.) the area of Mangu Local Government Area and about 55% (about 107,613.6 ha.) the area of Barakin-Ladi Local Government Area. The soils account for about 30% (about 50,851.2 ha.) the area of Jos Local Government Area. The aforegoing figures suggest that about half of the potato grown in the study area, is grown on the soils on unconsolidated deposits overlying granites.

The land suitability classes of the soils for potato production, as shown in this study, tends not to favour one, as the classification has shown that the soils on unconsolidated deposits are equally as suitable for potato production, as those on granites (both are class III potato soils), only the soils developed on basalt's (class II potato soils), are superior and this category of soils is of limited extent in the study area.

The normal expectation then, is that the soils on unconsolidate deposits, which are not only suitable for potato production, but constitute the greater proportion of the study area, will support the greater proportion of the potato grown in the study area, relative to any of the two other categories of soils.

It then follows that for the production of [illegible] to be stepped up on the Jos Plateau, it is this [illegible] soils that should be given the greater attention by way of adding sufficient amounts of the essential elements in which the soils are deficient; as fertilizers or manures. An application of the major elements (N.P.K), at the rates of 40kgN (Urea), 40kg P_2O_5(SUPA) and 20kg K_2O/Ha, (mixed), is sufficient for optimum yields.

8. SOIL IMPROVEMENT FOR POTATO PRODUCTION

This chapter of the study seeks to highlight what could be done to make the potato soils studied support the production of the crops better. In doing this, an understanding of the problems of the soils is a must, because what ever improvement package will be advanced, will be on the basis of the identified limitations or problems of the soils. The problems of the soils as revealed in this study are now highlighted as follow :

8.1 Problems of the potato soils studied

The observed inherently low fertility of soils of the Jos Plateau, is due largely to unfavourable environmental factors such as : (i) heavy relief rainfall which results in leaching of nutrient elements and acidification of the soils, (ii) the slope of the land encourages the washing away of the fertile topsoil (iii) the sandy nature of most of the soils encourages leaching of nutrients and acidification of the soils, (iv) increased pressure on the land, allows little or no time of fallow during which the soils could rebuild nutrients lost and also improve their structure (v) the use of acid forming fertilizers such as urea and ammonium sulphate, contributes further to the acidification of the soils, nutrients are made unavailable in a strongly acid soil environment.

The igneous parent materials of the soils are normally rich in minerals such as feldspares and micas among others, which release nutrient elements on weathering. The soils

inherit some of the minerals from the parent materials. The near-temperate climate of the Jos Plateau, should also encourage the formation of secondary minerals such as montmorillonite and vermiculite, which have large surface areas with which to bind cations in addition to the elements the minerals themselves have originally. The moderate to high cation exchange capacity of most of the soils involved in the study, lend weight to the possibility of the formation of secondary expansible minerals on the Plateau. These good assets the soils are endowed with, should normally have made them better in terms of their nutrient status, but the afore-mentioned adverse environmental conditions, have constantly robbed the soils of the assets.

8.2 Improvement package for the soils

Efforts at improving the potato soils, will be geared towards minimising the impacts of the unfavourable environmental factors as well as correcting whatever imprints the factors have left or leave on the soils, before and after the application of the soil improvment package to be given shortly.

All the soils share similar problems though varying in extent; they require similar solutions, with modifications wherever necessary. The improvement package is as follows :

8.2.1 Package aimed at minimising the impacts of unfavourable environmental factors

1. Mulching - the soils should be mulched with crop residues such as vines of harvested potato crop when not being used for a second crop, cover crops could also be planted on the land when it is not being cultivated. The cover crop could be ploughed into the soil, sometime before seeding. The mulches or cover crop serve(s) to check erosion, they serve to protect the structure of the land and they improve the organic matter content of the soil.

2. Avoidance of steep land for potato cultivation. Potato should not be grown on steep land, so as to prevent a serious erosion hazard. The vegetal cover on such a land should not be disturbed.

3. Minimum tiliage - should be used in seeding the land to potato. This involves least disturbance to the soil in the process of cultivation. Hand cultivation using light implements such as rakes or spades, or the use of light, animal drawn implements or light tractors, should be preferred to heavy equipments such as big tractors, which over pulverize the soil.

4. Contour ploughing should be used on slopy land, to minimize erosion.

. . Corrective measures

1. Lime should be done to raise the pH of the soils to the desired level pH 6.3-6.5 (slightly acid).

. . Split application of Calcium Ammonium Nitrate, urea, muriate of and compound fertilizer (N:P:K) should be applied to make up for the insufficiency of the soils in nutrients.

. Broadcasting of fertilizers, (for example urea, should be done on the wet bottom), should be avoided.

. Split - application of fertilizers should be employed to minimize leaching losses.

5. The nutrient status of the soils could be improved through crop rotation; potato should be rotated with legumes such as cowpea and groundnut.

6. Soil and leaf tests should be conducted to know the conditions of the soils and appropriate steps should be taken depending on results of tests.

9. SUMMARY AND CONCLUSION.

The Jos Plateau occupies about 8,600km^2 within the area marked by 8^o 22'E and 9^o 30'E and 8^o 30'N and 10^o 10'N; (Hill, 1978). Its geology consists of precambrian to cambrian undifferentiated basement complex (mainly gneisses) and "Old Granites" which have been eroded to expose the "Younger Granites", Grove (1952), Tomlinson (1965) Kogbe (1976), Ojanuga and Awujoola (1951). Tertiary and Quaternary Volcanic rocks (mainly basalts) also occur on the Plateau. The climate of Jos Plateau is moderate due to the high altitude. The climatic data of Jos 9^o 52'N, is relevant to the study area. The vegetation of the Plateau is the Northern Guinea Savanna, land use on the Plateau includes Farming, Rangeland, Forestry and Mining. The soil moisture regime is inferred to be ustic and the soil temperature regime is isohyperthermic Ojanuga and Awujoola (1981).

Only relatively few comprehensive soil studies upon which meaningful landuse policies can be based, have been conducted up to date, on the Jos Plateau. A lot more needs to be done, for a better understanding of the soils and their optimum use.

The present study is on the characterization and classification of major Irish potato growing soils on the Jos Plateau. It is aimed at generating more comprehensive data on the soils, for their better understanding, management and consequently, their better utilization. It is also aimed at enhancing their identity and understanding world-wide by classifying them using internationally recognized systems.

Furthermore, Irish potato, a very promising and nutritive crop which is popular on the Jos Plateau, will benefit much from the study, as the potentialities of the soils for potato production are closely examined, based on important characteristics of the soils.

The soils investigated were selected from three (Jos, Barakin-Ladi and Mangu Local Government Areas of Plateau State), of the five major potato Zones on the Plateau, which constitue about 78% percent the land area of the major potato producing Zones of the area and accounting for about 81% percent the land under potato production in the year 1986 in the Zones, Ifenkwe (1987). The soils were selected from the three main geologic formations on the Plateau.

Important characteristics determined for the soils include PH, Texture, Organic carbon, Exchange Acidity, Cation Exchange Capacity, Exchangeable Cations, Base Saturation, Total Nitrogen and Available Phoshorus, following recognised, standard procedures.

The soils have been classified in accordance with both the USDA (1975) and FAO/UNESCO (1974) systems. The land suitability classification for Irish potato is also done.

Most of the soils are sandy and their texture ranges from sandy loam or loamy sand to sandy clay loam or clay loam for the surface horizons and from sandy loam, sandy clay loam to clay loam or clay for the lower horizons. The surface horizons are yellowish brown, dark grayish brown or dark reddish brown while the subsurface horizons are light gray, yellowish brown or red. Most of the soils are mottled and gravelly. The soils are deep, well drained or imperfectly drained.

The soils are all acid in reaction, they range from extremely acid to stongly acid. Exchangeable Aluminum accounts for the greater proportion fo the exchange acidity of the soils. The soils are low in nutrient elements but those formed on Newer basalts are better of th n both those on granites and on unconsolidated deposits.

The soils have moderate or low cation exchange capacity with most falling in the moderate category which suggests that they have some explansible 2:1 clay minerals.

The soils have been classified under the Order of Ultisols and Alfisols in the USDA 1975 System and as Acrisols, in the FAO/UNESCO 1974 system. Ultisols and Alfisols have been identified by previous soil studies on the Jos Plateau, this study has lent weight to those earlier findin s, thus confirming the existence of the soils on the Jos Plateau.

All the soils investigated are suitable for potato they fall into classes II and III potato land. The soils on Newer Bacalts are class II Potato land while those on granites and unconslidated deposits are class III potato land.

The inherently low fertility of the soils of the Jos Plateau is due largely to unfavourable environmental factors such as heavy relief rainfall which encourages leaching.

the slope of the land, which encourages the washing away of the fertile topsoil; the sandy nature of most of the soils which further encourages leaching, there is also the continuous cropping of the land with little or no fallow period allowed and the non-application of fertilizers quite often, there is also the acidification of the soils by the use of acid-forming fertilizers. All the factors mentioned, add up together to rob the soils of the nutrials elements they inherit from their igneous parent materials and the contributions by some explansible 2:1 clay minerals likely present in the soils - the near temperate climate of the Jos Plateau should enhence the formation of such minerals, (Ugwu 1993). The moderate, cation Exchange Capacity of most of the soils, lend weight to this notion.

Improvement of the soils for potato production enbraces minmising the effects of the unfvaourable environmental factors mentioned, as well as correcting whatever imprints they have left or inevitably leave in the soils.

Measures at minimising the impacts of unfavourable environmental factors include mulching or use of cover crops, avoidance of steep slopes for cultivation, avoidance of heavy implements which over-pulverise the soils, thus breaking down the structure and encouraging erosion. As much as possible, acid-forming fertilizers should be avoided.

Measures at correcting the undesirable imprints left in the soils by environmental factors include liming to raise the PH to the desirable level (slightly acid), use of chemical fertilizers or organic manures to improve the nutrient status, crop rotation involving potato and legumes such as cowpea and Groundnuts, should also be practised to maintain or improve the fertility of the soils; split application of fertilizers should be used, to minimize leaching losses and finally, occasional soil tests should be conducted to know the conditions of the soils and appropriate actions should be taken based on the results of the soil tests.

In conclusion, the major potato growing soils of the Jos Plateau, investigated in this study, are generally sandy, deep, well or imperfectly drained; they are acid, low in nutrients, have moderate, or low cation exchange capacity they are Ultisols or Alfisols, USDA (1975) system; or Acrisols, FAO/UNESCO (1974) system; they are highly or moderately suitable for Irish Potato, their inherently low fertility is due largely to unfavourable environmental factors which rob the soils of the gains from the adequately nutrient-rich igneous parent materials; soil improvement measures should be directed at minimizing the impacts of unfavourable environmental factors as well as correcting whatever imprints they have left or inevitably leave in the soils

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11. APPENDIX

Appendix 1 : Soil Property Ratings

SOIL DEPTH

Very shallow	30 cm
Shallow	30 - 50 cm
Moderately deep	50 cm - 1 m
Deep	1 m

SOIL REACTION

Extremely acid	pH
Very strongly acid	4.5
Strongly acid	5.1-5.5
Moderately acid	5.6-6.0
Slightly acid	6.1-6.5
Netral	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

ORGANIC MATTER

Very low	0.4% carbon
Low	0.4-1.0% carbon
Moderate	1.0-1.5% carbon
High	1.5-2.0% carbon
Very high	2.0% carbon

EXCHANGEABLE CATIONS

	Range in meq/100 g soil			
	Ca	Mg	K	Na
Very low	2	0.3	0.2	0.1
Low	2-5	0.3-1	0.2-0.3	0.1-0.3
Moderate	5-10	1-3	0.3-0.6	0.3-0.7
High	10-20	3-8	0.6-1.2	0.7-2
Very high	20	8	1.3-2	2

CATION EXCHANGE CAPACITY (CEC)

Very low	6 meq per 100 g soil
Low	6-12 meq per 100 g soil
Moderate	12-25 meq per 100 g soil
High	25-40 meq per 100 g soil
Very high	40 meq per 100 g soil

PERCENTAGE BASE SATURATION

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

Available P (Melich)

Very low	1.1 ppm
Low	1.1 - 3.3 ppm
Medium	3.4 - 6.7 ppm
High	6.8 - 11.2 ppm
Very high	11.2 ppm

(In Handbook on reference methods for soil testing, by The Council on Soil Testing & Plant Analysis, Athens, Georgia, 1974).

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