RECONNAISSANCE SOIL SURVEY OF PART OF DANGE AREA OF SOKOTO STATE, NIGERIA

BY

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10. Recommendation:

We recommend that he be awarded the degree of M.Sc. in soil science subject to the corrections to be made because we are satisfied that his thesis is original and well presented and he has demonstrated a satisfactory knowledge of his subject.

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DEDICATION

This work is dedicated to my late uncle

NWAKO AGBU

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INTRODUCTION

The ever present threat of hunger, especially in the developing parts of the world poses a very serious problem to mankind. In Nigeria, the ever increasing population hints at the prospect of imminent starvation if food production is not stepped up to meet the increasing demand.

Since the ultimate source of food is the land, steps must be taken to make very efficient use of the limited natural resource (land) and also conserve it for future generations. Therefore, to produce more food, the land already under cultivation must be made more productive without deterioration and new arable land must be cleared for cultivation. To achieve this goal, proper agricultural planning must be done. As a base for land resource planning, an inventory of the soil characteristics must be obtained through soil survey. The need for reliable soils data for Nigeria cannot be over-emphasized at this period that the country is making a rapid transition from traditional to a modern economy. Therefore, there is a need to introduce a programme of systematic survey, classification and mapping of our soil resources. The lack of such a programme constitutes a major obstacle in introducing innovations in our resource management systems. Also the transfer of the results of research to the generality of land users and resource managers throughout the country is highly impaired by limited documented data and unspecificity in land resource research.

The small quantity of real technical data and scientific information on the country's environment and particularly the soils resource is evidenced by scarcity of maps of local areas, that is, large scale maps. Apart from a series of topographic maps at a scale of 1:50,000 which was produced in the nineteen sixties, most of the maps available in the country (e.g. soil, geological, landuse, vegetation) are at scales of 1:100,000; 1:250,000 and less.

The present study evaluates the soil conditions of the Dange area at the reconnaissance level in order to gather soil information that can support agricultural planning for the area. Some of the pertinent soil characteristics useful in agricultural planning and soil classification were studied. The soils were finally classified using the FAO/UNESCO and the USDA systems of soil classification.

LITERATURE REVIEW

Pedology and Soil Survey

Pedology is the pure science concerned with the study of the soils in their natural environment, which means the consideration of their distribution, genesis, characteristics and classification. It is a science, which although young, compared with various related sciences such as geology and biology, has recorded some very interesting results. Within a period of slightly more than ninety years, this subject, starting with the concepts of Dokuchaiv (1888) has developed into a world wide science with large storehouse of various techniques which are used by many thousands of people (Vink, 1962).

Soil survey is considered to be part of the fundamental soil science called pedology. It certainly has a very important meaning for pedology. However, from the practical point of view, the need for soil surveys for development purposes especially for the development of agricultural and non-agricultural projects, is growing even more. Soil survey is one of the most typical links between the fundamental pedology and the applied aspects of soil science.

Past Concepts of Soil

Up to about a half century ago, most scientists who studied the soil thought of it as disintegrated rock mixed with some decaying organic matter. This is evident from the studies of Fallou (1862) and Merrill (1906). If soil is considered to be disintegrated rock, weathering alone provides an adequate explanation for its formation. Nothing further is necessary to provide a satisfactory theory of soil genesis.

This early concept was replaced first in Russia (Glinka, 1927) and later in other countries by the idea that soils were more than weathered rock and that they had profiles consisting of genetically related horizons. After this concept was fully developed, weathering alone was no longer an adequate theory of soil formation.

In the early Russian studies (Glinka, 1927); Neustruev, 1927) much stress was placed on climate and vegetation as factors of soil formation though parent materials, relief and time were also considered. Functional relationships between soils and their environment were recognised in these studies.

The studies of Dokuchaiev and his colleagues were centred on soils with marked horizonation, such as the

Chernozems and Podzols (Neustruev, 1927). In USA, processes of soil formation have been related directly to prominent great soil groups by names such as podzolization, laterization and solonization (Kellogg, 1936). The latter are gross processes thought to differ from one another in a number of essential properties. In fact, some processes such as podzolization and laterization have been considered to be opposite in a large measure.

The Russian school of thought holds soil evolution to be a continuous process (Neustruev, 1927; Nikiforoff, 1942). According to this view, all kinds of soils existing on the earth at any given time are temporary stages. Each kind represents one stage which may disappear, recur, disappear and recur again. Each stage is succeeded by some other stage in the process of continuing evolution.

Present Concept of Soil

The current concept of soil widely held is that, soils are three-dimentional natural bodies formed on the earth's surface, occupying space, and having unique morphology (Glinka, 1927). The character of the soil profile remains important though it must share place with other features of the soil.

Simonson (1957) stated that each body of soil occupies volume or space. It is an entity with three dimensions; namely, length, breadth and depth. Each soil body has a distinct upper boundary where it meets the atmosphere. Each has a less distinct lower boundary where it grades into weathered rock.

Individual bodies of soils are seldom set apart from their neighbours by sharp boundaries. Adjacent bodies commonly grade into one another. Every landscape comprises of a number of separate geographic bodies or segments of the soil continuum. The pattern of individual soil bodies thus introduces local differences into the soil continuum. Every soil type has a characteristic region of occurrence. The occurrence of specific soil types in definite geographic regions is reflected in regional difference in the soil mantle of the earth.

Soil Genesis

Soil genesis is the mode of origin of the soil with special reference to the processes responsible for the development of the solum or true soil, from the unconsolidated parent material. It is convenient to subdivide the broad and complex topic of soil genesis, as has been done in the following earlier discussions. Ideas that have been expressed about soil genesis can be summarized as follows: the reference to combined effects of weathering and of living organisms by Dokuchaiev (Nuestruev, 1927), the outlining of destructional activities of weathering and constructional biological activities by Kellogg (1936), the distinction between weathering and soil evolution made by Nikiforoff (1949) and the subdividion of soil formation into soil wasting, the organic cycle and inorganic cycle by Taylor and Cox (1956).

However, Simonson (1959) proposed that soil genesis be considered as two overlapping steps; mainly, the accumulation of parent materials and the differenciation of horizons in the profile. He considered the second step of more immediate concern to soil scientists and ascribed horizon differenciation to additions, removals, transfers, and transformations within the soil system. Examples of important changes that contribute to development of horizons are additions of organic matter, removals of soluble salts and carbonates, transfers of humus, sesquioxides and transformations of primiary into secondary minerals. He further suggested that the balance within the combination of changes governs the ultimate nature of the soil profile.

The view above has been supported by Ojanuga, Lee and Folster (1976), in the study of soils and stratigraphy in South Western Uplands of Nigeria. They revealed that cyclic erosional and depositional phenomena produced simple to complex stratification of pedisediments in the inselberg landscapes in the region. The pedogenetic processes that were inferred from the existing soil properties were, the addition of organic matter to surface horizons, strong leaching of bases, eluviation of iron oxides, incrustation of subsoil concretionary materials to form petroferric horizons (hardpan) in lower slope positions, and clay migration.

Soil Classification

Soil classification is the systematic arrangement of soils into groups or categories on the basis of their characteristics. Broad groupings are made on the basis of general characteristics and subdivisions on the basis of more detailed differences in specific properties. Mill (1925) in formulating a natural classification considered all the attributes of a population. Those attributes which have the greatest number of covariant or associated characteristics were selected as the ones to define and separate the various classes. On the other hand, Cline (1949) said that in formulating general and simple classification systems, the practice is to arrange or structure the system so that it does some, if not all, of several functions. Such classification designed for a specific, applied, practical purpose is a technical grouping.

Baeyens (1948) gave the relative importance of the different categories of pedological characteristics in connection with the practical classification of tropical soils. He advised grouping of facts obtained into several categories of relatively unequal importance. Climatic factors, morphology of the profile, physical properties of the profile, water regime of the soil, organic matter content, and chemical properties were considered important differentiae for tropical soils.

However, Kellogg (1948) stated that adequate soil classification in tropical and equatorial regions depends on greatly increased soil research. He said that the first need is for detailed soil surveys with classification according to carefully defined units of

Classification Systems

To study the soil comprehensively at different places in the earth's surface and to communicate in an orderly manner information about it, man has developed systems of soil classification. Different classification systems are in use by different countries. The French system was mostly used in the past by many African countries especially the francophone countries. The classification is hierarchical with ten classes subdivided into subclasses, groups and subgroups. Features used in division at the class level are degree of evolution as indicated by horizon differentiation, type of weathering as shown by the composition, humus type, and two features which fundamentally affect processes, hydromorphy and halomorphy (Aubert, 1965). The several USSR systems are little used outside the Soviet Union. The approach is genetic with a multivariate structure based on the influences of climate, drainage and parent material (Rozov and Ivanova, 1968). The United States system, Soil Taxonomy (Soil Survey Staff, 1975) is an artificial system with limiting values for classes exactly specified. It makes use of diagnostic horizons, in many cases similar to the FAO system but defined in more precise and considerably more lengthy terms. The classification is hierarchical with six categories, namely orders, sub orders, great groups, sub groups, families and series. The FAO classification which the FAO itself disclaims being a classification system, holding only that it is a map legend of the Soil Map of the World, is stated not to replace any of the national classification schemes but to serve as a common denominator (FAO-UNESCO, 1974). The system is a bi-categorical system with highest or upper class being approximately but not completely equivalent to the 'Great Group' level of the US system and to the 'Soil Type' of the USSR system. The lower category is composed of integrades or soils with special horizons. Phases are used to subdivide the secondary classes according to differences in characteristics or qualities important in use and management of the soils (Dudal, 1968 a).

Aerial Photo-interpretation

Aerial photo-interpretation is the systematic analysis of aerial photographs to enable the division of the terrain into geographical units by establishing the boundaries between units each of which has a well defined content.

Principles and techniques

As detailed from previous studies (Belcher, 1948; Smith et al, 1951; Burger, 1957) the general principle of soils mapping from aerial photographs, is that the nature of the soil is correlated to a greater or lesser degree with: geomorphic features or landforms, local topographic position of the soil site, vegetation cover, soil surface detail and human land use.

The general procedures of systematically and efficiently studying aerial photographs have been summarized by Stone (1956), as falling into four general steps which he stated as follows:

(i) interpretation should be done methodically

(ii) interpretation should be made by beginning with the general items and proceeding to the specific

(iii) interpretation should proceed from the known to the unknown features and

(iv) the photographic qualities of the particular photography must be kept in mind constantly.

In carrying out the photo-interpretation, the observer must ask himself repeatedly questions that cause him progressively to limit the possibilities of identification until the object under investigation is positively identified, or at least classified as falling into a small group of alternatives (Seymour, 1957).

Objects are recognised on aerial photographs because of pictorial elements, of which shape, dimension, tone, texture, shadows, location and association are the most important. Black and white photographs may contain a wide variety of tones varying from one extreme to the other. Daehn (1949) standardized the tone scale into ten grades progressing from white to black. Colwell (1954) gave the principal factors which determine photographic tone as:

(i) the light reflectivity of the object photographed

(ii) the light sensitivity of the film employed

(iii) light scattering by atmospheric haze and

(iv) light transmission by the filter used.

Spurr (1960) added the angle of elevation of the sun and the position of the object on the ground with relation both to the position of the camera and the location of the ground.

The use of textural characteristics to interpret farm practices in the photographic study of farm crops has been detailed by Goodman (1959). Fields have a lined texture if the plowing and planting is in parallel rows, a plaid texture if the rows are planted at right angles to plowing, a corduroy texture after tall crops such as corn have become tall enough to stand in relief, and a striped texture if tall crops have been recently intertilled. Similarly, swath textures are visible after harvesting, while mottled textures develop from variations in soil moisture content.

The association of objects on aerial photograph is basic to photo-interpretation (Heath, 1955; Churchill ans Stitt, 1955). Geological formations are recognised because of their inter-relationships with drainage patterns and vegetation. Vegetation types are identified because of their association with particular topographic locations. Buildings are characterized by their grouping and location with regard to other cultural and natural features. Nevertheless, Colwell (1954) stated that it cannot be denied that the visual ability of the observer, his intelligence and the ways and means by which he arrives at a decision are of basic importance in the solution of the photo-interpretation problem.

Obviously, the soil profile cannot be seen or evaluated directly on aerial photographs, but as Frost (1960) has indicated, pattern elements which are indicative of surface and subsurface conditions can be analysed. Inferences can be drawn about soil conditions after studying the patterns created by the elements which are landform, drainage, erosional features, vegetation, photographic tone and cultural features.

Value of aerial Photo-interpretation

Vink (1968) estimated savings in time, cost, and gain in accuracy from using aerial photo-interpretation as compared with ground survey alone as 70 percent for small scale mapping; and about 20 percent for large scale mapping. Bie and Beckett (1971) have shown after a total analysis of actual surveys that those using photo-interpretation required on average 55 percent of the time of those not using it to survey the same area irrespective of scale.

Aerial photo-interpretation has been proven to be of particular value in soil and land classification of tropical and developing countries (Van der Ejik and Hendriks, 1953; Veenenbos, 1956).

Previous Soil Survey in the Sokoto-Rima Basin

FAO (1969) undertook an integrated survey involving the soils and water resources of the Sokoto Valley to supply the necessary data for establishing irrigation schemes in the basin. The soil survey which also covered the Dange area was conducted at the reconnaissance level. Aerial photographic interpretation of 1:40,000 contact prints was employed and the scale of mapping was 1:250,000. The soils that were identified in the Dange area using the French System of classification were:

Acid Sands
Kaolinitic Soils
Ferruginous Soils on Non-crystalline Rocks
Brown Soils of Arid and Semi-arid Tropical Regions
Ironstone crusts and Associated Soils and
Hydromorphic Brown Soils of Arid and Semi-arid Tropical Regions.

THE ENVIRONMENT

Location

The Dange area surveyed is located in the Sokoto State of Nigeria, situated between latitudes 12° 51' and 12° 58' north, and longitudes 5° 16' and 5° 21' east, (fig. 1). The area is represented on the topographical map, sheet 29 NW Dange (Federal Surveys, 1964). The area comprises approximately 10,000 hectares and extends from near Dange village, northwards beyond Shunni village, six kilometers to Sokoto, on the Sokoto-Gusau road which traverses the project area. Some parts of the area can be reached by poor motorable roads, but most of the area can be traversed only by footpaths and cut traverses.

Population

The population is concentrated in Dange and Shunni villages, but smaller settlements are scattered in the area. The settled population belongs mainly to the Sudan-negridic Hausa tribe, but its ruling class is formed largely by descendants of Fulani, a tribe of presumably Eastern Mediterranean origin (Johnston, 1967). A small portion of the population belonging exclusively

LOCATION MAP OF DANGE AREA

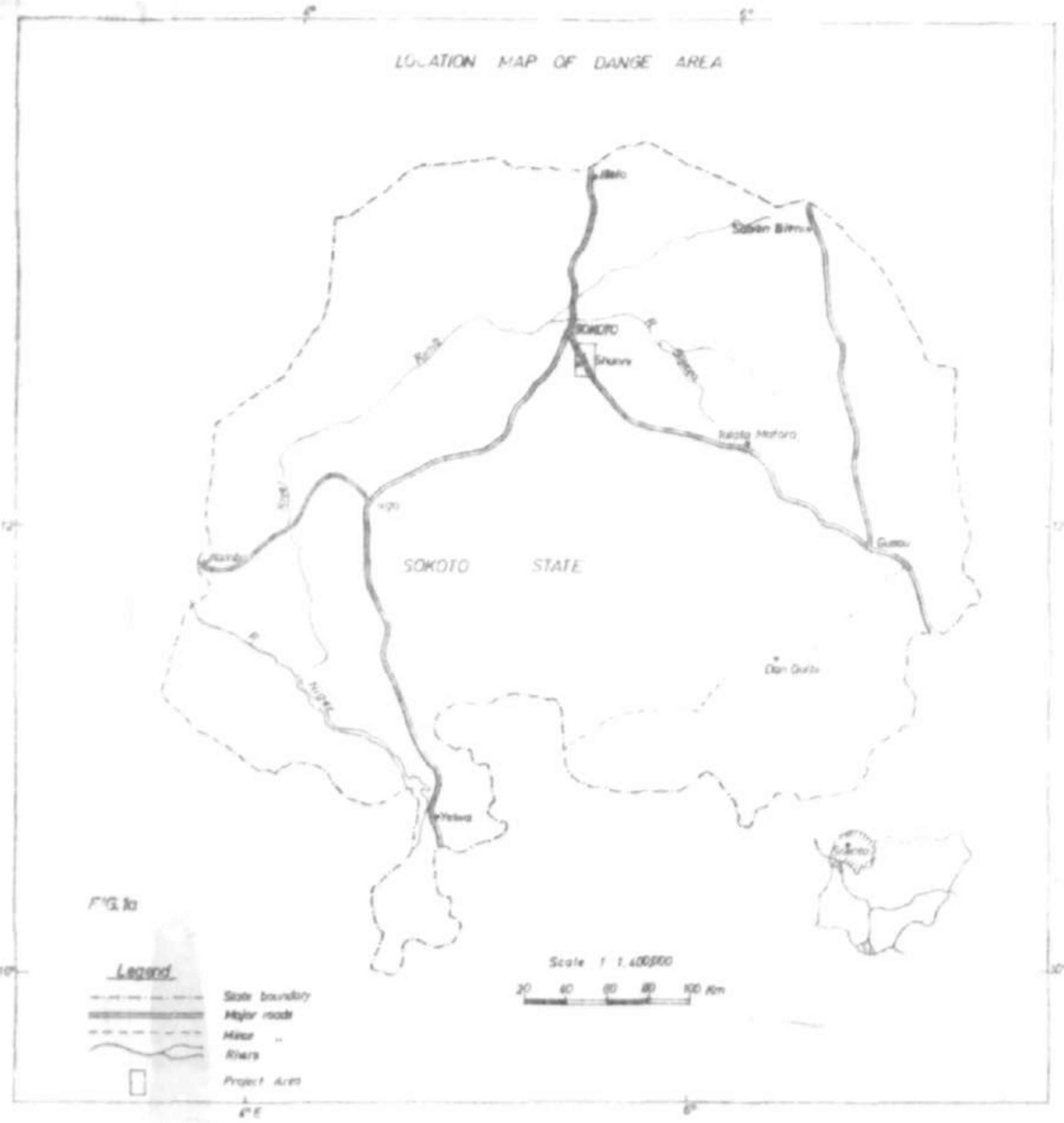


FIG. 1a

MAP OF DANGE AREA

FIG. 1b

to an unmixed group of Fulani tribe, has a nomadic way of life. Their cattle graze on uncultivated soils covered with tree and shrub savanna du"ing the wet season, on the stubble of the arable fields during the first part of the dry season, and in the floodplains during the later part of the dry season. Farming is the main occupation of the population.

Climate

There is no meteorological station within the project area, but long records of climatological data are available for Sokoto which is about six kilometers from the project area (British West African Meteorological Services, 1954).

The present day climate of the area is hot, semi-arid tropical, type Aw in the Koppen classification (Sombroek and Zonneveld, 1971). It is characterized by a long and severe dry season lasting from October until May (fig. 2) and a short but intensive wet season from May/June until September. The dry season results from a dry and hot continental air mass blowing from the north-east through the Sahara desert. The rainy season is caused by a humid equatorial maritime air mass blowing from the south-west over the Gulf of

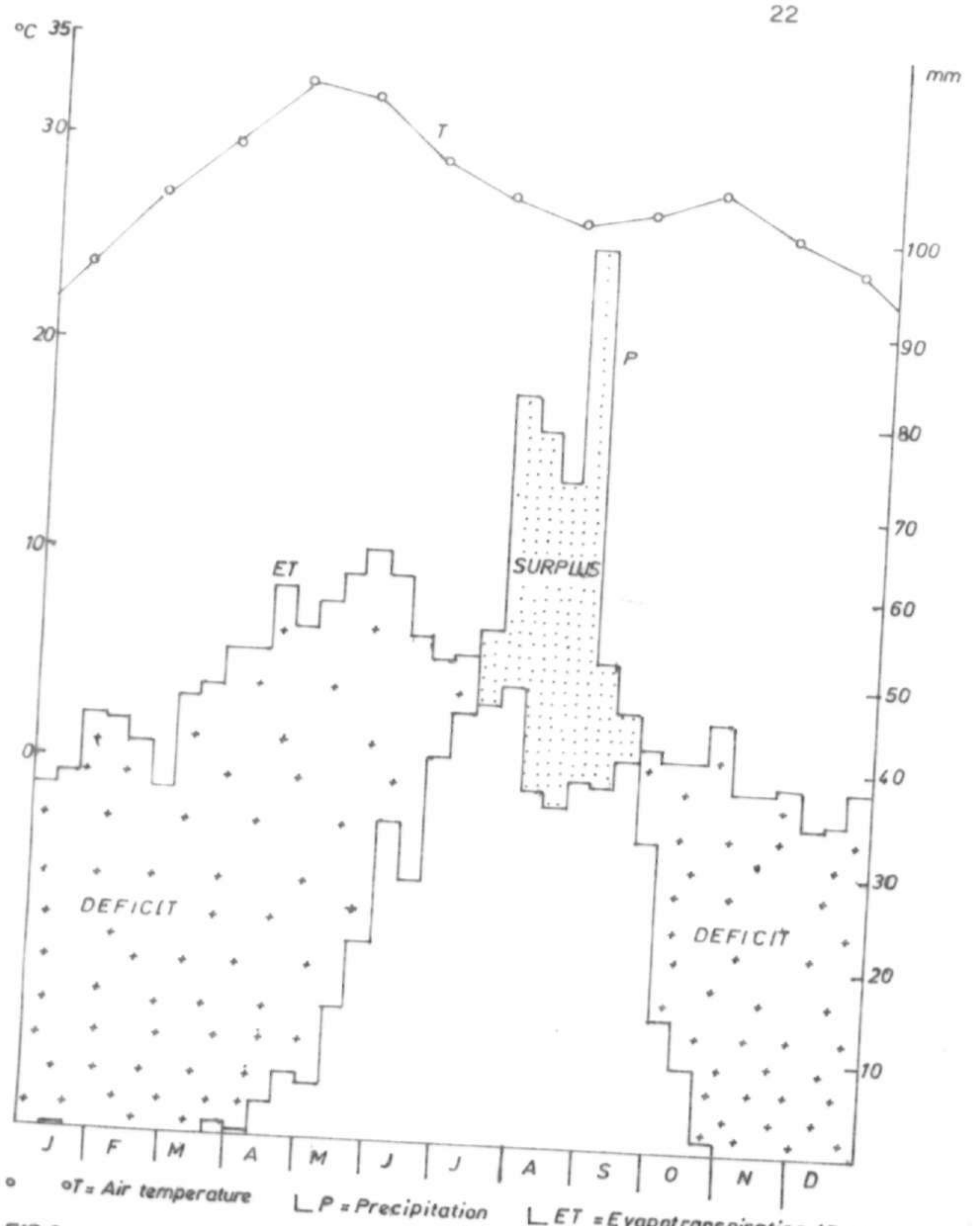


FIG. 2: MEAN PRECIPITATION AND EVAPOTRANSPIRATION IN TEN-DAY PERIODS AND MONTHLY AIR TEMPERATURES FOR SOKOTO FOR 20 YEARS (Kowal, 1972)

Guinea (Higgins et al, 1960; Pullan, 1961; FAO, 1969).

Owing to the position of the area in the extreme nortwest of the country and about 1,000 kilometers away from the sea, the area remains largely under the influence of the 'hamattan', which is frequently dust carrying, for a longer period. The effect of the humid wind from the southwest is consequently reduced, resulting in a short wet season and a long dry season (FAO, 1969). The area belongs bio-climatically to the 'Sudan Zone' (Keay, 1959).

The rainfall pattern is characteristically single peak with its maximum in August, and a sharp drop in October (fig. 2). The three wettest months are July with an average precipitation of 180 - 200 mm, August with 230 - 250 mm and September with 130 - 180 mm (Kowal and Knabe, 1972).

In November, December, January, February and March there is either no rain at all or the total monthly precipitation is less than 10 mm. The mean annual rainfall decreases gradually from south to north, for example 965 mm at Gusau (Latitude 12° 10') and 710 mm at Sokoto (Latitude 13° 01'). The wet season is characterized by frequent torrential rains of relatively short duration (Sombroek and Zonneveld, 1971).

Evapotranspiration

Evapotranspiration, the combined effect of evaporation from the soil and transpiration by plants, depends largely on the soils, the vegetation cover and the water available in the ground. In the area, the actual evaporation almost equals the rainfall (fig. 2), and the runoff is only in the order of 0 - 20% of the rain. However, part of the rain is stored in the soils and lost by evapotranspiration after the rainy season (FAO, 1969).

Temperature

Kowal and Knabe (1972) found that for a twenty year period 1950 - 1969, the mean maximum temperature increases from January onwards reaching a peak of 38^{o} - $40^{o}C$ or more in April. The mean minimum temperature is lowest in December - January (the hamattan months) and is $13^{o}C$, when the nights are cloudless and there is a considerable radiation of heat from the ground. The mean maximum and minimum temperatures are generally highest from March to June.

Relative Humidity

The mean relative humidity reaches its peak of over 90% in August and is lowest at 10 - 30% in December and January. FAO (1969) stated that there is an overall increase in relative humidity in the area from north to south. During the rainy season there are many hot humid days, but during the hamattan the humidity may fall at mid-day to desert-like levels of about 10%, resulting in very high moisture losses from soils, animals and plants. Mean relative humidity percentages are shown in fig. 3.

Geology

Jones (1948) studied the geology of Sokoto Province carefully, arriving at conclusions which differ radically from those of his predecessors (Raeburn and Tattam, 1930; Swinton, 1930). The then Sokoto Province is made up of what is now Sokoto, parts of Niger and Kwara States. He observed that the geological structure of Sokoto province is simple. A pre-cambrian complex of gneisses, granites, phyllites and quartzites forms the foundation

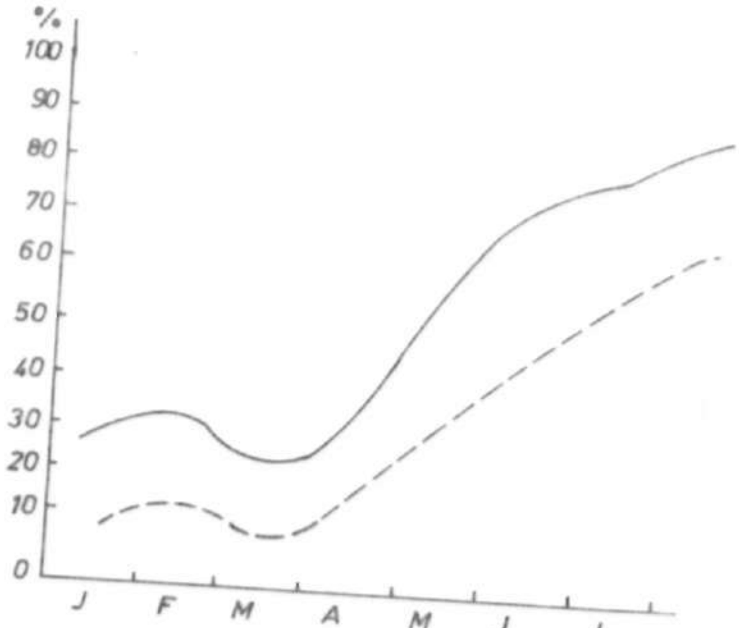


Fig 3 MEAN RELATIVE HUMIDITY AT SOKOTO

——— at 0600 GMT
- - - - " 1200 "

of the province. This outcrops in the south-east to occupy nearly half of the total area. From the point where the basement complex crosses the north eastern frontier from Niger Republic, the line separating this complex and the sedimentary rocks runs in a south-westerly direction for a long distance. It then turns sharply and continues roughly southwards into now Kwara State.

Kogbe (1976) stated that the sediments of the Iullemmeden basin, of which the Sokoto-Rima basin is part, were deposited during three main phases of deposition; continental Pre-Maastrichtian and Tertiary phases, with an intervening marine Maastrichtian to Palaeocene phase. Overlying the Pre-Cambrian basement unconformably, the Illo and Gundumi formations, made up of grits and clays, form part of "Continental Intercalier" of West Africa. They are overlain unconformably by the Maastrichtian Rima group consisting of mudstones and friable sandstones (Taloka and Wurno formations) separated by the fossiliferous shaly Dukamaje formation. The Palaeocene Dange and Gamba formations (mainly shales) are separated by the calcareous Kalambaina formation. The overlying continental Gwandu formation is of tertiary age. These sediments dip gently and thicken gradually towards the north-west with a maximum thickness of over 1,000 meters near the frontier of the Niger Republic. They were deposited on the south-eastern flank of the Iullemmenden basin, a large synclinal structure trending NW - SE.

Various workers have dated the beds of the Pre-Maastrichtian deposits as Cretaceous or Tertiary (Falconer, 1911; Jones, 1948). It is now fairly well established that these sediments are Cretaceous and not Tertiary (Kogbe, 1976).

In the Dange area the formations are the Wurno-Taloka formations, the Dange formation and the Kalambaina formation. The Wurno formation is very similar to the Taloka formation and consists of fine grained sandstones, mudstones and siltstones (Kogbe, 1976).

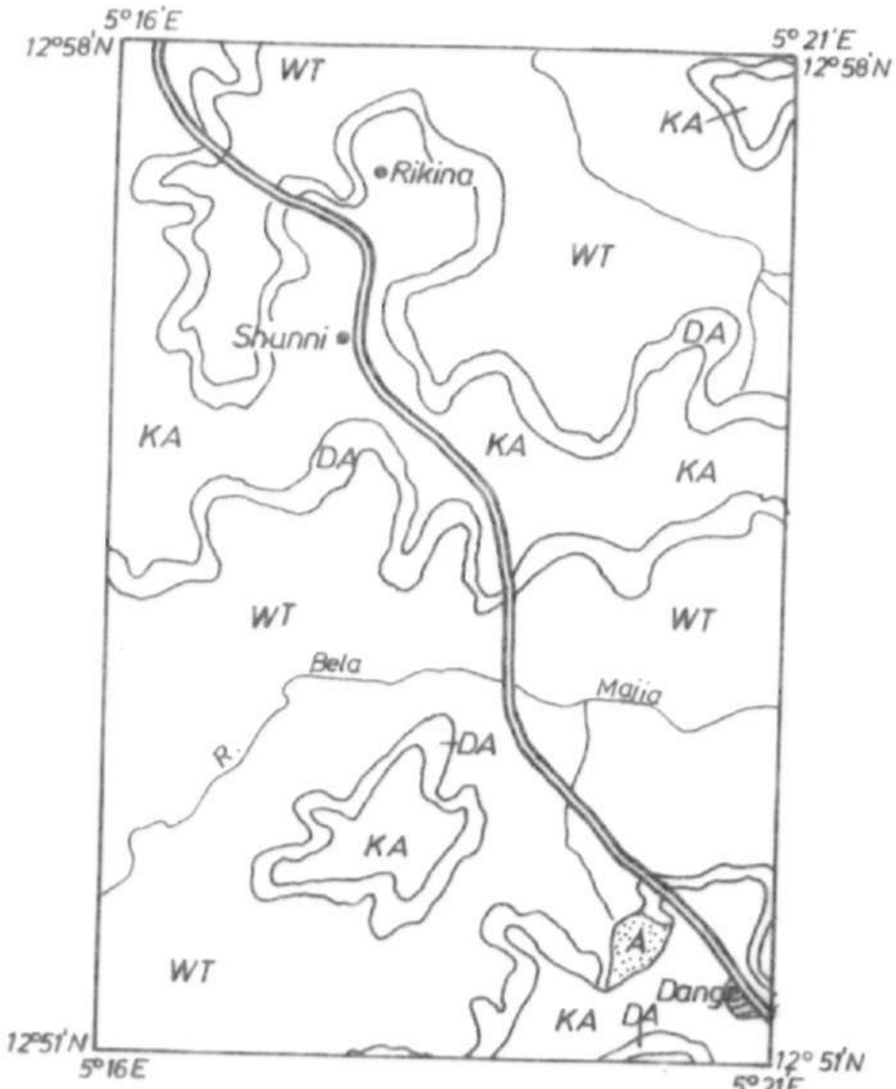
The Dange formation consists of slightly indurated bluish-grey shale. It is interbedded with thin layers of yellowish-brown limestone. In surface outcrops the maximum thickness of the formation is about 22 meters near Sokoto but in subsurface wells, it attains a thickness of over 45 meters. Kogbe (1972) described a type section near Dange village on the Sokoto-Gusau road. Generally, outcrops of the formation are restricted to the slopes of the 'Dange Scarp' (fig. 4). The shales include bands of fibrous gypsum with a large number of irregular shaped phosphatic nodules. Specimens analysed by Jones (1948) were found to consist largely of calcium phosphate, which is most probably derived from the abundant vertebrate fossil remains found in the formation. The vertebrate fossil assemblage have been described by White (1934).

The Kalambaina formation consists of a white marine clayey limestone and shale. Kogbe (1972) has described a type section at Kalambaina quarry. The maximum thickness of the formation recorded from boreholes is below 20 meters.

The sedimentary area of Sokoto-Rima basin is a region of undulating plains in which the solid geology is for the most part concealed by unconsolidated material. Falconer (1911) used the term 'drift' for the unconsolidated mantle which covers the plains as an indication that during its accumulation the products of rock weathering of which it is composed were resorted and widely distributed by river, rain and wind.

A notable feature on these sedimentary rocks is the occurrence of massive indurated ironstone. The

GEOLOGY OF DANGE AREA



Scale 1 : 125.000

FIG. 4

A	Aeolian sand formation
KA	Kalambaina ,,
DA	Dange ,,
WT	Wurno Taloka ,,

From Geological Survey of Nigeria

material occurs principally as a lateritic crust or capping on the rocks and in some areas it forms thick sheets extending continuously for many meters. These laterites are common on the shales (FAO, 1969).

Geomorphology

The study area is located in the central portion of the Sokoto-Rima basin. As part of this big basin, the general geomorphic processes that sculptured the basin is relevant in the study area.

The Sokoto-Rima basin has a complex geomorphic history that began in the Jurassic period when the oldest erosion surface was formed, commonly referred to as the Gondwana peneplain (Pugh and King, 1952). A general subsidence occurred during the Cretaceous, and the Gondwana surface was covered by the lacustrine and fluviatile Gundumi and Illo sediments. It is likely that the subsidence stopped. A marine period commencing in the Maastrichtian and continuing into the Eocene prevailed. During this period the Rima group and the clay-shale and calcareous groups were laid down. This was followed by an uplift of the landscape, probably in the late Eocene times, leading to the retreat of the sea and accompanied by gently folding. After that, a continental period represented by the Gwandu group prevailed (Jones, 1948).

It is known that the climatic conditions in West Africa during the Quaternary included at least one period of severe dessication during which desert conditions extended further south than they do now (Jones, 1948).

A physiographic feature of the Dange area is the existence of two plains, a low lying plain over the Wurno - Taloka formations and a higher plain underlain by the Dange and Kalambaina formations. The 'drift' which covers the upper plain is frequently separated from the underlying sediments by a thick layer of secondary ironstone. The ironstone is present in every portion of the upper plain underlain by the Kalambaina formation. The drift is deep on the lower plain, often more than 2 meters and grades downwards into the underlying sediments without an ironstone layer.

Generally the plains form a gently undulating country with elevation between 270 - 350 m above mean sea level. As earlier stated Falconer (1911) used the term 'drift' for the unconsolidated mantle which covers the plains as an indication that during its accumulation the products of rock weathering of which it is composed were resorted and widely distributed by river, rain and wind. The drift over the greater part of the area is sandy, but becomes more clayey in bottomlands.

The prominent Dange Scarp marks the end of the upper plain. This scarp is broken by V-shaped valleys, which penetrate only as far as the clay-shale group of underlying sediments and trend south and souteast. The Dange scarp overlooks the wide sandy undulating lower plain, which is broken occasionally by tabular hills (mesas) with ironstone cuirasses and by ridges covered with ironstone rubble (Jones, 1948).

Hydrology

The major river in the Dange area is the Bela-majia river. Its arms drain the central and southern parts of the area. The river flows southwesterly out of the Dange area to join the Rima river. The northern part of the area is drained by the arms of the Buji river which is a tributary of the Sokoto river. The Rima and Sokoto rivers are the largest in the Sokoto - Rima basin.

Gill (1974) found that the rivers have well defined and narrow waterways and steep bed gradients with the result that the rivers are flashy. The flood waves are generated suddenly when it rains, and have fast speeds of propagation. During the dry season all the rivers and waterways dry up.

The lower plain have very few drainage waterways and when they are present are very widely spaced, because of the high permeability of the soils. On the midslopes of the higher plain, a high density of dendritic drainage pattern occurs.

Groundwater conditions can generally be reached at shallow depths. The water table is frequently within 1 - 15 meters from the surface. The chemical quality of ground and surface water is considered excellent to good for all purposes. Less than 25 mm of the rains is contributed as runoff and 0.2% of this has been assumed to represent soil erosion (FAO, 1969).

Vegetation

The Dange area is located in the so-called 'Sudan Zone' which is a savanna woodland on the better soils and tree and shrub savanna on less good soils. The

Sudan Zone lies between the 'Sahel Zone' of shrubby and thorny vegetation, and the densely wooded vegetation of the 'Guinea Zone' (Clayton, 1957, 1960· de Leeuw, 1966; Keay, 1959).

The natural vegetation of the Dange area is that of open shrub savanna. It consists of shrubs at various densities, with the trees rarely exceeding 6 meters in height. The native vegetation has been tremendously influenced by man, under shifting cultivation and other fallow systems. A shrub savanna establishes itself under a few years and may even develop into a tree savanna. If there is no burning, over-grazing or over-cutting, it may regenerate to a woodland stage. The main species are Combretum nigricans var. elloitii, Combretum micranthum and Guiera senegalensis. An upper crown above the shrub is a scattered upper storey in which the commonest trees are Prosopis africana, Sclerocarya bierra, Balenites aegyptiaca, Combretum lamprocarpum and Terminalia avicennioides, Anogeissus leicarpus, Vitex doniana.

The common grasses are Loudetia togoensis, Andropogon pseudapricus, Tripogon minimus, Zornia diphylla, Brachiavia stigmatisata, Sporobolus festivus.

In the farmlands are found park-like vegetation made up of umbrella-shaped trees of Acacia albida, Acacia arabica, Parkia clappertonia, Adansonia digitata. Along the river courses are found Borassus and other palms (Jones, 1948).

Azadirachta indica (neem) has been planted extensively as shade trees in the villages, especially along avenues, by the Health Department to open them up (Pullan, 1961).

Present Land Use

FAO (1969) has described the common types of land use in the area. Numerous wandering herds of cattle owned by Fulanis' graze extensively in both the fallow farmland and the uncultivated areas. Tree and shrub cutting for firewood is also common, particularly in the vicinity of the settlements. Shifting cultivation is common in upland areas with cultivable soils but lacking the water supply for domestic use. With a rapid increase in the population the fallow period is being shortened.

Where water is available or groundwater is close to the surface, settlements have been established which are associated with permanent cultivation. There is permanent cultivation on the richer uplands with wet season cropping and also permanent cultivation on the 'fadamas' during and after the flood season. In the vicinity of ponds and wells, traditional shadoof irrigation is practiced. The water is lifted with calabash containers into small irrigation channels into the crop fields.

MATERIALS AND METHODS

Aerial Photo-interpretation

A reconnaissance soil survey at a scale of 1:50,000 which employed aerial photo-interpretation was carried out to establish probable soil units. Good quality panchromatic black and white aerial photographs that cover the area were obtained from Federal Surveys of Nigeria. The photographs were flown at a scale of 1:25,000. Interpretation lines or probable soil boundaries on aerial photographs were transferred to 1:50,000 topographic base map using a sketchmaster.

Field Studies

The photo-interpretation map was then checked in the field and soil transects were selected for the purpose of identification of the soils and determination of the relationship between soils in the mapping units. Soil profiles were dug at sites where the characteristics of the component soils (of the mapping units) are best expressed. The soils were described according to instructions in the Soil Survey Manual (1962) and samples of representative profiles were collected for laboratory analysis.

Laboratory Analyses

Preparation of samples

The soil samples were air-dried and passed through a 2 mm sieve. Particles larger than 2 mm were weighed as the gravel content in the sample.

Particle size determination

The proportions of the different size fractions less than 2 mm in each soil horizon, were determined by the hydrometer procedure of Bouyoucous as described by Day (1956). The soil was dispersed with sodium hexametaphosphate and mechanical high speed stirring. The sand fraction was separated into two sub-fractions (coarse and fine) by wet sieving using a 72-mesh sieve (210 um)

Moisture content

The 15-bar soil water content was determined on approximately 25 g samples which have passed through the 2 mm sieve using the pressure membrane apparatus. The soil was soaked overnight to equilibrate at saturation before the tension was applied for 24 hours (Richards, 1947).

Soil reaction

The soil pH was determined in a 1:1 soil:water mixture using a glass electrode and pH meter. The mixture was allowed to equilibrate for one hour before reading the pH.

Organic matter

The organic matter content of the samples was determined by the chromic acid oxidation method of Walkley and Black (1934). The soil was oxidized with standard potassium dichromate solution and sulphuric acid, which generates the heat for the reaction, followed by titration of the excess dichromate with standard ferrous ammonium sulphate, using orthophenanthroline as indicator.

Cation exchange capacity

The cation exchange capacity, CEC. of the samples were determined by saturating the soil with normal neutral ammonium acetate solution, washing out the excess ammonium with alcohol and subsequently distilling the adsorbed ammonium into boric acid solution. The distilate was titrated against standard hydrochloric acid (Peech <u>et al</u>, 1962). For some soils CEC was determined by saturating the soil with sodium acetate pH 8.4, the displaced sodium being determined by flame photometry.

Exchangeable cations

The soil was leached with neutral ammonium acetate solution and the exchangeable cations were determined in the ammonium acetate extract. Sodium and potassium were determined by flame photometry while calcium and magnesium were determined by atomic absorption spectrophotometry.

Extractable acidity

The samples were leached with potassium chloride solution. The aluminum and hydrogen ions in the leachate were titrated against standard sodium hydroxide solution using phenolphthalein as indicator. The sodium hydroxide used corresponds to the milliequivalents of aluminum plus hydrogen. The solution was brought back to the original colourless condition and subsequently titrated against standard hydrochloric acid to determine the amount of aluminum (McLean <u>et al</u>, 1959).

RESULTS AND DISCUSSION

Elements of Photo-interpretation Used

The aerial photographs covering the survey area were systematically analysed to establish the landforms in the area. Pattern elements which are indicative of surface and subsurface conditions (Frost, 1960) were employed in the analysis of the aerial photographs. The elements considered are:

a. landform
b. drainage
c. erosional features
d. vegetation
e. photographic tone
f. cultural features.

Photo Analysis

First by employing the elements in combination, the landscape was resolved into two broad landforms namely the uplands and alluvial bottomlands. The uplands which are flat to undulating, sparsely covered by vegetation or cultivated, show light photographic tones and villages are always situated on it. The alluvial bottomlands are almost flat and occur in the lowest elevation in the area. The latter being largely poorly drained, show as dark tones in the aerial photographs, either devoid of vegetation or cultivated. Settlements are always absent.

These two major landforms were further resolved into smaller units by examining stereoscopically the pattern elements. By considering elevation, slope and erosional features, the upland was subdivided into a high plain, an escarpment and a lower plain. The bottomland was divided into fadamas and recent floodplains. Further subdivisions were made using the following parameters: slope position, dissection, cultication and presence of ironstone into the following units:

(i) crestal and/or upper slope unit

(ii) midslope unit

(iii) moderately dissected lower slope unit

(iv) highly dissected lower slope unit

(v) cultivated alluvial land

(vi) Uncultivated alluvial land that is seasonally flooded

(vii) exposed ironstone caps on escarpment and mesas.

(viii) broken ironstone rubble areas with vegetation and

(ix) fadama.

Some of these units were however, not mapped eventually.

Description of Mapping Units

The high plain of the upland was divided into two. The first part is the almost flat ironpan mesa (U1) mantled with eolian sandy deposit on Kalambaina formation (fig. 5). It is intensively cultivated and has widely spaced rectangularly patterned drainage lines showing evidence of rill erosion. The second part is a small slightly undulating ironpan mesa (U2) without an eolian mantle but with ironstone boulders at the surface. The latter is devoid of vegetation and has very few drainage lines. It always occurs on the Wurno - Taloka formation. The escarpment was not subdivided. It is a sloping to steep escarpment (M) on the Dange formation with thin eolian sandy deposit or ironpan and ironstone boulders on the surface. It is sparsely

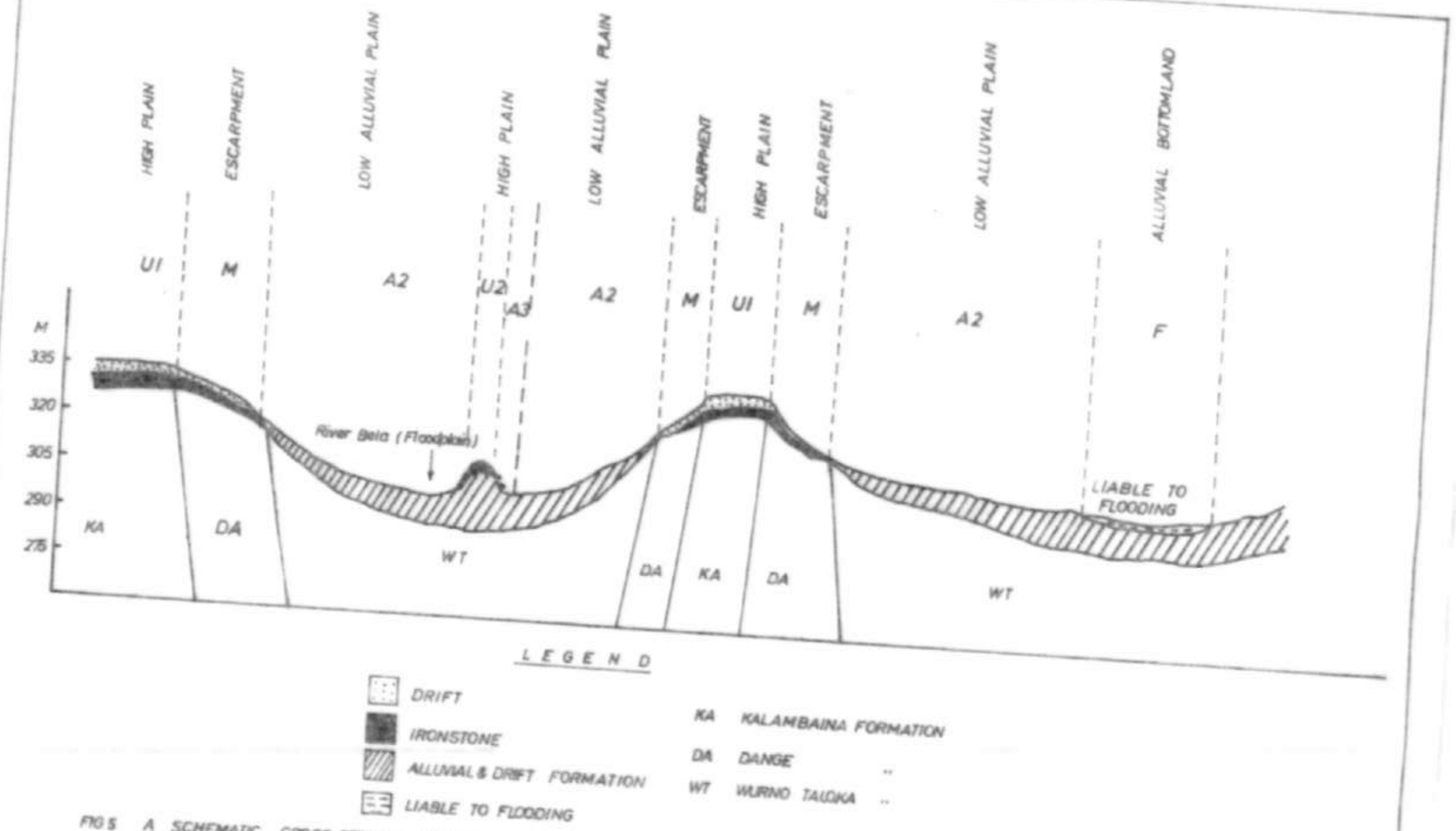


FIG 5 A SCHEMATIC CROSS-SECTION SHOWING THE RELATIONSHIP BETWEEN LANDFORMS AND GEOLOGY IN THE DANGE AREA

cultivated and has numerous rills and gullies.

The lower plain has eolian-alluvial sandy deposits mantling the Wurno-Taloka formation. It is subdivided into two; The first part is the gently sloping land (A3) characterized by sparse vegetation of shrubs, many ironstone boulders on the surface and few dendritic rill drainage channels. The second part is the gently undulating land (A2) intensively cultivated. It has many dendritic rills and gullies at the base of the escarpment, and many parallel rills and few gullies further downslope. The alluvial bottomland was also subdivided into two. The first unit is almost flat alluvial land (A1) in the recent floodplain of River Bela-majia, on the Wurno-Taloka formation. It is characterised by dense vegetation in some parts, bare in some others, seasonally flooded and uncultivated fadama. The other alluvial bottomland unit occurs as slightly concave depressions (F) in the valleys of the lower plain underlain by the Wurno-Taloka formation. The latter are intensively cultivated fadama areas.

Soil Distribution

The soils in each of the landform units were examined by augering. Based on the soil patterns, geology and internal variability of soils in each of the units, soil association was thought to be the best mapping unit. A soil association is a mapping unit that has a large internal variation due to content of more than one taxonomic unit that cannot be separated under lower mapping scale. The formulation of the names of the soil associations were based on the names of some villages in the survey area. The soil mapping units (soil associations) designations as they appear in the soil map of the area (fig. 6) are shown in the soil map legend (Table 1) with a brief description of the landform in which they occur.

Two of the transects cut to document the soils of the study area show the general distribution of the soil associations relative to the elevations and geology in the area. Along transect A streching from the Primary School at Kindiru village on the southern part of the project area to Aliu-Dange hamlet (fig. 7) the Dange association occurs on the high plain at a general elevation of 335 m above seal level. Below

SOIL MAP OF DANGE AREA

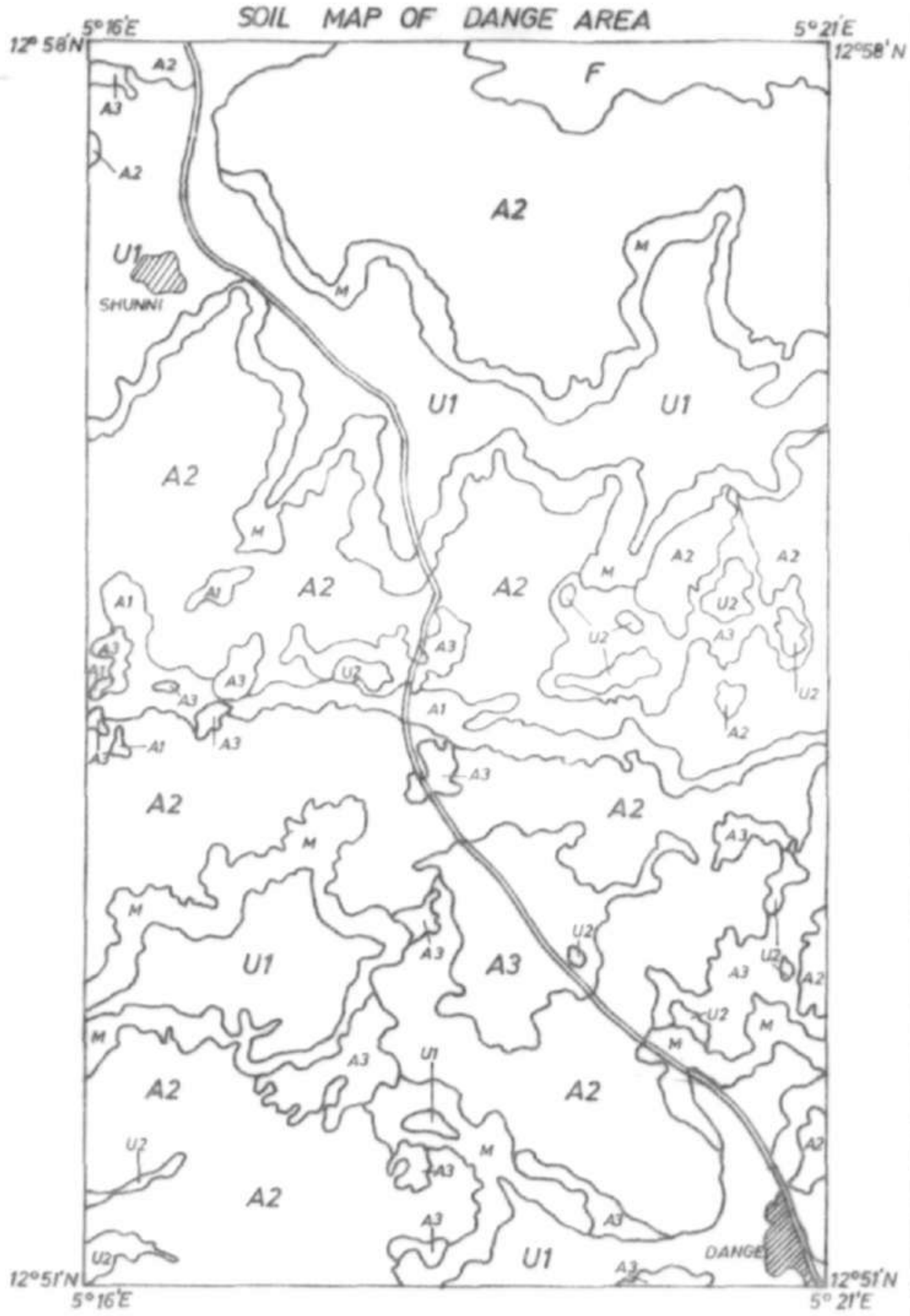


FIG 6

SCALE 1: 50,000

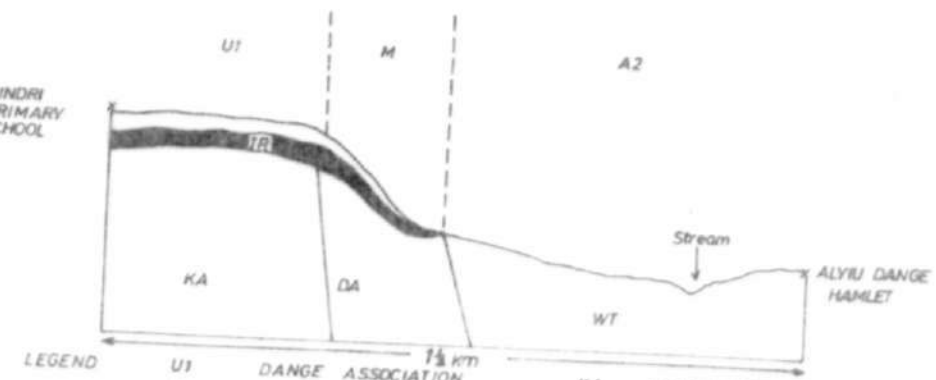
LEGEND

Landform Unit	Map Symbol	Soil association
FLOODPLAIN	A1	BELA
UPLAND LOW PLAIN	A2	MERINA
ROCKY UPLAND LOW PLAIN	A3	AMANAWA
BOTTOMLAND	F	TUDA
ESCARPMENT	M	ZAFANADI
UPLAND HIGH PLAIN	U1	DANGE
IRONSTONE CAP	U2	DUTSE

Table 1

Soils of Dange area

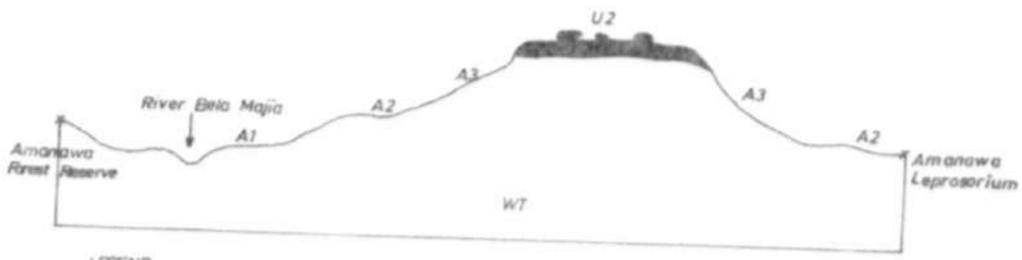
Map symbol	Landform	Soil association
A1	Almost flat alluvial bottomland, on Wurno-Taloka formation.	Bela
A2	Gently undulating lower plain of upland, on Wurno-Taloka formation.	Merina
A3	Gently sloping, slightly raised and rocky lower plain of upland, on Wurno-Taloka formation	Amanawa
F	Slight depression of valley bottomland, on Wurno-Taloka formation.	Tuda
M	Sloping escarpment of ironpan mesa with ironstone boulders at the surface, on Dange formation.	Zafanadi
U1	Almost flat upland high-plain of ironpan mesa mantled with eolian deposit, on Kalambaina formation.	Dange
U2	Slightly undulating upland high plain of ironpan mesa with ironstone boulders at the surface, on Wurno-Taloka formation.	Dutse



LEGEND

U1	DANGE ASSOCIATION	KA	KALAMBAINA FORMATION
M	ZAFANADI "	DA	DANGE "
A2	MERINA "	WT	WURNO-TALOKA "
IR	IRONSTONE LAYER		

FIG 7 SCHEMATIC CROSS-SECTION OF TRANSECT A



LEGEND

U2	DUTSE ASSOCIATION	WT	WURNO-TALOKA FORMATION
A3	AMANAWA "		
A2	MERINA "		
A1	BELA "		

FIG 8 SCHEMATIC CROSS-SECTION OF TRANSECT B

this plain is the escarpment at an elevation of about 304 m on which the Zafanadi association occurs. The latter grades into the Merina association which occurs on the lower plain that forms the main valley in the area. Along transect B (fig. 8) from near Amanawa Leprosorium (which is located in the central part ot the project area and just about 500 m after the bridge over River Bela from Dange village) southwards to the River Bela floodplain near the Amanawa forest reserve, the high plain now at about 290 m is occupied by the Dutse association. The plain grades into a lower plain occupied by soils of the Amanawa association with broken ionstone rubbles. The latter grades into the Merina association in the lower plain. The Merina association in turn grades into the Bela association in the river floodplain at about 270 m elevation. On the northern fringe of the study area the Merina association grades into the Tuda association which occupies the imperfectly drained and seasonally flooded fadama areas.

The Dange association is made up of three component taxonomic units (Soil Series). One unit occurs as shallow soils with ironstone outcrops on crestal positions and is about 5 percent of the association. The second unit is fairly deep, most extensive and occur on the gentle slopes. They constitute about 80 percent. The third is not so deep and occurs on the lower slope positions. It makes up about 15 percent. Two taxonomic units make up the Zafanadi association. The very rocky and shallow one occurs on the upper slope position and constitutes about 65 percent of the association, while the fairly deep unit occurs on the footslopes and is about 35 percent of the association.

In the Merina association the unit that occupies the crestal positions is very deep and constitutes about 20 percent of the association. The most extensive is the unit that occurs on the midslope positions with a lithologic discontinuity. They constitute about 60 percent. Another unit occurs on the base of the escarpment and is transitional to the soils of the Zafanadi association. The latter constitute about 10 percent while the unit that occurs on lower slope positions constitute about 10 percent. The Amanawa association is made up of two units. One is the ironstone rubble covered unit on upper and middle slope positions, it constitutes about 70 percent.

The second, is the relatively bare unit that occurs on lower slope positions. It constitutes about 30 percent of the association.

The Bela association consists of three units, one with appreciable amount of concretions occurs on the first terrace of the river Bela-majia and constitutes about 80 percent of the association. The second unit which is more gleyed occurs on the recent floodplain of the river and makes up about 15 percent, while the third unit which is mostly on recent deposits occurs on depressions in the recent floodplain and constitutes about 5 percent of the association. Tuda association is made up of two units. One unit with little gleying occurs on the crestal and upper slope positions and constitute about 25 percent, while the other unit with more gleying occupies the lower slope positions. The latter constitutes about 75 percent. The Dutse association is made up of mostly massive ironstone, rubbles of ironstone and sandstones.

Another aspect of the general soil distribution in the area is the close relationship between soil associations and the geology of the area. As previously mentioned, different landforms occur on different geological formations (fig. 5). Consequently, the delineated soil associations are underlain by different geological formations as is represented in figures 7 and 8. The Dange association overlies the drift-mantled Kalambaina formation. The Zafanadi association occurs on the ironstone crusted Dange formation mantled with thin drift while Merina, Bela, Amanawa, Dutse and Tuda associations occur on the undifferentiated Wurno-Taloka formations mantled by alluvial, colluvial or drift deposits.

Soil Morphological Characteristics

Soil descriptions

Dange association

The soils of the Dange association usually occur on the almost flat to undulating uplands of the high plain with slopes commonly ranging from 0 to 4%. These soils occur extensively in the area.

The parent material is eolian sandy deposit mantling an ironpan over the calcareous Kalambaina limestones. The ironpan is frequently reached at a depth of 40 cm to 100 cm. The epipedon is non-gravelly but the subsoil especially the ironpan is gravelly. The ironstones in the ironpan are irregular, hard, dense and dusky red to reddish-black in colour.

On the soil surface are found few ironstones and boulders. Sometimes medium sized termite mounds are present on the surface. The soils have an ochric epipedon less than 15 cm thick. The colour of the epipedon is dark-yellowish-brown (10 YR 3/4) to strong brown (7.5 YR 3/2). Subsoil colours are usually reddish-brown (5 YR 5/8), yellowish-red (5 YR 4/6) or strong brown (7.5 YR 5/8). The texture of the soil is usually sand to sandy loam in the epipedon changing to gravelly sandy loam to gravelly sandy clay loam in the subsoil. An argillic horizon is usually present.

The majority of the soils are well drained. Usually, only rill erosion occurs on the lower slope positions and the erosion hazard is slight on the nearly level areas but moderate on gently sloping areas. A representative soil (pedon 8) described during the dry season is given below.

Location: Opposite Dange Primary School, 50 m from Dange-Danchadi road, inside the NAFPP farm.

Parent material: Eolian sandy deposit

Relief: Gently sloping upper slope position

Slope: Undulating (3%)

Vegetation: Fallow plot of short and tall grasses, previously cultivated to sorghum

Drainage: Well drained.

Depth to water table: 3.2 m in nearby well.

Date described: 19/11/80

Horizon	Depth (cm)	Description
A1	0 - 14	Yellowish brown (10 YR 5/4, dry) sand, dark yellowish brown (10 YR 3/4, moist); weak, coarse, subangular blocky structure; soft dry, very friable moist, non-sticky wet; many, fine

Horizon	Depth (cm)	Description
		and medium roots; many, fine and medium interstitial, open pores; few potsherds; occasional, small, irregular, hard iron oxide nodules; slightly acidic (pH 6.4); abrupt, smooth boundary.
A3	14 - 40	Dark yellowish brown (10 YR 3/4, dry) loamy sand, very dark brown (10 YR 2/2, moist); strong, coarse, subangular blocky structure; slightly hard dry, friable moist, non-sticky wet; abundant, fine and medium roots; many, fine and medium interstitial and tubular pores; few potsherds; occasional, small, irregular, hard iron oxide nodules; slightly acidic pH 6.3); clear, smooth boundary.

Horizon	Depth (cm)	Description
B1t	40 - 72	Dark brown (7.5 YR 4/4, dry) loamy sand, brown (7.5 YR 3/2, moist); strong, coarse, subangular blocky structure; soft dry, friable moist, slightly sticky and slightly plastic wet; few, fine and medium roots; many, fine and medium interstitial open pores; thin cutans on pore faces; occasional, small, irregular, hard iron oxide nodules; very slightly acidic (pH 6.6); gradual, smooth boundary.
B21t	72 - 98	Strong brown (7.5 YR 5/6, dry) gravelly sandy loam, brown to dark brown (7.5 YR 4/4, moist); strong, coarse, angular blocky structure;

Horizon	Depth (cm)	Description
		hard dry, friable moist, slightly sticky and slightly plastic wet; very few, fine roots; many, fine interstitial open pores; thin cutans on ped and pore faces; occasional, small, irregular, hard iron oxide nodules; very slightly acidic (pH 6.8); abrupt, smooth boundary.
II B22t	98 - 130	Strong brown (7.5 YR 5/8, dry) matrix containing gravelly, structureless, massive, indurated ironstone and sandstone gravel to boulders; abundant, large, dark red (10 YR 4/8) iron oxide nodules; very few, fine roots; very slightly alkaline (pH 7.3).

Zafanadi association

Soils of the Zafanadi association occupy the upland escarpment below the high plain. The slopes commonly range from 2 to 6% but are very steep in some areas. The soils usually grade into the Dange association on the high plain and into the Merina association on the lower plain.

The parent material of the soil is a thin eolian sandy deposit over ironpan which overlies the shales of the Dange formation. The ironpan is frequently reached at depths of 20 to 36 cm but is sometimes exposed at the surface. The gravel in the ironpan is irregular, rounded, hard and dense with dusky red, yellowish red or reddish black colours. The soil usually has non-gravelly epipedon and subsruface soil but becomes gravelly in the subsoil.

The soil surface is rocky, about 10% of it being covered by secondary ironstone crust. Stones and boulders of ferruginous sandstones and shales abound on the surface of the soil. The epipedon is ochric. Soil colours are brown (7.5 YR 5/4) to dark brown (7.5 YR 4/4), soil colours changing with depth to dark reddish brown (5 YR 3/4) or dark yellowish brown (10 YR 3/4). Texture is loamy sand or sandy loam in the epipedon becoming gravelly sandy loam to gravelly sandy clay loam in the subsoil. Although the soil is shallow, an argillic horizon is present and occurs at about a depth of 18 cm and is about 20 cm thick.

Most of the soils are well drained. Gully erosion is common and erosion hazard is high on the very sloping areas. A representative soil (pedon 3) of the Zafanadi association is described below.

Location: Near the two-kilometer post on the Dange-Danchadi road and 104 m from the road.

Parent material: eolian sandy deposit over ironpan

Relief: Gently sloping midslope of escarpment

Slope: Gently sloping (2 - 4%)

Landuse: Cultivated to sorghum, cowpea and millet

Drainage: Well drained

Depth to water table: 2.5 m in nearby well.

Date described: 17/11/80

Horizon	Dept (cm)	Description
A11p	0 - 10	Yellowish brown (10 YR 4/4, dry) loamy sand, dark brown (10 YR 3/3, moist); weak, fine crumb structure; soft dry, loose moist, non-sticky wet; common, fine roots; many, fine and medium, interstitial open pores, few, medium, charcoal fragments; occasional, small, irregular and rounded, hard iron oxide nodules; very few ferruginized stones; very slightly acidic (pH 6.9); clear, smooth boundary.

Horizon	Depth (cm)	Description
A12p	10 - 18	Brown to dark brown (10 YR 4/3, dry) loamy sand, dark yellowish brown (10 YR 3/4, moist); moderate, medium, subangular blocky structure; soft dry, very friable moist, non-sticky wet; many fine and medium roots; common, fine and medium, interstitial open pores; occasional, small, irregular, hard iron oxide nodules; very few, ferruginized stones; slightly acidic (pH 6.3); clear, smooth boundary.
Bt	18 - 38	Dark yellowish brown (10 YR 3/4, dry) sandy clay loam, dark brown (10 YR 4/3, moist);

Horizon	Depth (cm)	Description
		strong, coarse, subangular blocky structure; hard dry, friable moist, slightly sticky and slightly plastic wet; common, fine and medium roots; many, fine and medium, iterstitial, open pores; thin cutans on pore faces; few, medium and many fine, termite holes; occasional, medium, irregular, hard iron oxide nodules; few, large ferruginized stones; moderately acidic (pH 6.0); clear, wavy boundary.
II C1	38 - 58	Brown (7.5 YR 5/4, dry) gravel, brownish yellow (10 YR 6/8, moist); structureless, indurated ferruginized stones and

Horizon	Depth (cm)	Description
		boulders of clay shales and sandstones; common, fine roots; very slightly acidic (pH 6.7); diffuse, wavy boundary.
II C2 m	50 - 100	Same as horizon above, but more bouldery and indurated; no roots.

Merina association

Soils of the Merina association occupy the nearly level to undulating lower plain of the upland which is mantled by alluvial - colluvial deposits. They are usually found on the colluvial footslopes of the escarpment and the alluvial land up to the better drained positions on the river terrace. The soils are extensive in the study area, with slopes ranging from 0 to 3%.

The parent material is alluvial, aolian - alluvial or colluvial sandy deposit mantling the undifferentiated Wurno-Taloka formations. The deposits are very deep and frequently more than two meters deep.

The soil surface is stony and few boulders are present. The epipedon is ochric. Epipedon colours are brownish yellow (10 YR 6/6), yellowish brown (10 YR 5/8) or dark yellowish brown (10 YR 4/4). Subsoil colours are pale yellow (5 Y 7/3) or olive yellow (2.5 Y 6/6). Mottling is typical of the subsoil and sometimes of the epipedon, the mottles are diffuse or sharp and always reddish in colour. Texture is sand or loamy sand in the epipedon, usually changing to sandy loam or sandy clay loam in the subsoil. A cambic horizon is usually present in some members of the association.

The soils are imperfectly drained. The imperfect drainage is probably caused by a shallow perched water table under the ironpan level of the escarpment underlain by the Dange formation (FAO, 1969) which greately influences the nearby soils by providing a continuous supply of underground water; hence, subsoil gleying often occurs in the soils. Erosion is not a problem more likely there is some runoff but this does not cause erosion.
A representative soil (pedon 6) is described below.

Location: One and a half kilometers from the Dange-Danchadi road, on the lower plain.

Parent material: Alluvial sandy deposit.

Relief: Valley bottom

Slope: Undulating (2%)

Landuse: Cultivated to cassava, sorghum, millet, and cowpeas between scattered Acacia trees.

Drainage: Imperfectly drained.

Depth to water table: 2.5 m in nearby well.

Date described: 18/11/80

Horizon	Depth (cm)	Description
Apg	0 - 26	Yellow (2.5 Y 7/6, dry) fine sand; light olive brown (2.5 Y 5/4, moist); few, sharp reddish mottles (2.5 YR 4/6, 4/8); weak, medium, subangular

Horizon	Depth (cm)	Description
		blocky structure; soft dry, very friable moist, non-sticky wet; common, fine roots; many, fine and medium, interstitial, open pores; moderately acidic (pH 5.5); clear, smooth boundary.
B1g	26 - 54	Light olive brown (2.5 Y 5/4, dry) loamy fine sand; olive brown (2.5 Y 4/4, moist); common, sharp, reddish mottles (2.5 YR 4/6, 4/8); weak, coarse, subangular blocky structure; slightly hard dry, friable moist, non-sticky wet; common, fine and few, medium roots; many, fine and medium, interstitial, open pores;

Horizon	Depth (cm)	Description
		occasional, small, irregular, hard iron oxide nodules; moderately acidic (pH 5.6); clear, smooth boundary.
B21g	54-96	Light yellowish brown (2.5 Y 6/4, dry) loamy sand; olive brown (2.5 Y 4/4, moist); common, diffuse, reddish mottles (2.5 YR 4/6); moderate, coarse, subangular blocky structure; hard dry, friable moist, non-sticky wet; common, fine and medium roots; many, fine, interstitial, open pores; medium, charcoal fragments; occasional, small, irregular, hard iron oxide nodules; slightly acidic (pH 6.0); abrupt, smooth boundary.

Horizon	Depth (cm)	Description
B22g	96 - 135	Light gray (2.5 Y 7/2, dry) sand; light olive brown (2.5 Y 5/4, moist); common, diffuse, reddish, mottles (2.5 YR 4/8); moderate, medium, subangular blocky structure; hard dry, friable moist, non-sticky wet; common fine and few, medium roots; common, fine, intertitial open pores; occasional, small, irregular, hard iron oxide nodules; very slightly acidic (pH 6.5); clear, smooth, boundary.
II B3g	135 - 180	Olive yellow (2.5 Y 6/6, dry) sandy clay loam, light olive brown (2.5 Y 5/6, moist); many, sharp, red (2.5 YR 5/8) mottles; strong, medium, angular

Horizon	Depth (cm)	Description
		blocky structure, very hard dry, firm moist, very sticky and very plastic wet; few, medium roots; many, fine and medium, interstitial, open pores; abundant, large, irregular, hard iron oxide nodules; moist and massive horizon; very slightly acidic (pH 6.8).

Bela association

The soils of the Bela association occur on the floodplain of the river Bela-majia which flows through the central portion of the area. The terrain is almost flat.

The parent material is alluvium and is frequently very deep. The colour of the epipedon is dark yellowish brown (10 YR 4/4) changing to strong brown (7.5 YR 5/8) in the subsoil.

Yellowish red (5 YR 5/8) mottles occur frequently in the soils. The texture is sandy clay loam in the surface horizon and sandy loam in the subsoil. The soils have a relatively higher silt content compared with other soils. Silt content being in the range of 12% to 25% unlike soils of the other associations.

The soils are imperfectly to poorly drained and are usually temporarily water-logged, being submerged for as long as three months in the rainy season. The soil surface usually has a layer of decomposing organic litter of leaves and twigs. The soils are subject to slight deposition during periods of flooding. A representative soil (pedon 10) is described below.

Location: On the terrace of the present floodplain of river Bela-majia, about 30 m from the edge of Amanawa forest plantation towards Dange village.

Parent material: River alluvium

Relief: Floodplain

Slope: Nearly level (0 - 1%)

Vegetation: Water loving aquatic grasses and creeping plants. Grazed by wandering herds of cattle in the dry season.

Drainage: Poorly drained

Depth to water table: very deep.

Date described: 27/11/80

Horizon	Depth (cm)	Description
A1	0 - 20	Dark yellowish brown (10 YR 4/4, dry) sandy clay loam; dark yellowish brown (10 YR 3/4, moist); few, sharp, yellowish red (5 YR 5/8) mottles; strong, coarse, angular blocky structure; very hard dry, firm moist, very sticky and plastic wet; common, fine and medium, inter-stitial, open pores; numerous cracks; thin cutans on ped faces;

Horizon	Depth (cm)	Description
		occasional, small, irregular, hard iron oxide nodules; slightly acidic (pH 6.3); clear, smooth boundary.
A3	20 - 60	Grayish brown (10 YR 5/2, dry) sandy loam; dark brown (10 YR 3/3, moist); many, sharp, yellowish red (5 YR 5/8) mottles; strong, coarse, angular blocky structure; very hard dry, firm moist, very sticky and very plastic wet; few, coarse roots; many, fine and medium, interstitial, open pores; numerous cracks and slickensides; thick cutans on ped and pore faces; occasional, small, irregular, hard iron oxide

Horizon	Depth (cm)	Description
		nodules; slightly acidic (pH 6.1); clear, smooth boundary.
B21	60 - 105	Yellowish brown (10 YR 5/4, dry) sandy loam; dark yellowish brown (10 YR 3/4, moist); many, diffuse, yellowish red (5 YR 5/8) mottles; strong, coarse, angular blocky structure; very sticky and very plastic wet; few, fine and medium roots; numerous, fine and medium, interstitial, open pores; thin cutans on pore faces; occasional, small, irregular, hard iron oxide nodules; moderately acidic (pH 6.0); clear, smooth boundary.

Horizon	Depth (cm)	Description
B22	105 - 160	Strong brown (7.5 YR 5/8, dry) sandy loam, dark brown (7.5 YR 3/2, moist); many, diffuse, yellowish red (5 YR 5/8) mottles; strong, coarse, angular blocky structure; very hard dry, firm moist, very sticky and very plastic wet; few, fine roots; many, fine and medium, interstitial, open pores; occasional, small, irregular, hard iron oxide nodules; moderately acidic (pH 5.9).

Amanawa association

Soils of the Amanawa association occur on raised level grounds on the lower plain. The slopes are gentle to almost flat. The soils always grade into the Merina association without an intervening scarp or break of slope.

The parent material is eolian sandy deposit and is usually very deep. The soil surface is littered with stones and boulders of broken ironstone crust. Soil colour is red (2.5 YR 4/8) in the epipedon changing only slightly in value and chroma in the subsoil to red (2.5 YR 5/8). Soil textures are loamy sand both in the epipedon and in the subsoil.

The soils are mostly well drained. Erosion hazard is slight but rill and gully erosion occurs on the middle slope soils. A representative soil (pedon 9) described during the dry season is given below.

Location: 50 meters from the channel of river Bela-majia, towards the Amanawa Leprosorium. Approximately 150 m from the Sokoto - Gusau road.

Parent material: Eolian sandy deposit

Relief: Middle slope of a small mesa

Slope: Nearly level (0 - 2%)

Vegetation: Scattered woody shrubs and thorny scrubs that are cut for firewood. Sparse grass vegetation grazed by cattle.

Drainage: Well drained

Depth to water table: 10 m in nearby well.

Date described: 2/12/80.

Horizon	Depth (cm)	Description
A1	0 - 22	Red (2.5 YR 4/8, dry) loamy sand; dark red (2.5 YR 3/6, moist); strong, coarse, angular blocky structure; hard dry, firm moist, non-sticky wet; very, few, medium roots; many, fine and medium, interstitial, open pores; abundant, small, irregular, hard iron oxide nodules; few, ferruginized stones; extremely acidic (pH 3.9); gradual, smooth boundary.

Horizon	Depth (cm)	Description
B21	22 - 46	Red (2.5 YR 5/8, dry) loamy sand; dark red (2.5 YR 3/6, moist); moderate, coarse, subangular blocky structure; soft dry, friable moist, non-sticky wet; few, fine roots; many, fine and medium, interstitial, open pores; thin cutans on pore faces; occasional, small, irregular, hard iron oxide nodules; extremely acidic (pH 4.2); gradual, smooth boundary.
B22	46 - 80	Red (2.5 YR 5/8, dry) loamy sand; dark red (2.5 YR 3/6, moist); moderate, coarse, subangular blocky structure; soft dry, friable moist,

Horizon	Depth (cm)	Description
		non-sticky wet; very few, fine and medium roots; common, fine and medium, interstitial, open pores; thin cutans on pore faces; occasional, small, irregular, hard iron oxide nodules; extremely acidic (pH 4.4); difuse, smooth boundary.
B31	80 – 154	Red (2.5 YR 5/8, dry) loamy sand; dark red (2.5 YR 3/6, moist); strong, coarse, sub-angular blocky structure; soft dry, friable moist, non-sticky wet; very few, fine roots; common, fine and medium, interstitial, open pores; thin cutans on pore faces; many, small, irregular, hard iron oxide nodules; few, ferruginized stones; extremely acidic

Horizon	Depth (cm)	Description
		(pH 4.4); diffuse, smooth boundary.
B32	150 - 170	Same as horizon above but contains more ferruginous gravel and stones.

Dutse association

The Dutse association occurs as reddish, massive, indurated ironpan crust or cap. The cap is mainly restricted to the top of small isolated flat-topped hills or mesas found in the lower plain. There is no drift mantling the cap, instead there may be broken ironpan boulders on the surface of the cap. The association is of limited extent in the area. The ironpan crust is sometimes up to two or more meters in thickness. The Dutse association always grade into the Amanawa soils. No representative member of the soils could be described because no soil profile pit could be dug in the area.

Tuda association

Soils of Tuda association occupy the valley bottomlands. They are seasonally flooded during the rainy season. The floodwater ponds the soil surface. The terrain is almost flat to gently undulatting.

The parent material is alluvial deposit over the Wurno-Taloka formation. The soils have an ochric epipedon. Soil colours are gray (5 Y 5/1) in the epipedon changing to yellowish brown (10 YR 5/6) in the subsoil. Mottling is prominent diffuse and brownish in the soil. The texture of the soil is sandy clay in the epipedon changing through sandy clay loam to loamy sand in the subsoil. The soils show vertic properties such as the presence of numerous wide cracks in the dry season and pressure faces up to a depth of 50 cm.

Tuda soils are poorly drained. A representative soil (pedon 20) is described below.

Location: 430 meters to Gyalaude village from Sokoto - Gusau road.

Parent material: Alluvial deposit

Relief: Valley bottom land

Slope: Almost flat (0 - 1%)

Landuse: Cultivated to rice, sorghum, millet and groundnut in the wet season, during the dry season cultivated to irrigated vegetables example pepper, tomatoes.

Drainage: Poorly drained

Depth to water table: 2.3 meters in nearby well.

Date described: 17/12/80

Horizon	Depth (cm)	Description
A1pg	0 - 25	Gray (5 Y 5/1, dry) sandy clay; gray (5 Y 3/1, moist); many, diffuse, brownish (7.5 YR 5/6) mottles; strong, coarse, subangular blocky structure; very hard dry, firm moist, very sticky and very plastic wet; many fine and medium roots; many fine and medium,

Horizon	Depth (cm)	Description
		interstitial and tubular, open pores; many, cracks, few pressure faces; about 1 mm thick cutans on ped faces; occasional, large, irregular, hard iron oxide nodules; moderately acidic (pH 5.8); diffuse, smooth boundary.
A3	25 - 50	Brown to dark brown (10 YR 4/3, dry) sandy clay loam; dark yellowish brown (10 YR 4/4, moist); many, diffuse, brownish (7.5 YR 5/6) mottles; strong, coarse, angular blocky structure; very hard dry, friable moist,

Horizon	Depth (cm)	Description
		very sticky and very plastic wet; very, few fine roots; common, pressure faces, thick (2 mm) cutans on ped faces; numerous fine, few medium, interstitial open pores; occasional, large, irregular, hard iron oxide nodules; moderately acidic (pH 5.9); diffuse, smooth boundary.
B1	50 - 75	Yellowish brown (10 YR 5/4, dry) sandy clay loam; dark yellowish brown (10 YR 3/4, moist); many, diffuse, brownish (7.5 YR 5/6) mottles; strong, coarse, sub-angular blocky structure; very hard dry, firm, moist, slightly sticky

Horizon	Depth (cm)	Description
		and slightly plastic wet; few, fine roots; many fine, few medium, inter-stitial, open pores; common, pressure faces; cutans of about 1.5 mm on ped faces; many, large irregular, hard iron oxide nodules; moderately acidic (pH 5.8); diffuse, smooth boundary.
B2	75 - 100	Brown to dark brown (10 YR 4/4, dry) sandy clay loam; dark yellowish brown (10 YR 3/4, moist); many, diffuse brownish (7.5 YR 5/8) mottles; strong coarse, angular blocky structure; very hard dry, friable moist, slightly sticky and slightly plastic wet;

Horizon	Depth (cm)	Description
		very few, fine roots; many, fine, interstitial, open pores; few pressure faces; many, large, irregular, hard iron oxide nodules; few, ferruginized sandstones; moderately acidic (pH 5.8); diffuse, smooth boundary.
B3	100 - 125	Yellowish brown (10 YR 5/6, dry) sandy loam, dark grayish brown (10 YR 4/2, moist); many, diffuse, brownish (7.5 YR 5/8) mottles; moderate, coarse, subangular blocky structure; very hard dry, friable moist, slightly sticky and slightly plastic wet; no roots; common, fine, interstitial, open pores;

Horizon	Depth (cm)	Description
		very few pressure faces; many, large, irregular, hard iron oxide nodules; few ferruginized sandstones; moderately acidic (pH 5.6); diffuse, smooth boundary.

Physical Characteristics

Soil texture

The epipedons in all soils of the area generally have little gravel but the subsoils especially the soils of the high plain and escarpment tend to be very gravelly. The gravel is as much as 75 to 85 per cent by weight in the subsoils of the soils of Dange association while it is 63 to 85 per cent in the subsoils of the soils of Zafanadi association. These gravelly subsoils are due to the influence of the ironpan that separates the drift parent material from the underlying geology in the two mentioned associations.

The high plain soils represented by the Dange association have sand content ranging from 51 to 90 percent (Table 2) and this usually decreases from the surface horizon to the subsoil. The soils of the Zafanadi association contain sand ranging from 39 to 86 percent. The lower plain soils of Merina and Amanawa associations have sand content ranging from 64 to 93 percent and 64 to 87 respectively. The sand content in the soils of the area generally increases from soils in the upper slope positions to the soils in the lower slope positions. Sand content tends to decrease with depth in the soils on the upper slope positions, while it tends to increase with depth in the soils on the lower slope position. In the soils of the alluvial bottomlands the sand content is not as high as those of the upland areas. Two representatives of the soils of the bottomlands are the Bela and Tuda associations and they have sand content ranging from 23 to 58 percent and 49 to 84 percent respectively (Table 2). The sand content of bottomland soils

Table 2

Some physical characteristics of the soils

Soil	Profile	Horizon	Depth (cm)	Gravel (> 2 mm)	Coarse Sand 2.0 - .2mm	Fine Sand .2 - .05mm	Total Sand 2 - .05mm	Silt .05 - 002	Clay <.002
				%					
Dange	8	A1	0 - 14	.5	28	62	90	4	6
		A3	14 - 42	.7	30	53	83	4	13
		B1t	42 - 72	.6	34	49	83	5	12
		B21t	72 - 98	.6	32	50	82	4	14
		II B22t	98 - 130	78.7	39	38	77	5	18
Zafanadi	3	A11p	0 - 10	1.8	33	52	85	6	9
		A12p	10 - 18	1.9	28	53	81	6	13
		Bt	18 - 38	2.6	23	47	70	7	23
		II C1	38 - 58	85.4	35	38	73	5	22
Merina	6	Apg	0 - 26	.4	38	50	88	5	7
		B1	26 - 54	.1	32	54	86	4	10
		B21	54 - 96	.1	30	57	87	4	9
		B22	96 - 135	.4	40	50	91	3	6
		II B3gt	135 - 180	.5	27	49	76	4	20

*Clay estimated from 15 bar moisture content = 15 bar moisture content X 2.5.

Table 2 continued

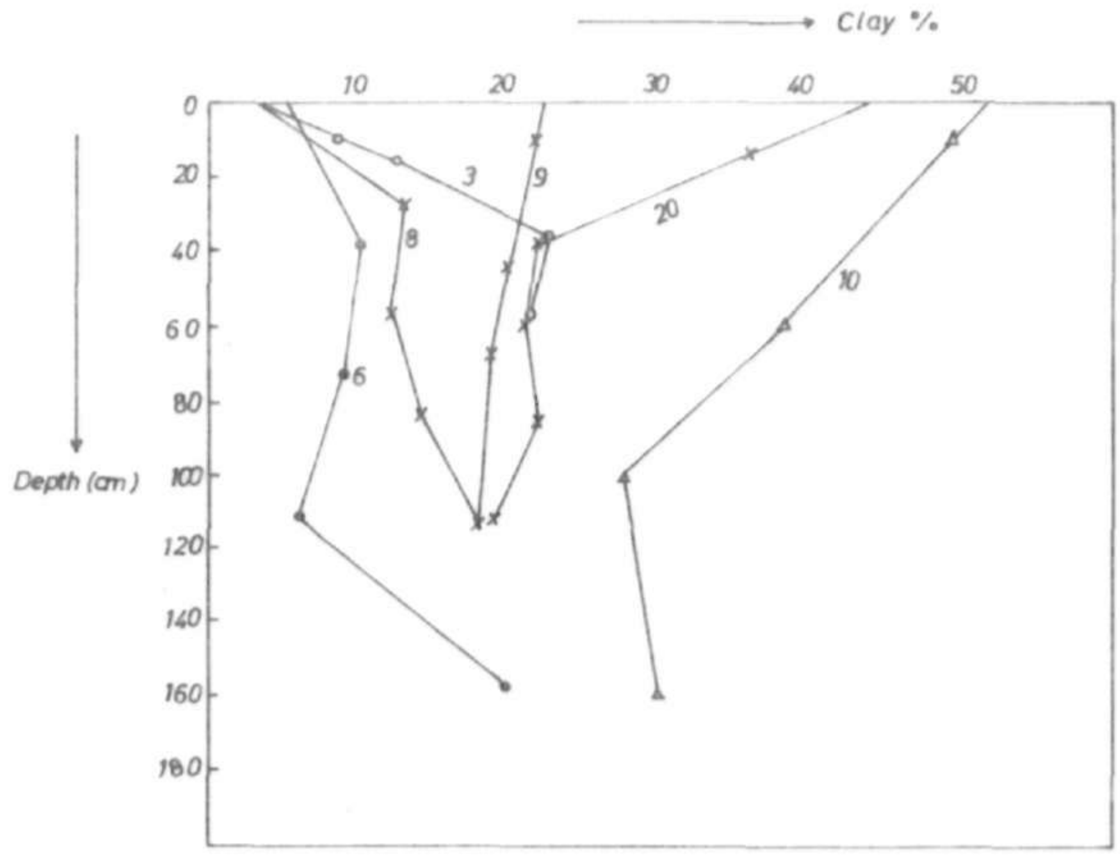
Amanawa	9	A1	0 - 22	.5	18	46	64	14	22
		B21	22 - 46	-	19	49	68	12	20
		B22	46 - 80	.1	20	45	65	16	19
		B3	80 - 154	.2	20	48	68	14	18
Bela	10	A1	0 - 20	-	4	19	23	27	50
		A3	20 - 60	-	11	27	38	24	38
		B21	60 - 105	-	6	46	52	20	28
		B22	105 - 160	-	3	55	58	12	30
Tuda	20	A1g	0 - 25	-	14	35	49	15	36
		A3	25 - 50	-	22	47	69	9	22
		B1	50 - 75	-	24	47	71	8	21
		B2	75 - 100	1.3	24	46	70	8	22
		B3	100 - 125	2.4	27	47	74	7	19
		C	125 - 150	.8	27	47	84	4	12

*Clay estimated from 15 bar moisture content = 15 bar moisture content X 2.5.

generally increases with depth. This probably supports the sandy nature of the underlying parent material and shows that the finer textured surface horizons are probably derived from fine materials brought by floodwater during the rainy season.

The silt content of all the upland soils are low, they are always lower than the sand and clay content. The silt content ranges from 4 to 10 percent in the soils of Dange association, 5 to 13 percent in the soils of Zafanadi association, 2 to 7 percent in the soils of Merina association, and 2 to 6 percent in the soils of Amanawa association. In the soils of the upper plain, silt content increases with depth from the soil surface but subsequently decrease in the subsoil. The soils of the lower plain show a decrease with depth in silt content from the surface horizon but a subsequent increase in the subsoil. The bottomland soils of Bela and Tuda associations have silt content ranging from 12 to 27 percent and 4 to 15 percent respectively. The silt content of the latter generally decreases from the surface horizon to the subsoil.

The clay content of the upland soils are generally lower than those in the soils of the alluvial bottomlands (fig. 9). Clay content ranges from 6 to 41 percent in the Dange soils, 8 to 48 percent in the Zafanadi soils, 4 to 21 percent in the Merina soils and 8 to 22 percent in the Amanawa soils. Generally clay content increases from the soils of the high plain to the soils of the lower plain. A characteristic of the upland soils is the downward movement of clay especially in the Dange and Zafanadi associations where this results in the formation of textural B horizons which are referred to as argillic horizons (fig. 9). This translocation and accumulation of clay at a lower depth in the soil profile is enhanced by the effective percolation of rain water in the wet season through the porous sandy upland soils. The downward movement of clay causes a low degree of structural development in the surface horizon but well developed structure in the subsoil.



LEGEND

PEDON	ASSOCIATION	LANDFORM
8	DANGE	LIGHT PLAIN
3	ZAFANADI	ESCARPMENT
6	MERINA	LOW PLAIN
9	AMANAWA	LOWER PLAIN
10	ALLUVIAL	FADAMA FLOODPLAIN
20	TUDA	FADAMA

FIG 9 CLAY DISTRIBUTION WITH DEPTH FOR SOME SOILS OF THE DANGE AREA.

The bottomland soils of Bela and Tuda associations have clay content ranging from 28 to 50 percent and 12 to 36 percent respectively. The clay content decreases from the surface horizon to the subsoil in the bottomland soils. The relatively high clay content in the surface horizon or surface layer of the soils is due to clay addition by floodwater. Also the higher clay content in the soils of the floodplain suggests that the river flood deposits more fine particles in the floodplain than in the ponded water in the bottomland depression.

Chemical Characteristics

Organic matter

The soils of the Dange area have a consistently low organic matter content. FAO (1969) observed the same for all the soils of the Sokoto-Rima basin, of which the study area is part. In all the soils, the organic matter is highest in the surface horizon and decreases sharply to its lowest level in the subsoil. In the upland soils, the organic matter content ranges from 0.3 to 1.86

percent in the Dange association, o.3 to 0.75 percent in the Zafanadi association, 0.3 to 1.04 percent in the Merina association and 0 to 0.4 percent in the Amanawa association (Table 3). In the uplands the organic matter content is higher in the soils of the high plain than in the soils of the lower plain. Similarly the soils of the bottomlands, that is, the Bela and Tuda associations have about the same amount of organic matter as the soils of the uplands being 0.22 to 1.71 percent and 0.04 to 0.74 percent respectively, in the two soils.

The generally low level of organic matter is attributable to three main factors. First, the hot semi-arid climate coupled with the sparse vegetative cover of the soil surface results in direct insolation of the soil surface hence causing rapid mineralization of humus. Secondly, widespread and frequent bush-fires and burning of farm residues destroys much of the potential humus present. The potential humus is mainly in form of leaf and grass litter.

Table 3 Some Chemical Characteristics of the soils

Soil	Profile	Horizon	Depth (cm)	pH (H_2O)	OM %	Ca	Mg	K	Na	Al	TEB	CEC	CEC*	BS %	BS* %
						meq/100 g									
Dange	8	A1	0 - 14	6.4	1.06	2.5	.7	.06	.11	.1	3.4	21.6	.4	5	100
		A3	14 - 40	6.3	1.21	5.1	1.0	.08	.13	.1	6.3	21.8	5.2	28	100
		B1t	40 - 72	6.6	1.86	3.4	.5	.07	.09	.1	4.1	22.0	2.6	18	100
		B21t	72 - 98	6.8	.95	5.0	.5	.08	.11	.1	5.8	23.8	3.4	24	100
		II B22t	98 - 130	7.3	1.02	5.4	.8	.08	.16	.1	6.5	25.6	4.7	25	100
Zafanadi	3	A11p	0 - 10	6.9	.63	4.6	1.2	.15	.10	.1	6.1	1.9	3.0	100	100
		A12p	10 - 18	6.3	.39	5.2	1.3	.07	.41	.1	6.7	1.6	4.7	100	100
		Bt	18 - 38	6.0	.75	11.2	1.6	.10	.19	.1	13.2	2.3	2.1	100	100
		II C1	38 - 58	6.7	.51	6.8	.8	.12	.16	.1	8.0	1.7	7.3	100	100
Merina	6	Apg	0 - 26	5.5	1.02	2.5	1.0	.06	.09	.1	3.7	5.6	2.1	66	100
		B1	26 - 54	5.6	.95	3.0	.6	.06	.09	.1	3.7	4.1	.87	90	100
		B21	54 - 96	6.0	.94	2.7	.5	.06	.11	.1	3.4	5.1	1.3	67	100
		B22	96 - 135	6.5	.90	2.2	.4	.04	.11	.1	2.7	3.9	.43	69	100
		II B3gt	135 - 180	6.8	.89	6.2	.8	.12	.16	.1	7.3	7.4	6.5	98	100

CEC = CEC by NH_4OAc method

BS = BS calculated from CEC by NH_4OAc method

CEC* = CEC by NaOAc method

BS* = BS calculated from CEC by NaOAc method

Table 3 continued

Amanawa	9	A1	0 - 22	3.9	.23	.9	.3	.07	.10	.1	1.4	1.7	.8	82	100
		B21	22 - 46	4.2	.04	.3	.1	.04	.08	.2	.6	1.6	.8	37	68
		B22	46 - 80	4.4	.04	.3	.1	.04	.07	.2	.5	1.4	.6	35	83
		B3	80 - 154	4.4	.01	.8	.1	.04	.10	.2	1.2	1.5	.7	80	100
Bela	10	A1	0 - 20	6.3	1.71	18.7	4.4	.50	.28	.80	23.9	34.0	28.3	70	84
		A3	20 - 60	6.1	.59	11.2	3.0	.26	.20	.10	14.8	19.6	18.7	75	79
		B21	60 - 105	6.0	.54	7.6	2.0	.20	.15	.10	10.0	14.6	12.6	68	79
		B22	105 - 160	5.9	.22	6.6	2.0	.18	.15	.10	9.0	13.2	10.2	68	82
Tuda	20	A1g	0 - 25	5.8	.74	14.6	4.1	.21	.25	.1	19.2	23	21.3	83	90
		A3	25 - 50	5.9	.18	6.5	1.6	.18	.19	.1	8.5	9.1	7.8	93	100
		B1	50 - 75	5.8	.15	6.2	1.4	.15	.27	.1	8.1	10.5	6.1	77	100
		B2	75 - 100	5.8	.11	6.5	1.5	.14	.23	.1	8.4	8.9	6.5	95	100
		B3	100 - 125	5.6	.08	5.1	1.3	.14	.27	.1	6.9	9.0	4.3	77	100
		C	125 - 150	4.6	.04	2.5	.6	.09	.13	.1	3.4	4.7	18.3	72	100

CEC = CEC by NH_4OAc method

CEC* = CEC by NaOAc method

BS = BS calculated from CEC by NH_4OAc method

BS* = BS calculated from CEC by NaOAc method

Thirdly, erosion of the topsoil which is a consequence of low organic matter, poor structure and poor vegetative cover results in further losses of organic matter.

Soil reaction

The reaction of the soils is generally slightly acidic to mildly alkaline in the soils of the high plain and escarpment while it tends to be slightly acidic to acidic in the soils of the lower plain and bottomlands. Soil pH in the soils of the Dange association varies from 5.5 to 7.5. The surface horizon is usually very slightly acidic while the subsoil is moderately acidic or very slightly alkaline. Soils of the Zafanadi association have soil pH values ranging from 5.6 to 8.0. The epipedon of the latter is generally slightly acidic while the subsoil is slightly or moderately alkaline. In both Dange and Zafanadi associations the soil pH usually decreases from the surface horizon down the profile but subsequently increases in the subsoil. The soil pH of the Merina association ranges from 4.7 to 7.0 and is generally moderately acidic in the surface horizon and very slightly acidic in the subsoil, though some members have strongly acidic subsoils. Soils of the Amanawa association have soil pH values ranging from 3.9 to 6.7. Most soils of the latter have extremely acidic surface horizons and very strongly acidic subsoils. The bottomland soils of the Bela and Tuda associations have pH values of 5.9 to 6.3 and 4.6 to 5.9 respectively. Soils of the Bela association are slightly acidic in the surface horizon and change to moderately acidic in the subsoil. The Tuda soils also change from moderately acidic in the surface horizon to very strongly acidic in the subsoil.

The acidity of the soils of the area is a consequence of low base status and very low organic matter content in the soils.

Exchangeable bases

The dominant exchangeable cations in the soils of the study area are Ca and Mg. Magnesium is present in lesser amounts to calcium. Both cations are lower in amount in the soils of the lower plain than in the soils of the high plain. Using calcium as an example, the Ca content in the soils of the Dange association representing the high plain soils ranges from 2.5 to 15.1 meq/100 g soil and from 2.3 to 12.5 meq/100 g in the soils of the Zafanadi association representing the lower plain soils. Also, Ca content ranges from 0.3 to 4.3 meq/100 g in the soils of the Amanawa association representing the lower plain soils.

Soils of the bottomlands tend to contain more Ca and Mg than all other soils, examples being the soils of the Bela association with 6.6 to 18.7 meq/100 g of Ca. This is probably because the bases are brought from the higher grounds by groundwater during the rainy season and deposited in these soils. In the upland soils, except for the soils of the Zafanadi association, the content of the two cations increases from the surface horizon down the profile but subsequently decreases in the deeper layers. In the Zafanadi association, the

Ca and Mg contents in the soils of the transitional member which grades into the Merina association are unique because the underlying rock is frequently reached at shallow depths. The rock, being the calcareous shales of the Dange formation, gives the subsoil very high Ca content of up to 54.6 meq/100 g soil; otherwise the topsoil horizons contain similar amounts like the other upland soils.

Potassium and sodium are very low in all the soils of the area ranging from 0.04 to 0.5 meq/100 g soil. Soils of the bottomlands contain the highest amounts which decrease from the surface horizon to the subsoil, probably because fresh amounts are brought periodically every rainy season by the floods and deposited in the soils. In the upland soils both cations tend to increase with depth. This could be attributed to downward movement by leaching during the rains. The low content of K and Na in the soils may partly be due to low content in the parent material.

Extractable aluminum

The extractable Al content of most of the soils were low, being about 0.1 meq/100 g soil. Only the acid soils of Amanawa association and the surface horizon of the Bela association showed significant values of 0.1 to 1.8 meq/100 g.

Cation exchange capacity

The cation exchange capacity (CEC) of the soils was determined mainly by the normal ammonium acetate (pH 7.0) method. Also normal sodium acetate (pH 8.4) was used to measure the CEC of the representative soils of the various associations (Table 4).

The results show that the CEC (by NH_4OAc) in the soils of the Dange association were generally between 5.1 and 12.0 meq/100 g soil (profiles 15 and 19). Though some of the soils of the association showed unreasonably high values as examplified by profile 8 which has CEC (by NH_4OAc) values ranging from 21.6 to 25.6

meq/100 g. Nevertheless, the CEC (by NaOAc) which is expected to be close to the true value, for the same soil (pedon 8) gave values of 0.4 to 5.2 meq/100 g. Inference from clay content (Table 2, Appendix) supports the range of 5.1 to 12.0 meq/100 g for soils of the Dange association. The high values obtained in some of the soils (despite a repeat of the procedure) might probably be due to interference of $CaCO_3$ which might have come from the calcareous Kalambaina formation which underlies the soils.

The soils of the Zafanadi association have NH_4OAc - CEC values commonly ranging from 1.6 to 18.8. The subsoil of the intergrade of the Amanawa and the Merina associations have extremely high values of 43.8 to 58.6 meq/100 g. The high value is perhaps influenced by the clayey calcareous underlying geology (the calcareous shales of Dange formation) which is frequently reached at shallow depths (profile 18). NH_4OAc - CEC values for the soils of the Merina association generally ranged from 0.3 to 14.7 meq/100 g except for profiles 6 and 7 which have high values of 18.4 to 29.3 meq/100g

(Table 3, appendix). The NaOAc - CEC value for profile 6 as compared with NH_4OAc - CEC should be similar to those of other soils of the association (appendix), that is, close to 0.8 to 6.52 meq/100 g. The interference of $CaCO_3$ is also suspected here as in the Dange association. The NH_4OAc - CEC for the soils of the Amanawa association ranged from 1.1 to 7.2 meq/100 g. Soils of the bottomlands showed relatively higher values of NH_4OAc - CEC mainly because of their higher clay content than the upland soils. The values ranged from 13.2 to 34.0 meq/100 g in the soils of Merina association and 4.7 to 23 meq/100 g in the soils of the Tuda association. The CEC values for all the soils generally tended to be more related to the clay content since organic matter was generally low, especially in the subsoils. The NH_4OAc - CEC were generally higher than the NaOAc - CEC.

Base saturation

Total exchangeable bases (TEB) is the sum of exchangeable Ca^{2+}, Mg^{2+}, K^{+} and Na^{+} ions determined for the soils. Base saturation (BS) is the TEB divided by the CEC, expressed as a percentage. The soils show full or nearly full saturation of the exchange complex throughout their depths. They have a range of 35 to 100 percent (Table 4, and appendix). Soils of Merina and Amanawa associations have widely varied saturation percentages ranging from 9 to 100 percent, with low values dominating (appendix).

Soil Classification

An attempt is made below to classify the soils into higher categories of soil classification in the FAO/UNESCO system (FAO, 1974) and USDA system, Soil Taxonomy, (Soil Survey Staff, 1975).

Estimation from climatic data previously discussed indicates that the soil moisture regime of the Dange area is Ustic. The soil moisture control section at approximately 50 cm is expected to be dry in some or all parts for 90 or more cumulative days. The Temperature regime is estimated to be Hyperthermic because the mean annual soil temperature for June, July and August (rainy season) and for December, January and February (dry season) is expected to differ by more than $5^{o}C$ at a depth of 50 cm.

Soils of the Dange association are classified as Chromic Luvisols in the FAO/UNESCO system because the soils have an argillic horizon which have a base saturation of 50 percent or more (by NH_4OAc) at least in the lower part of the B horizon within 125 cm of the surface. The argillic B horizon is strong brown and the soil lacks a mollic A and an albic E horizon. Hydromorphic properties are also absent. In the Soil Taxonomy the soils are classified as Plinthustalfs because they have an ochric epipedon, and argillic horizon, moderate to high base saturation and water is held at less than 15 atmosphere tension during at least 3 months each year when the soil is warm enough for plants to grow, have an ustic moisture regime, have plinthite that constitutes more than half the matrix of some subhorizon of the argillic horizon within 1.25 m of the soil surface (Table 4).

Soils of the Zafanadi association are classified into Plinthic Luvisols in the FAO/UNESCO system because most of the soils have plinthite within 125 cm of the surface. The USDA system classifies the soils as Plinthustalfs for the same reasons given for the Dange association. The subgroups of the Plinthustalfs have not been developed.

Soils of the Merina association are classified in the FAO/UNESCO system as Plinthic Gleysols because the soils are formed from unconsolidated materials exclusive of recent alluvial deposits, they show hydromorphic properties within 50 cm of the surface, have an ochric A and a cambic B horizons and have plinthite within 125 cm of the soil surface.

In the <u>Soil Taxonomy</u> the soils are classified as Fluventic Ustochrepts because the soils have altered horizons that have lost bases or iron and aluminum but retain some

TABLE 4

Classification of the Soils

Soil Association	FAO/UNESCO	USDA
Dange	Chromic Luvisols	Plinthustalf
Zafanadi	Plinthic Luvisols	Plinthustalf
Merina	Plinthic Gleysols	Fluventic Ustochrepts
Amanawa	Eutric Regosols	Typic Ustipsamments
Bela	Eutric Fluvisols	Mollic Psammaquents
Tuda	Plinthic Gleysols	Mollic Haplaquents
Dutse	Ironstone	Ironstone

weatherable minerals, are light coloured, brownish, more or less freely drained and formed on alluvium. Also the soils have an ustic moisture regime and temperature regime warmer than cryic. An ochric epipedon is present.

Soils of the Amanawa association belong to Eutric Regosols in the FAO/UNESCO system as the soils are formed from unconsolidated materials, exclusive of recent alluvial deposits, have no diagnostic horizons other than an ochric A horizon; lack hydromorphic properties within 50 cm of the soil surface, lack high salinity, lack lammellae of clay accumulation and features of cambic or oxic B horizons or albic material and have a base saturation (by NH_4OAc) of more than 50 percent between 20 and 50 cm from the surface. In the Soil Taxonomy the soils are classified as Typic Ustipsamments because the soils have little evidence of development of pedogenic horizons, they are formed in cover sands with thick regolith, do not have lammelae of silicate clays and have an ustic moisture regime.

The Bela soils are classified into Eutric Fluvisols in the FAO/UNESCO system because they are developed on recent fluviatile deposits, they have no diagnostic horizons, have a base saturation (by NH_4OAc) of more than 50 percent between 20 and 50 cm from the surface but are not calcareous at this depth. In Soil Taxonomy the soils are classified as Mollic Psammaquents because the soils have little evidence of development of pedogenic horizons, have sandy textures, have a hyperthermic soil temperature regime, saturated with water at some time of the year and the base saturation (by NH_4OAc) is more than 50 percent in more than half the thickness of the subhorizons within the upper 1 m of the soil.

Tuda soils belong to the Plinthic Gleysols in the FAO/UNESCO system because the soils are formed from unconsolidated materials exclusive of recent alluvial deposits, show hydromorphic properties within 50 cm of the surface, have no diagnostic horizons other than an ochric A horizon, lack characteristics diagnostic of vertisols and have plinthite within 125 cm of the surface. In Soil Taxonomy Tuda soils are classified as Mollic Haplaquents because they have little or no evidence of development of pedogenic horizons, are saturated with water at some time of the year, are soils of depressions where fresh sediments do not accumulate, have mottles and have colour hue yellower than 2.5 Y with chroma (moist) less than 2 to a depth of 25 cm.

SUMMARY AND CONCLUSION

A reconnaissance soil survey at a scale of 1:50,000 was conducted in the Dange area of Sokoto State, Nigeria. Seven soil associations were delineated in the area. They are the Dange, Zafanadi, Merina, Amanawa, Bela, Tuda and Dutse associations. The soils of the Dange association which are extensive in the area usually occur on the almost flat to undulating uplands of the high plain. Soils of the Zafanadi association occupy the upland escarpment below the high plain. The soils usually grade into the Merina association on the lower plain. Below the escarpment soils of the Merina association occupy the nearly level to undulating lower plain of the upland which is mantled by alluvial and colluvial deposits. The association is the most extensive in occurence in the area. The Bela association occurs on the floodplain of the river Belamajia. Soils of the Amanawa association occur on the raised level grounds on the low plain with gentle to almost flat slopes. The soils always grade into the Merina association without an intervening scarp or break of slope. The Dutse association occurs as reddish massive, indurated ironpan crust cap on the small isolated flat-topped hills or mesas found in the lower plain. They are of limited extent in the area. Soils of the Tuda association occupy the valley bottomlands. They are seasonally flooded during the rainy season. The flood water ponds the soil surface of the almost flat to gently undulating terrain.

The epipedon of all the soils generally have little gravel but the subsoil especially in the soils of the high plain and escarpment are very gravelly reaching 75 to 85 percent in some subsoils. The soils of the area generally have sandy textures of which the fine sand fraction predominates. Silt content are generally very low in most of the soils with only the bottomland soils showing appreciable quantities. Clay content in the upland soils are generally lower than those in the soils of the alluvial bottomlands. In the uplands the soils are characterized by the downward movement of clay culminating in the formation of textural B or argillic horizons in the Dange anf Zafanadi associations.

The soils of the area have consistently low organic matter content. In all the soils the organic matter content is highest in the surface horizon and decreases to its lowest level in the subsoil. The hot semi-arid climate, widespread and frequent bush fires and burning of farm residues coupled with erosion of the topsoil results in destruction and losses of potential organic matter.

The soil reaction is generally strongly acidic to mildly alkaline in the soils of the area. Most of the soils are acidic due to low base status and very low organic matter content. The soil pH in the soils of the area ranges from 3.9 to 8.0 with the epipedon being more acidic than the subsoil in most soils.

The dominant exchangeable cations in the soils of the area are Ca and Mg. Magnesium is present in lesser amounts than Ca. Exchangeable K and Na are very low in all the soils. Soils of the bottomlands tend to contain more exchangeable cations than the upland soils. The extractable Al content of most of the soils were consistently low at about 0.1 meq/100 g soil. Only the extremely acidic soils contained appreciable amounts of up to 1.8 meq/100 g soil.

The CEC determined by the NH_4OAc method for the soils generally ranged from 0.4 to 34.0 for the soils. Some of the soils of the Dange and Merina associations showed high values. As a check the NaOAc method was used to determine the CEC of the representative soils. The CEC results by NaOAc confirmed that the high values obtained in some of the soils by NH_4OAc method were too high. It is suspected that $CaCO_3$ (probably from the Kalabaina formation below) interfered during the NH_4OAc - CEC determination. The Zafanadi subsoil influenced by the underlying geology has the highest CEC value of 58.6 meq/100 g soil. The CEC values for all the soils generally tended to be more related to the clay content since organic matter was generally low, especially in the subsoils.

The soils of the Dange, Zafanadi, Bela and Tuda associations show full or nearly full base saturation (79 to 100 percent) of the exchange complex. The epipedon in most of the soils is usually more base saturated than the subsoil. Soils of the Merina and Amanawa associations have widely varied base saturation percentages ranging from 9 to 100 percent.

The soils of the area were classified using two systems of soil classification namely the FAO/UNESCO system and the Soil Taxonomy of USDA respectively. The Dange association belongs to the Chromic Luvisols or Plinthustalfs. The escarpment soils of the Zafanadi association are classified into Plinthic Luvisols or Plinthustalfs. Soils of the lower plain of Merina association belong to the Plinthic Gleysols or Fluventic Ustochrepts while the Amanawa soils are classified as Eutric Regosols or Typic Ustipsamments. The bottomland soils of Bela association are classified as Eutric Fluvisols or Mollic Psammaquents and Tuda association are classified as Plinthic Gleysols or Mollic Haplaquents.

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APPENDIX

Some physical characteristics of the soils

Soil	Pedon	Horizon	Depth (cm)	Gravel (>2 mm)	Coarse Sand	Fine Sand	Total Sand	Silt	Clay	*Clay
				%						
Dange	1	Ap	0 - 12	4	23	44	67	9	24	16
		A3	12 - 22	4	23	43	66	7	27	16
		B1t	22 - 40	5	20	40	60	9	31	18
		B21t	40 - 66	75	24	34	58	8	34	26
		II B22t	60 - 120	78	21	30	51	8	41	31
Dange	2	A1	0 - 4	3	33	46	79	8	13	12
		A3	4 - 15	2	21	38	59	11	30	20
		B1t	15 - 25	5	21	41	62	10	28	15
		B21t	25 - 35	12	22	40	62	10	28	19
		II B22t	35 - 50	70	23	29	52	10	38	26
		II B23t	50 - 120	85	30	34	64	9	37	30
Amanawa	4	Ap	0 - 20	5	29	58	87	5	8	7
		B1	20 - 40	14	26	57	83	4	13	11
		B21	40 - 66	0	28	57	85	4	11	11
		B22	66 - 90	.5	31	55	86	2	12	10
		II C	90 - 120	83	47	37	84	3	13	20

*Clay = Clay estimated from 15 bar moisture content = 15 bar moisture content X 2.5.

II

Some physical characteristics of the soils

Soil	Pedon	Horizon	Depth (cm)	Gravel (> 2mm)	Coarse Sand	Fine Sand	Total Sand	Silt	Clay	*Clay
				%						
Merina	5	Ap	0 - 12	.6	30	54	84	4	12	11
		B1	12 - 40	.1	31	55	86	3	11	10
		B21	40 - 78	.4	33	57	90	3	7	6
		B22	78 - 125	4	28	61	89	2	9	9
		II B3	125 - 150	79	38	44	82	4	14	14
Merina	7	A1	0 - 17	.9	32	52	84	5	11	8
		B1	17 - 44	2	34	51	85	3	12	11
		B21	44 - 78	3	31	55	86	3	11	13
		B22	78 - 110	2	30	56	86	4	10	10
		II B3	110 - 150	3	28	59	87	4	9	11
Merina	11	A1	0 - 15	1	23	61	84	12	4	3
		A3	15 - 35	1	30	60	90	6	4	5
		B1	35 - 60	3	43	44	87	7	6	6
		B21	60 - 100	0	19	45	64	26	10	8
		II B22	100 - 145	.2	20	46	66	22	12	10
		II B3	145 - 160	.2	20	54	74	20	6	4

*Clay = Clay estimated from 15 bar moisture content = 15 bar moisture content X 2.5.

IV

Some physical characteristics of the soils

Soil	Pedon	Horizon	Depth (cm)	Gravel (> 2mm)	Coarse Sand	Fine Sand	Total Sand	Silt	Clay	*Cla
				%						
Dange	15	A1	0 - 15	3	30	45	75	5	20	12
		A3	15 - 40	1	27	32	59	9	32	23
		B1	40 - 55	3	30	31	61	7	22	21
		B21t	55 - 78	3	28	33	61	8	31	22
		II B22t	78 - 150	80	31	29	60	10	30	22
Zafanadi	16	A1	0 - 5	5	37	47	84	5	11	7
		B1	5 - 30	6	28	35	63	8	29	17
		II B21t	10 - 52	74	21	23	44	10	46	31
		II B22t	52 - 90	80	18	20	38	13	49	15
Merina	17	A1	0 - 18	.1	29	59	88	5	9	3
		A3	18 - 36	.6	34	53	87	5	8	6
		B1	36 - 62	1	48	45	93	2	5	3
		II B2	62 - 91	1	28	59	87	5	8	6
		II B3	91 - 150	.1	36	53	89	4	7	5

*Clay = Clay estimated from 15 bar moisture content = 15 bar moisture content X 2.5.

V

Some Physical characteristics of the soils

Soil	Pedon	Horizon	Depth (cm)	Gravel (> 2mm)	Coarse Sand	Fine Sand	Total Sand	Silt	Clay	*
				%						
Zafanadi	18	A1	0 - 10	6	28	49	77	7	16	
		B1	10 - 25	10	34	43	77	5	18	
		B21	25 - 62	77	45	25	70	9	21	
		B22	62 - 100	80	44	20	64	10	26	
		II C1	100 - 113	63	26	16	42	13	43	
		II C2	113 - 130	20	10	15	25	17	58	
Dange	19	Ap	0 - 11	5	37	49	86	4	10	
		B1t	11 - 26	1	30	47	77	4	19	
		B21t	26 - 60	.9	29	49	78	4	18	
		II B22t	60 - 100	73	42	36	78	5	17	

*Clay = Clay estimated from 15 bar moisture content = 15 bar moisture content X 2.5.

Some Chemical Characteristics of the Soils

Soil	Pedon	Horizon	Depth (cm)	pH (H_2O)	OM %	Ca	Mg	K	Na	Al	TEB	CEC	B.S %
						meq/100 g							
Dange	1	Ap	0 - 12	6.7	.71	7.5	2.2	.10	.15	.1	10.0	27.9	35
		A3	12 - 22	5.9	.56	5.3	2.1	.09	.13	.1	7.7	30.2	25
		B1t	22 - 40	5.8	.37	5.2	1.7	.07	.14	.1	7.2	31.9	22
		B21t	40 - 66	5.8	.55	6.2	2.0	.10	.15	.1	18.5	37.4	49
		II B22t	66 - 120	5.7	.30	6.2	2.3	.12	.20	.1	8.9	26.8	33
Dange	2	A1	0 - 4	6.9	.81	7.6	1.7	.29	.16	.1	9.8	29.6	33
		A3	4 - 15	6.9	1.1	15.1	1.9	.12	.25	.1	17.4	42.4	41
		B1t	15 - 25	6.8	.81	12.5	1.3	.10	.23	.1	14.4	36.8	39
		B21t	25 - 35	6.7	.68	11.2	1.2	.09	.21	.1	12.7	32.7	39
		II B22t	35 - 50	6.3	.51	12.5	1.2	.12	.35	.1	14.2	31.5	38
		II B23t	50 - 120	7.5	.43	8.5	.63	.08	.23	.1	9.5	23.8	39
Amanawa	4	Ap	0 - 20	6.1	.40	3.1	1.1	.08	.10	.1	4.4	22.8	19
		B1	20 - 40	6.0	.34	4.3	1.1	.07	.13	.1	5.7	24.0	24
		B21	40 - 66	6.4	.14	2.8	.3	.06	.11	.1	3.3	24.7	13
		B22	66 - 90	6.6	.08	3.6	3.4	.07	.14	.1	7.3	25.4	29
		II C	90 - 120	6.7	.11	4.2	.4	.07	.16	.1	4.9	25.2	19

CEC = CEC by NH_4OAc method.

Some chemical characteristics of the soils

Soil	Pedon	Horizon	Depth (cm)	pH (H_2O)	OM %	Ca	Mg	K	Na	Al	TEB	CEC	B.S %
						meq/100 g							
Merina	5	Ap	0 - 12	5.5	.15	3.1	1.1	.07	.11	.1	4.4	10.1	43
		B1	12 - 40	5.3	.14	2.5	.7	.06	.10	.1	3.3	10.0	33
		B21	40 - 78	5.8	.06	1.5	.3	.04	.09	.1	2.0	19.2	10
		B22	78 - 125	6.6	.03	1.9	.3	.04	.16	.1	2.4	12.6	19
		II B3	125 - 150	6.8	.04	3.7	.7	.08	.25	.1	4.7	9.2	52
Merina	7	A1	0 - 17	5.9	1.02	2.6	.7	.07	.13	.1	3.5	20.0	17
		B1	17 - 44	6.8	1.04	4.3	.7	.09	.15	.1	5.3	18.4	28
		B21	44 - 78	7.0	.92	3.3	.8	.07	.22	.1	4.5	20.4	22
		B22	78 - 110	6.6	.89	3.9	1.0	.09	.21	.1	5.2	21.4	24
		II B3	110 - 150	6.5	.94	3.7	1.0	.08	.16	.1	5.0	20.2	24
Merina	11	A1	0 - 15	6.1	.26	.7	.2	.13	.07	1.6	1.2	1.8	68
		A3	15 - 35	5.6	.04	.6	.1	.16	.10	.1	1.0	2.4	45
		B1	35 - 60	5.3	.07	.5	.2	.07	.10	.1	.9	3.0	30
		B21	60 - 100	4.8	.18	.5	.1	.10	.11	.1	.9	2.3	41
		II B22	100 - 145	4.7	.16	.8	.2	.24	.11	1.2	1.4	3.1	47
		II B3	145 - 160	4.7	.03	.2	-	.08	.13	.6	.5	1.2	44

CEC = CEC by NH_4OAc method

VIII

Some chemical characteristics of the soils

Soil	Pedon	Horizon	Depth (cm)	pH (H_2O)	OM %	Ca	Mg	K	Na	Al	TEB	CEC	BS %
						meq/100 g							
Amanawa	12	A1	0 - 15	4.6	.04	.3	.1	.03	.14	.1	.5	1.5	38
		A3	15 - 40	4.8	.04	.8	.1	.03	.08	1.6	1.0	1.1	96
		B21	40 - 80	4.6	.01	.3	.08	.03	.06	1.6	.4	7.2	13
		B22	80 - 120	4.1	.02	.4	.08	.04	.06	1.8	.5	6.5	9
		B3	120 - 170	5.0	-	.4	.1	.04	.10	1.8	.6	4.9	13
Merina	13	A1	0 - 18	5.3	.73	1.6	2.7	.14	.15	.1	4.7	2.3	10[illegible]
		A3	18 - 56	4.9	.72	..8	.2	.03	.07	.1	1.1	1.4	84
		B21	56 - 98	5.0	.66	1.1	.2	.04	.09	.7	1.4	2.6	57
		B22	98 - 150	5.1	.71	3.9	.8	.13	.11	1.4	4.9	6.7	73
Merina	14	Ap	0 - 26	6.3	1.14	6.7	1.8	.18	.17	2.4	8.9	13.8	65
		B1	26 - 48	6.4	1.09	6.7	.8	.12	.15	.1	7.8	14.6	54
		B21	48 - 70	6.7	.97	6.5	.7	.19	.16	.1	7.9	15.8	50
		B22	70 - 140	6.8	.72	6.7	.9	.13	.15	.1	7.9	14.7	54

CEC = CEC by NH_4OAc method

Some chemical characteristics of the soils

Soil	Pedon	Horizon	Depth (cm)	pH (H_2O)	OM %	Ca	Mg	K	Na	Al	TEB	CEC
						meq/100 g						
Dange	15	A1	0 - 15	5.5	1.23	5.2	1.4	.08	.15	.1	6.9	8.2
		A3	15 - 40	5.7	1.53	8.5	2.3	.14	.28	.1	11.3	9.3
		B1	40 - 55	5.8	1.15	5.6	1.7	.13	.14	.1	7.6	8.7
		B21t	55 - 78	5.7	1.29	7.3	2.0	.13	.13	.1	9.6	10.9
		II B22t	78 - 150	6.0	1.16	6.7	2.0	1.0	.50	.1	10.3	12.0
Zafanadi	16	Ap	0 - 5	6.2	.27	2.3	.9	.07	.10	.1	3.4	4.2
		B1	5 - 30	5.6	.30	4.6	1.7	.10	.16	.1	6.7	8.4
		II B21t	30 - 52	6.0	.31	5.7	2.0	.09	.19	.1	8.1	12.2
		II B22t	52 - 90	6.2	.27							
Merina	17	A1	0 - 18	5.3	.24	1.2	.6	.04	.09	.4	2.0	3.4
		A3	18 - 36	5.4	.18	3.3	.6	.06	.17	.4	4.1	4.9
		B1	36 - 62	5.6	.12	1.5	.2	.06	.11	.1	1.9	0.3
		II B2	62 - 91	5.9	.16	2.7	.5	.07	.14	.1	3.4	0.2
		II B3	91 - 150	6.2	.09	2.6	.5	.10	.11	.1	3.5	0.4

CEC = CEC by NH_4OAc method

X

Some chemical characteristics of the soils

Soils	Pedon	Horizon	Depth (cm)	pH (H_2O)	OM %	Ca	Mg	K	Na	Al	TEB	CEC
						meq/100 g						
Zafanadi	18	A1	0 - 10	6.6	.83	8.1	1.2	.12	.17	.1	9.6	9.2
		B1	10 - 25	6.7	.37	9.7	.8	.10	.20	.1	10.9	11.7
		B21	25 - 62	7.1	.21	12.5	.5	.14	.23	.1	12.4	16.3
		B22	62 - 100	7.5	.11	16.5	.8	.16	.25	.1	17.8	18.8
		II C1	100 - 113	7.9	.06	54.6	2.9	.26	.75	.1	58.6	77.4
		II C2	113 - 130	8.0	.04	39.0	3.4	.42	.92	.4	43.8	55.4
Dange	19	Ap	0 - 11	6.5	.96	4.0	1.0	1.0	.15	.1	5.3	5.1
		B1t	11 - 26	6.3	.93	7.6	1.4	.12	.15	.1	9.3	6.2
		B21t	26 - 60	6.6	.76	5.4	1.0	.09	.25	.1	6.8	6.7
		II B22 t	60 - 100	6.7	.74	5.1	.9	.14	.17	.1	6.3	9.5

CEC = CEC by NH_4OAc method

X

Some chemical characteristics of the soils

Soils	Pedon	Horizon	Depth (cm)	pH (H_2O)	OM %	Ca	Mg	K	Na	Al	TEB	CEC
						meq/100 g						
Zafanadi	18	A1	0 - 10	6.6	.83	8.1	1.2	.12	.17	.1	9.6	9.2
		B1	10 - 25	6.7	.37	9.7	.8	.10	.20	.1	10.9	11.7
		B21	25 - 62	7.1	.21	12.5	.5	.14	.23	.1	12.4	16.3
		B22	62 - 100	7.5	.11	16.5	.8	.16	.25	.1	17.8	18.8
		II C1	100 - 113	7.9	.06	54.6	2.9	.26	.75	.1	58.6	77.4
		II C2	113 - 130	8.0	.04	39.0	3.4	.42	.92	.4	43.8	55.4
Dange	19	Ap	0 - 11	6.5	.96	4.0	1.0	1.0	.15	.1	5.3	5.1
		B1t	11 - 26	6.3	.93	7.6	1.4	.12	.15	.1	9.3	6.2
		B21t	26 - 60	6.6	.76	5.4	1.0	.09	.25	.1	6.8	6.7
		II B22 t	60 - 100	6.7	.74	5.1	.9	.14	.17	.1	6.3	9.5

CEC = CEC by NH_4OAc method

ABSTRACT

A reconnaissance soil survey at a scale of 1:50,000 was conducted in the Dange area of Sokoto State, Nigeria. The interpretation of aerial photographs was employed in the survey. The landforms were resolved into

(i) the high plain mantled by drift deposit

(ii) the high plain covered by an ironstone crust

(iii) the escarpment

(iv) the low alluvial plain

(v) the floodplain and

(vi) the bottomland liable to flooding.

The different landforms occur on different geological formations which in turn influence their characteristics.

Seven soil associations were delineated in the area. They are the Dange association which occurs on the high plain and its soils are classified as Chromic Luvisols or Plinthustalfs. The soils of the Zafanadi

association occurs on the escarpment and are classified as Plinthic Luvisols or Plinthustalfs while the soils of Merina association which occurs on the lower plain belong to the Plinthic Gleysols or Fluventic Ustochrepts. Soils of the Amanawa association occur on the raised level grounds on the lower plain and are classified as Eutric Regosols or Typic Ustipsamments. The soils of Bela association occur on the river floodplain and are classified as Eutric Fluvisols or Mollic Psammaquents while the soils of the Tuda association which occupy the seasonally flooded valley bottomland are classified as Plinthic Gleysols or Mollic Haplaquents. The Dutse association are massive, indurated ironpan crust covering the small isolated flat-topped hills or mesas found on the lower plain.