OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE, NIGERIA.

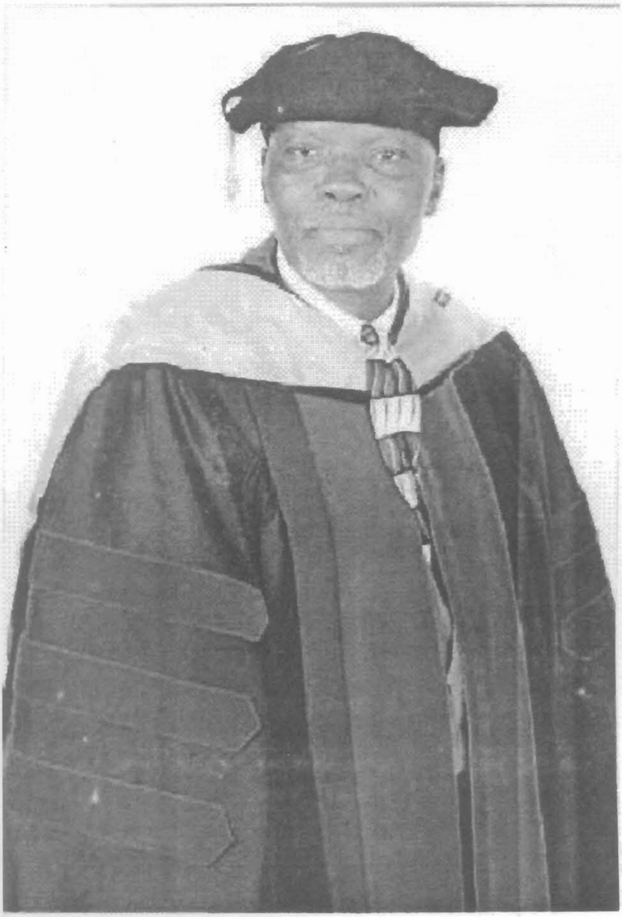
Inaugural Lecture Series 237

SUSTAINABLE LAND USE: Pedology Perspective

By

Temitope Abayomi OKUSAMI
Professor of Pedology

OBAFEMI AWOLOWO UNIVERSITY PRESS LIMITED.



Temitope Abayomi OKUSAMI
Professor of Pedology

SUSTAINABLE LAND USE: Pedology Perspective

By

Temitope Abayomi OKUSAMI
Professor of Pedology

An Inaugural Lecture Delivered at Oduduwa Hall,
Obafemi Awolowo University, Ile-Ife, Nigeria
On Tuesday, 22nd February, 2011

Inaugural Lecture Series 237

Obafemi Awolowo University Press Limited
Ile-Ife, Nigeria.

ISNN 0189-7848

Printed by
Obafemi Awolowo University Press Limited
Ile-Ife, Nigeria.

Mr. Vice-Chancellor, the Registrar, distinguished colleagues and friends, and dear students,

PREAMBLE

David Gauntlett (http://www.artlab.org.uk/inaugural.htm; June 2004) introducing his inaugural lecture wrote;

> "Not everybody is born with the knowledge of what an inaugural lecture is, of course, I asked around and looked it up in my dictionary. My dictionary, the one that sits beside my desk says this: 'marking a beginning,' which I thought was quite nice."

The challenge here is that you have to give an inaugural lecture to have the "knowledge of what an inaugural lecture is". You also have to give one to have a beginning or probably a shift in paradigm with regards to your research or making a new beginning in thoughts of ongoing research or start a new line within the same discipline or start now looking at policy statements to actualize what one considers as a follow up to years of academic pursuit.

Mr. Vice-chancellor, it is in the context of all the above but with emphasis on the latter that I view the giving of my inaugural lecture.

I welcome you all to this inaugural lecture and to follow the recent numbering by my colleagues from the Department of Soil Science and Land Resources Management (previously Department of Soil Science), the 7th from the Department.

DEFINITIONS

(i) Sustainable (ity)

Sustainability has taken on an image of everyday use that it may lose its meaning/value to the extent that it may not connote the seriousness in management that the word requires. I was recently browsing for information when I ran into a Springer page (the language of science, [http://

www.editorialmanager.com/sust/mainpage.html] which exclaimed!:

> "Welcome to the Online Manuscript Submission, Review and Tracking System for the Journal, Sustainability Science",

indicating the significance of the word sustainability for the "giant" publisher to have initiated an online international journal probably in line with the conclusion reached by participants at a meeting in Sweden (McCarthy and Dickson, 2000) which stated that promoting the goal of sustainability requires the emergence and conduct of the new field of sustainability science.

At the institution level, the United Nations University Institute for Sustainability and Peace became operational on January 1, 2009 and it was

> "to create trans-disciplinary synergies that can more effectively address pressing global problems of human survival, development and welfare" (http://isp.unu.edu/).

This is the cynosure of the science of sustainability.

Still on the meaning of sustainability, Tiessen and Anderson (1992) gave two definitions:

- Stable, continuing production without degradation of the supporting ecosystems, and
- Increasing production to sustain the increases in human populations, i.e. "sustainability" with a built-in growth factor.

  The authors concluded that sustainability can therefore not be achieved with land management alone, but requires major efforts to control the growth of consumption and populations. Land management is a focus of this inaugural with the assumption that the socio-economic aspect will be under control. The evolution in Global Sustainability issues as perceived by Will Steffen et al., (2001) is inter-disciplinary but with a need to have

- A sound disciplinary base of science; and
- Clear scientific questions to guide us towards integrated solutions beyond disciplinary boundaries

Pedology as a science fulfills these two requirements as stated above.

(ii) Land Use

Land use in its simplest form describes how a land is used for a purpose. The term "Land Use" is multidisciplinary and sometimes assuming an unhealthy competition between the different disciplines. It transcends the disciplines of soil science/agriculture, geography and the environmental sciences.

Under the "Glossary of Statistical Terms" (http://stats.oecd.org/glossary/detail.asp?ID=6493), it is defined-

> "Land use is based on the functional dimension of land for different human purposes or economic activities. Typical categories for land use are dwellings, industrial use, transport, recreational use or nature protection areas".

A look at the 'Source Publication' for this definition indicated that the sources consisted of institutions such as – United Nations, European Commission, International Monetary Fund, Organisation of Economic Co-operation and Development, World Bank, Handbook of National Accounting, and Integrated Environmental and Economic Accounting. That agriculture does not constitute a category is therefore not surprising since the above institutions are all about fiscal growth with all the financial derivatives subsumed.

In the foreword to the Monograph, "Planning the Uses and Management of Land", [Edited by M.T. Beatty, G.W. Petersen and L.D. Swindale (1979)],

> "land is virtually the sole source of our sustenance because it supports the plants and animals providing our food, fiber, and shelter. It is the watershed or reservoir for our water

supply. Also, land provides the minerals we use, the space in which we build our homes, communication systems, and the other elements of our economic infrastructure as well as a source of pleasure and satisfaction which we derive from our environment – the things we see, hear, and touch everyday. In addition, land is the receptacle for our waste; it helps hide and correct some of our mistakes".

This description of land, in juxtaposition (for clarification), should be read in conjunction with the words of Gibbs (1966) that.

"soil is the flesh and blood of land and cannot be omitted from assessment of land as a resource for human requirements. However, land is a wider concept than soil and a practical assessment of it must also include consideration of geographic and economic aspects. Those aspects are man-made, and as the range of their effects is commonly circumscribed by soils, it is appropriate to begin a land assessment with the soil factor".

The missing aspect (in the definition as contained in the Glossary of Statistical Terms as defined earlier) is therefore the geographic component. An apology on behalf of the latter could be rendered for possibly/probably subsuming agriculture under dwelling (typical category) or what else? OR for not singling out agriculture as a "typical category".

It can thus be concluded that land is a composite of soils, water (the hydrology), the microclimate – close to the surface of the land-and the biosphere and that the concept of Land Use is actually that of the Soil Use as modified/conditioned by the water, the microclimate and other appropriate environmental factors such as the rocks that may influence the use or usefulness of the soil (land).

(iii) Pedology

Pedology [Pedos, Greek word for soil, earth; logy – a combining form meaning (1) (specified kind of) speaking, (2) Science, doctrine, or theory of (biology, geology)] is considered to be the study of soils in its natural form or state.

Sensu Stricto, Pedology is the study of the origin of the soil, its description and its classification. Buol et. al. (1973, p.3) quoting from other sources (Editorial Staff 1940; Gibbs 1955; Leeper 1953, 1955; Northcote 1954) claimed that the word "pedology" has been used both as a synonym for soil science (Sigmund 1938) and as another name for soil genesis (Vilenskii 1957). However in its modern form, Soil Science Society of America for instance has categorized Pedology as consisting of

> "soil formation and geology, physical and chemical properties, soil survey and mapping, and interpretation of soil behaviour".

(iv) Inter-relatedness of all the Above

The relationship between the above defined variables could be summarized in the words of Cremens et. al., (1994, p.ix) as published in the preface to the publication "Whole Regolith Pedology":

"Traditionally, in pedology the focus has been on the soil survey and the information requirements of the soil survey. Soil genesis studies have often been used to develop predictive models to aid the soil survey effort, and to supply information for use in the development of management strategies for the mapped soils."

WHY STUDY SOILS?

(i) What is Soil?

> "Soil-Earth's living skin". (Planetearth, 2005).

To develop the concept 'soil' for this lecture, I will have to again quote from Gibbs (1966) which stated:

> "soil is the flesh and blood of land and cannot be omitted from assessments of land as a resource for human requirements",

be it agricultural or non-agricultural.

On the back cover of the National Geographic issue of September 2008 is a picture showing the cross section of the topsoil horizons and a plant with its root system with the title "WHERE FOOD BEGINS". In this issue is a section on "Our Good Earth. The future rests on the soil beneath our feet. Can we save it?" (National Geographic 2008, P.80-111). Thus it has been demonstrated with preceding phrases/statements that soil is an element most needed (in terms of priority) for human survival.

Because this discourse is about pedology's role in sustainable land use, the pedology's concept of 'what soil is' is apt and should be discussed or given. Historically, the concept/definition of soil started with the idea of soil as just a medium for plant growth (i.e. as source of plant nutrients), then as weathered rocks and in the modern context as a natural body that occupies the landscape. This latter concept has been attributed to the Russians led by V.V. Dokuchaev (1846-1903) who in the nineteenth century found that the soil of any particular location is a function of the combination of soil forming factors (parent material, climate, organisms, relief, and time) dominant in the environment. Jenny (1939, in Crocker 1967) later quantitatively gave expression to this concept through his famous equation that formalized the relationship between soils and the factors in their formation:

$$S = f(o, p, r, cl, t)$$

Where s = any soil property, o = organism, p = parent material, r=relief/ topography, cl = climate, and t = age of the system. Crocker therefore indicated that the equation can be re-written as

$$S = Soil = f(o, p, r, cl, t)$$

It is this equation that controls the dominant soil forming processes (physical and/or chemical and/or biological) acting on the parent materials that could be igneous/metamorphic/pre-weathered sedimentary rocks or their derivatives which eventually resulted (or result) in soils that occupy the landscapes or soil-scapes (to use Buol et al's.,[1973] terminology).

I love the definition of soil as given by Joffe (Jenny, 1941) which stated that soil is a dynamic natural body of mineral and organic constituents, differentiated into horizons, or variable depth, which differ from the materials below in morphology, physical make-up, chemical properties and composition, and biological characteristics. And this can be studied only in the field in a progression as shown in the diagram (Fig. 1) of Buol et al. (1973, p.23) – the opening up of the earth through the soil profile or better through the soil pedon to have a better information on the variability that characterizes the soil individual (polypedon).

The polypedon represents a soil unit on the landscape and represents what constitute a mapping unit in a soil mapping programme.

12

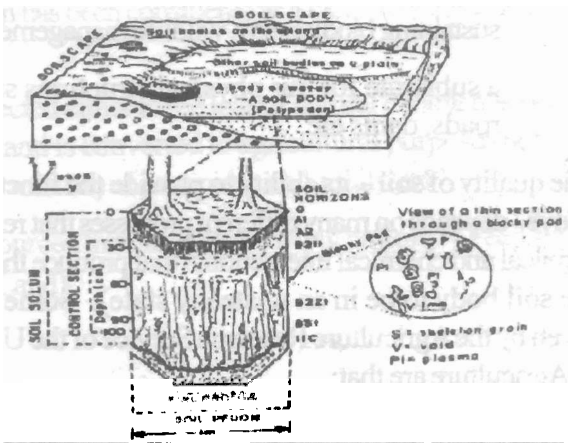


FIG. 1 Soil pedon and profile
Source: Buol et al., 1973

The concepts/paradigms peculiar to pedology consist of or are enveloped around:

Soil Formation:

- Factors: Dokuchaev,1846-1903;Jenny, 1941.
- Processes: Simonson, 1958., and

Soil Body (ies) -Dokuchaev, 1846-1903

(ii) <u>Soil: Renewable OR Non-Renewable Resource?</u>

Soils are studied to know their properties/characteristics needed to understand their reactions to an intended use and therefore manage/protect them for sustainable use:

- Soil is a key resource for mankind, vital to the environment and for societies across the world and with the following functions:
  - as substrate in which to grow food and fibre
  - transforming and recycling of wastes and pollutants

    sustaining biodiversity, wildlife management and

    a substrate for our physical structures such as houses, roads, dams etc.

- The quality of soil – its ability to provide the functions described above - depends on many different processes that reflect biological, physical and chemical interactions (that produce the soil and make the soil body to be in an unsteady state). Some of the facts as given by the Agriculture Research Service of the U.S. Department of Agriculture are that:

    soil is the largest natural resource

    it takes 100 to 600 years, or more to form an inch (~ 3cm) of the topsoil (wind and water erosion can take away much more than this in a single year). (Soil making processes are notoriously slow, requiring from 200 to 1000 years to form 2.5cm of topsoil under normal agricultural conditions [http://www.wri.org]).

It can therefore be concluded that soil is a NON-RENEWABLE NATURAL RESOURCE especially with reference to recent rate of degradation (especially that of loss).

(iii) Concern about the Health of Soils:

a. Aggravating Factors

Hazards to sustainable land use include erosion, rock outcrops, shallow soils, gravelly surface soils (i.e., physical degradation factors) and other forms of chemical and/or biological degradation. In Ratan Lal (1999), the accompanying figure (Fig. 2, modified) in his article on "World soils and the greenhouse effect" brings attention to the types of degradation and the accompanying consequences.

Soil degradation has been considered as a factor (for adverse environmental impacts)

> "connected either to the loss of natural habitat that occurs when land is converted to agricultural purposes or to the use (or misuse) of pesticides and fertilizers"

(In World Resources Institute [http://www.wri.org] - Feeding the World: Disappearing Land).

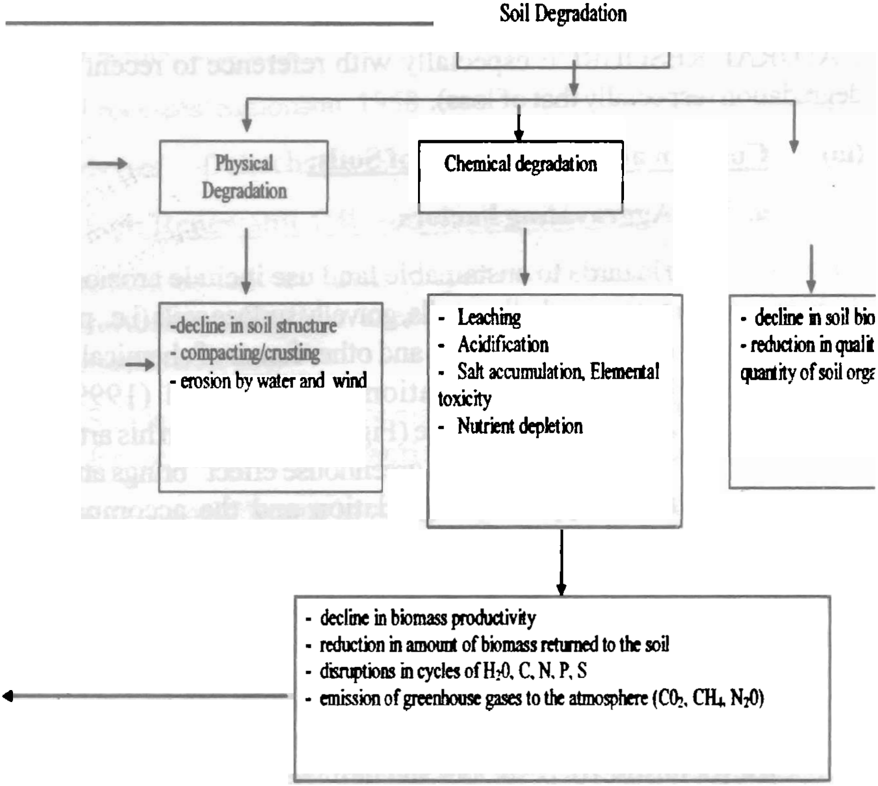


Figure 2: Soil Degrading: types, processes and consequences (result). (Modified after Ratan Lal, 1999).

The United Nations Environment Programme (UNEP 1997, cited in http://www.wri.org/node/8426/print) estimated that from 1990 an additional 5 million to 6 million hectares are being lost to severe soil degradation annually. World Resources Institute (WRI, 1992 in http://www.wri.org) attributed the causes of degraded soils to

- vegetation removal
- agricultural activities
- over-exploitation
- industrial and bio-industrial, and
- overgrazing

b. Unsustainable Land Use: Consequences

Unsustainable land use is the greatest aggravating factor and may result either from

- Inappropriate use of the land (i.e, wrong match between land (soil) characteristics and land use requirements), AND/OR
- Poor land use management practices

In either case, the results are the degradation or reduction in quality of any of the resources – air, water, land, habitat (biomass), and the communities – of the earth.

Writing under the title "Drivers of unsustainable land use in the Semi-Arid Khabur River Basin, Syria", Frank Hole (2009) wrote in the abstract:

> "The semi-arid zone of Southwest Asia, known as the Fertile Crescent, is under unprecedented stress because of agricultural development. Where rain-fed agriculture and transhuman herding had prevailed over ten millennium, today intensive cultivation with irrigation threatens future sustainability. A number of interconnected, but uncoordinated drivers of change combine to shape the

> landscape and its future, and their changes make it hard to anticipate future requirements and opportunities, as well as to implement policies whether by local stakeholders or at the national level. Among the factors that comprise the socio-natural systems are (1) climate, (2) water and soil resources, (3) history of land use, (4) social, economic and political factors, (5) infrastructural developments, (6) interstate impacts, and (7) legacies of the past........".

Although a Semi-Arid zone, the factors indicated as drivers of unsustainable land use seem to be at play in Nigeria for all its agro-ecological zones. In other words, we are currently faced with all the above, although there is dearth of empirical data/documentation as evidences of unsustainable land use in Nigeria.

Another historic case study is the impact of the combined effects of misuse of land and climate on sustainability as witnessed in the Dust Bowl of the 1930s in the United States of America (Regional Climate Impacts. Great Plains – The Dust Bowl: Combined Effects of Land Use and Climate, P.125):

"over the past century, large-scale conversion of grasslands to crops and ranchland has altered the natural environment of the Great Plains. Irrigated fields have increased evaporation rates, reducing summer temperatures, and increasing local precipitation.

The Dust Bowl of the 1930s epitomizes what can happen as a result of interactions between climate and human activity. In the 1920s, increasing demand for food encouraged poor agricultural practices. Small-scale producers ploughed under native grasses to plant wheat, removing the protective cover the land required to retain its moisture. Variations in ocean temperature contributed to a slight increase in air temperatures, just enough to disrupt the winds that typically draw moisture from the south into the Great Plains. As the intensively tilled soils dried up, topsoil from an estimated 100 million acres of the Great Plains blew across the continent. The Dust Bowl dramatically demonstrated the potentially devastating effects of poor land-use practices combined with climate variability and change. Today, climate change is interacting with a different set of poor land-use practices. Water is being pumped from the Ogallala aquifer faster than it can recharge. In many areas, playa lakes are poorly managed. Existing stresses on water resources in the Great Plains due to unsustainable water usage are likely to be exacerbated by future changes in temperature and precipitation, this time largely due to human-induced climate change".

The above is similar to a scenario that is gradually building up in the drier savanna part of Nigeria but with the combination of rainfall and wind, and agricultural land use techniques as the driving agents.

It is being tackled by the growing of trees as shelter belts and cover plants against wind erosion and water erosion respectively.

Some excerpts from the Federal Department of Agriculture and Land Resources (FDALR, 1982) pinpoint the problems and consequences within Nigeria: FDALR (1982, p.114) wrote:

> "Soil erosion occurs throughout Nigeria. Without adequate control on land use activities that predispose the soil to erosion, our land, which is an invaluable national

asset will be severely degraded with consequent losses in agricultural production and productivity."

In Ofomata (1982, p.120),

> "Man needs the soil for his cultivation and has to clear the land for farming. He also burns the grass and trees and has need to graze the animals. Each of these activities leads to exposing the soil to the elements and, invariably, to accelerated soil erosion and deterioration, depending on the existence of other favourable conditions. These other factors include climate, topographic disposition and lithology, especially the nature of surface material".

Ofomata (1982, p.119) clearly showed in his review that the study and awareness on erosion and anti-erosion measures were not new to Nigeria as of early 20th C especially concerning the situations within the forest zone. The author reiterated that

> "The Udi Forest Reserve was created in 1922, followed by an Anti-Erosion Plantation, also at Udi, in 1928 (Sykes, 1940), all aimed at combating the nefarious effects of soil erosion."

He cited other contemporary works of Stamp (1978) and Sada and Omuta (1979). Nevertheless, soil erosion in its different forms is still a menace as a critical accessory to soil degradation in Nigeria.

As part of the recommendation on the topic

> "Use and Misuse of Nigeria's Agricultural Land Resources", Ofomata (1982, p.128) advised: "Finally; .... due to erosion and increasing demand made on the land by agriculture, urban growth, industrialisation and other human activities make the need for integrated landscape planning urgent. What is required is the creation of a forum where thought should be harmonised and an adequate strategy

formulated to conserve our land resources through a coordinated and sustained land-use programme".

As a pedologist I had, in the past years, participated in such National fora as suggested by Ofomata:

- National Workshop on Enhancing Research and Development in Agriculture and Forestry towards Poverty Alleviation and Rural Development in Nigeria. Forest Research Institute of Nigeria (FRIN). 14th–18th February 2000.

  Discussant: Perspective on Land Use and Soil Management Practices for Sustainable Agricultural Development.

- USA-Nigeria Soil Survey Workshop. Abuja, Nigeria. February 27-28. 2002.

but still awaiting a national implementation call towards actualising the desire of the convening government agencies to formulate and actualise the agenda that will move us towards efficient land use.

International concern for efficient land use also held fora with relevance to Africa, nay Nigeria in which I have also participated:

- NATO Seminar on Land and its Uses: Actual and Potential-An environmental approach. Edinburgh, Scotland. September 10-October 1 1982.

  International Workshop on Multipurpose Use of Soil Survey Information for Efficient Land use. March 12-20, 1989. Nairobi. Kenya.

Abundant evidence exist on the field indicating that soil degradational processes are actively at work and there is currently no policy at any tier of governance to arrest such hence erosion /deposition surfaces continue to exist on our landscapes (Okusami et al., 1983). This had led to the exposure and subsequent hardening of some of the soils with these phenomena most rampant in the Derived/Southern Guinea Savanna of Nigeria (Okusami, observation). The soils on the lower slope positions show deeper sand lithology as evidence of greater colluvial deposits resulting from accelerated erosion. Apomu series as described by Smyth and Montgomery (1962) is a typical example [resulted from such erosion-deposition process - Dystropepts in Erio sequence (Okusami, 1991) and Ustic Quartzipsamments/Aquic Quartzipsamments in Ilero sequence (Table 1)]. This sometimes, as in Ustic Quartzipsamments, increases the depth of the groundwater to the surface, thus removing the advantage of the lower slope/bottom landforms for rain-fed rice or dry season location for vegetables, spices and other uses.

Studies initiated to characterize the status quo of land use on the landscapes of the savanna in Nigeria are at the preliminary stage. However, the accompanying figure (Fig. 3, an example) confirm the deteriorating stage of our forest lands as exemplified by the systematic removal of trees without replanting, thus exposing the land surface to erosion.

Table 1: Comparison of depositional surfaces on selected toposequences in South Nigeria: Evidence of erosional degradation

Horizon	Depth (cm)	Sand %	Silt %	Clay %	Texture
Ap	0-12	73	13	14	Sl
CA	12-35	75	11	14	Sl
2BC	35-65	78	5	17	Sl
3Bt	65-105	52	6	42	Sc
3BC	105-160	44	7	49	Sc
3C	160-200	50	9	41	Sc

Location: Eiye Watershed/Erio-Ekiti/Itawure

Ecology: Forest/Quartzite Ridge

Classification: Apomu Series
Fluventic Dystropepts

Slope: 4%

Source: Okusami 1991

Horizon	Depth (cm)	Sand %	Silt %	Clay %	Texture
A1	0-5	81	7	12	Is
A2	5-35	83	5	12	Is
A3	35-45	87	2	11	Is
C1	45-90	87	2	11	Is
C2	90-140	87	2	11	Is
C3	140-190	88	0	12	Is

Location: Ilero

Ecology: Derived Savanna/Pre-Cambrian

Classification: Shante/Apomu Series
Ustic/Aquic Quartzipsamments
Haplic/Gleyic Arenosols

Source: Okusami (unpublished)

Ap	0-20	74	10	16	Sl
A21	20-58	78	8	14	gsl
A22	58-70	62	7	31	gscl
Bv	70-120	54	12	34	Scl

Location: Teaching & Research Farm, OAU,Ile-Ife

Ecology: Cocoa Farm/Moist Forest –drier forest transition ecotone

Classification: Apomu gravelly
Petroferric Plinthustult
Plinthic Acrisols

Slope:

Source: Okusami (unpublished)

Apl	0-30	78	18	4	Ifs
Ap12	30-37	82	14	4	Ifs
A13	37-47	90	8	2	fs
2A1	47-56	81	20	3	Ifs
2B11	56-90	80	13	7	Ifs
2B12	90-110	86	8	6	Is
2B12	90-110	86	8	6	Is
3B23	130-152	61	9	30	Scl

Location: 4-5 kms South of River Osara directly off the Okene-Kaduna Road

Ecology: Derived Savanna/Southern Guinea

Classification: Apomu Aquic Ustifluvent

Slope: 1- 2%

Source: Okusami et al. 1983

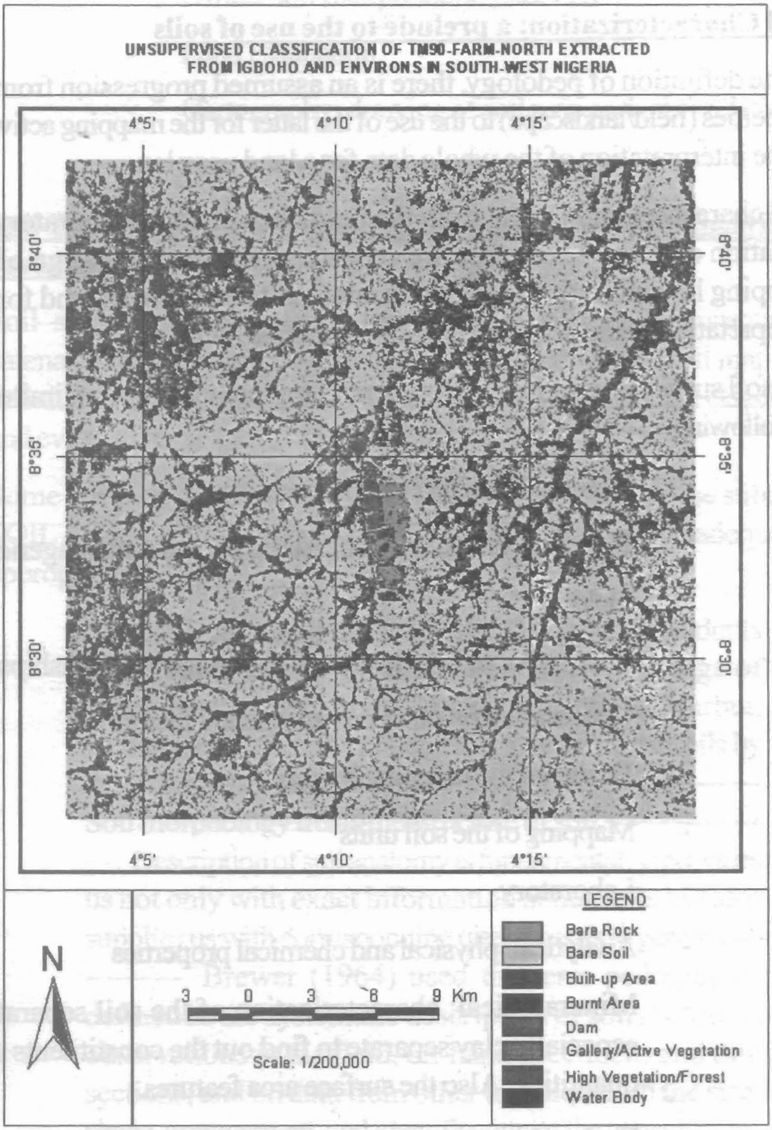


Figure 3: Unclassified Digital Image of Landuse type

SOIL DATA NEEDS TOWARDS SUSTAINABLE LAND USE

Soil Characterization: a prelude to the use of soils

In the definition of pedology, there is an assumed progression from the properties (field/landscape) to the use of the latter for the mapping activities to the interpretation of the whole data for a land use plan.

Soil characterization starts from the field, then on to the laboratory for collation of data. These data are very important for the design of the mapping legend (index to the delineated units on the map) and for the interpretation of the mapping units for a possible land use.

In a soil survey programme, characterization includes but not limited to the following:

· Remote Sensing / GIS Laboratory

- Inventory and analysis of Aerial photos and Imageries

· Field

- Research into (Study of) soil-landscape relationships
- Observation on other environmental factors
- Design of the mapping legend
- Mapping of the soil units

· Laboratory

- Analytical: physical and chemical properties
- Mineralogical: characterization of the soil separates; especially clay separate to find out the constituents and quantities. Also the surface area features.
- Engineering
- Soil - water relationships
- Climate

- Office/Soil Interpretation Laboratory:
  - Land Evaluation
  - Cartography: drawing of soil map and other related maps
  - Report Writing

Soil-Landscape Relationships: Mapping Units Delineation: Its Paradigm

Soil–slope sequence concepts (popularly identified as toposequence or catena concepts) continue to dominate the research into soil map legend definition and the basis for the insight into soil delineation, soil classification and evaluation.

Some quotes from Buol (1973, 11) in his writing under the subtitle "A SOIL AS AN ANATOMICAL SPECIMEN" may just be adequate and appropriate:

> "Just as Louis Agassiz (1809-1873) taught his students to learn about fish by making accurate drawings of specimens of fish, so Dokuchaev, Hilgard, Marbut, Kellogg, and others have taught us to learn about soils by describing them carefully (Marbut, 1935). ————— Soil morphology treats the structure of soil ————. Description of soil anatomy is fundamental. It provides us not only with exact information about soils but also supplies us with corresponding questions as to genesis —————. Brewer (1964) used the term pedography, defined as the systematic description of soils based on observations in the field, on-hand specimens and thin sections, and on data from other techniques on the size, shape, arrangement, and identification of the constituents."

To achieve the above, the best concept/paradigm is that of soil-slope sequence which allows access to the variabilities in soil morphology and therefore other derivative soil attributes. Soil-slope relationships on a landscape has been the cornerstone of pedological investigations into soil types of any geographic area (Okusami and Oyediran, 1985).

The soil-slope relationships could be due to the resultant impact/influence of the dominating soil forming factors thus we have the climosequence– climatic factor, biosequence – organism/vegetation factor, hydrosequence – landscapes exhibiting influence of topography induced wetness, lithosequence – parent material influence, and chronosequence – age factor (influence of time since time zero of the deposition of the parent material).

Hydrosequence – be it toposequence or catena – is of greater interest to us in Nigeria, being part of the African shield that has been stable outside the glacial zone (past or present). Sometimes this influence could be aggravated by the type/origin of the parent materials.

The toposequence/catena concept has been the basis of the study of soils of Nigeria. It has been the basis for the broad classification of soils into Soil Association as defined and described in Smyth and Montgomery (1962) and Moss (1957).

My study of soils, directly or indirectly (i.e., projects/theses supervision, or even giving assistance to colleagues), has taken me through the different agro-ecologies of Nigeria. Always, it started with the study of the soil-sequence on the landscape or the soil-landscape relationship.

A glimpse into some of the studied soil-slope relationships:

- **The Coastal Plains consist of the following:**

(i). The Lower Coastal Plain, variously described as 'the coastal plain sand' or 'acid sand' or 'coastal plain acid sand' (Okusami, 1996), occupies mostly the beach ridge sand adjacent to the Atlantic Ocean. The dearth of data on the properties and distribution of soils located on these coastal sand landforms has been described as

> "certain gaps in the classification will also be obvious, and cannot be filled until work has been done in the large areas of Benin, Ijebu and Delta provinces still unsurveyed" (Moss,1957 p.2)

and has therefore made it very challenging to study. The least variable of the properties were found to be the sand content, pH and base saturation. Other attributes are as shown in Figure 4(i). This study has contributed to the filling of some of the gaps referred to above and the proper distinction of these soils from the hitherto wrongly labelled upper coastal plain soils as coastal acid sand soils.

(ii) The upper coastal plain – Igbodu-sequence (Fig.4ii)–consists of landscapes formed in Tertiary sediments. A strong relationship between physiography/elevation and soil types exists on the upper coastal plains. Crestal positions are almost level and possibly indicative of past erosional surfaces and/or static ground water positions. These were plateau-like with that at 15m most dominating. In valley fringe positions, the presence of charcoal fragments at greater depth suggest colluvial origin - a pointer to the erosion-deposition cycles that this region has experienced and potentially will experience if the land is mismanaged. Soils were mostly sandy clay/sandy clay loam, very strongly acid (pH4.50-5.00) with low cation exchange capacity. Exchangeable Al constitutes >50% of the exchangeable cations in most subsoil horizons (Okusami, 1997).

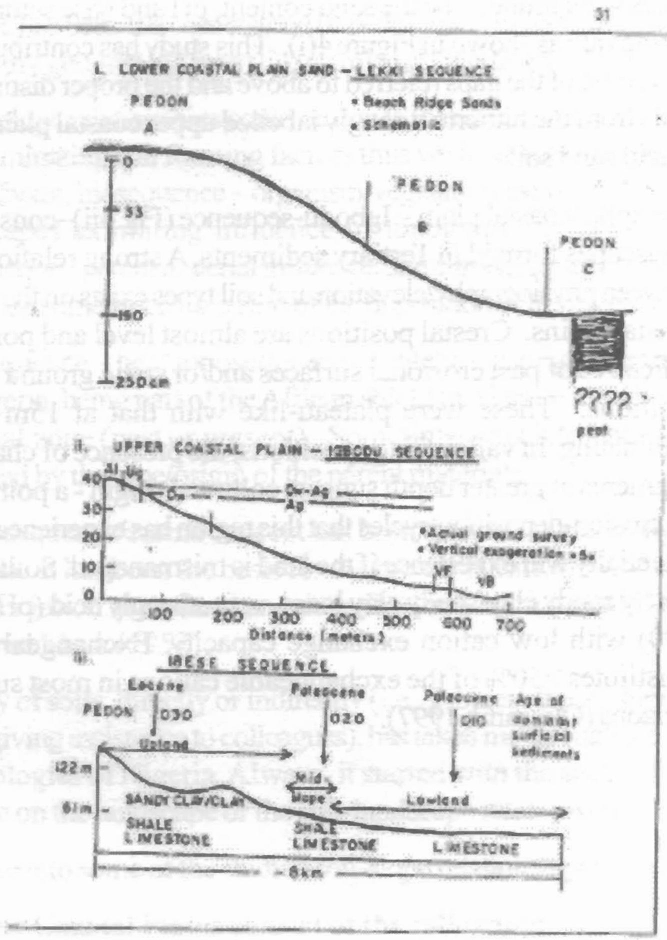


Figure 4. Soil-landscapes on Coastal Plain of South West Nigeria

Figure 4. Soil-landscapes on Coastal Plain of South West Nigeria

(iii). West of the above location is what is named Ibese-sequence of soils (Fig 4iii) (litho-sequence or chrono-sequence?). It was a simple sequence but with four land surfaces (Okusami, et al. 1985). The upper two (above 61m elevation) were formed in sandstone parent materials while the latter (<61m) formed in colluvial–shale and colluvial-limestone materials respectively. The mineralogy suite (Fig. 5) is very instructive of the differences (variabilities) in the soil mantles. The soils formed in sandstone have a dominant clay mineralogy of kaolinite, goethite and quartz. Soils formed in shale materials have a mixed clay mineralogy of smectite and kaolinite with depth. Those formed in colluvial/limestone material have a dominant kaolinite clay mineralogy with some subsoil smectite. Parent material and soil moisture play dominant roles in the direction of weathering. Another contribution to the lithology (horizontal and vertical) of soils on the coastal lowlands of Nigeria.

Similar landforms were observed (exist) along the Abakaliki-Ogoja road and similar locations in Southeast Nigeria (Okusami et al. 1985).

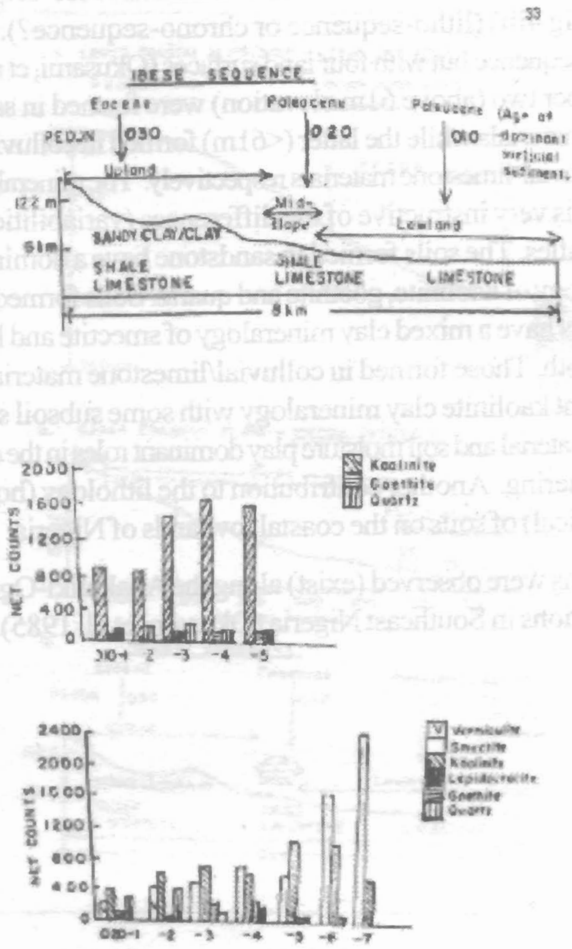


Figure 5. Soil Landscape- Soil Mineralogy for Ibese Sequence

Figure 5. Soil Landscape- Soil Mineralogy for Ibese Sequence

The pre-Cambrian formation exhibits the most variable soil-slope relationships.

(i) Erio-sequence (Fig.6) formed essentially in quartzite (with intrusion from mica schist) derived parent materials. The soil-slope sequence was studied through a 1,026m long transect with an elevation difference of 198m. Slopes on which soils form range from 2%-20%. The landscape is hilly and rolling with the middle-slope segment constituting the greatest percentage of the different physiographic units (Okusami, 1991). Soils on the upper slope (summit/crest, shoulder) and upper middle slopes were shallow. This study (Okusami 1991) established the relative position of Ipele series (Typic Eustrustult/Rhodi-Haplic Ferralsols) of Okemessi Soil Association on the sequence of soils since Smyth and Montgomery (1962, p.148) were not sure of its

"exact topographical relationships although they were confident that this series is confined to lower slope sites".

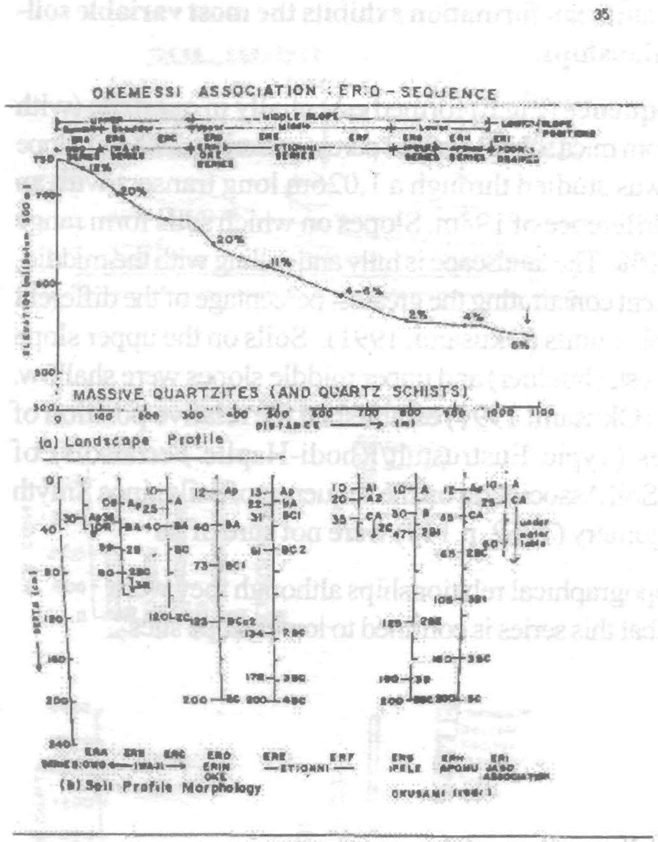


Figure 6. Erio Sequence: Soil Landscape Formed in Quartzite/Quartzschist-Okemesi Soil Association

Figure 6. Erio Sequence: Soil Landscape Formed in Quartzite/ Quartzschist-Okemesi Soil Association

This established position is a very relevant information and useful in soil mapping and soil survey interpretation studies. The classification of soils attest to the variabilities of the landforms and the corresponding soils-soils vary from Entisols/Inceptisols on the moderately steep upper slopes through Oxisols in the middle slope and Inceptisols/Entisols on the lower slope positions.

My participation at the 1994 (15th) and 2006 (18th) World Congresses of Soil Science (WCSS) gave me opportunities to present more data (Okusami, 1994, 2006) on soils of toposequences as studied on variable parent materials formed in the Basement Complex as discussed below:

(ii) Ilero-sequence:

a toposequence of soils possibly in irreversible soil degradational phase/ processes. The sequence represents the consequences of denudational processes in the forest – savanna mosaic ecology of southwest Nigeria. The landscape typified, generally, a degraded landscape exhibiting all forms of degradation: in upper slope areas, exposure of plinthites turned petroplinthites, and exposure of the subsoil B horizons; acid soil development: poor soil nutrient due to excessive leaching; reduced iron (Fe^{2+}) that may lead to iron toxicity at seepage points; greatly reduced vegetation cover with fire resisting species dominating (Illoh, unpublished data).

The above situation reflects land degradational processes similar to those observed by Gicheru (1966) in Kenya with the following causative factors: deforestation, overgrazing, soil types, footpaths and cattle tracks and low level of conservation practices. Except of course that zero level of conservation practices operate in Nigeria's rural lands.

Landscapes with evidences of past and continuing erosion have also been studied and highlighted. These include the soils on erosional topo-sequence in the Guinea savanna of Nigeria (Okusami et. al. 1983); the previous discussions on quartzite derived materials (Okusami, 1991). In all instances, the lower slope positions showed multi-layered soil regolith of the type of Apomu series (Quartzipsamments/Ustifluent/Dystropepts) and in some cases accumulated rubbles (quartz, concretional and broken petroplinthites) as evidences of depositional and erosional surfaces respectively.

(iii) 1FE sequence: This consists of landforms derived from Biotite Gneiss origin (a normally very weatherable rock because of its biotite content) consisting mainly of quartz >>> biotite > magnetite > orthodate feldspar (and garnet) primary minerals (some products of metamorphism).

The following is a synopsis of significant observations made on the landscape:

- Shallow depth of soil development even at the upper slope position transition to the crestal position (shoulder) where the soil sits on a rock at an average depth of 75cm.
- there also was a rock outcrop just on the land surface.
- above indicate resistant portions of the rock-vital information derivable only from soil survey activities
- clay mineralogy is found to be physigraphic dependent:
    - upper slope position (Figure 8): commonly kaolinite, feldspars, goethite and anatase,
    - middle slope position commonly illite and/or muscovite mica, and the
    - valley bottom and /or fringe (Figure 9): commonly smectite and Vermiculite,

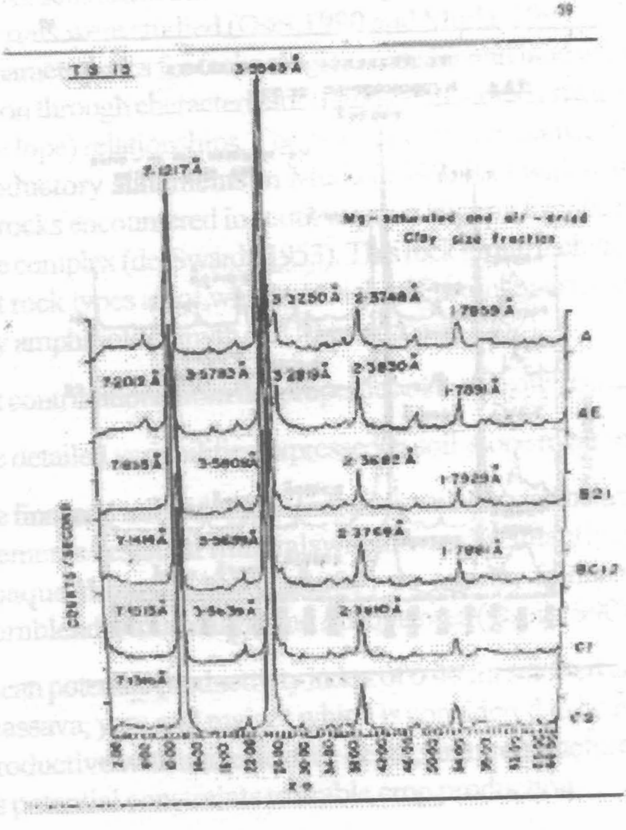


Figure 8. Clay Mineralogy in a Crestal Slope Position- Egbeda Series

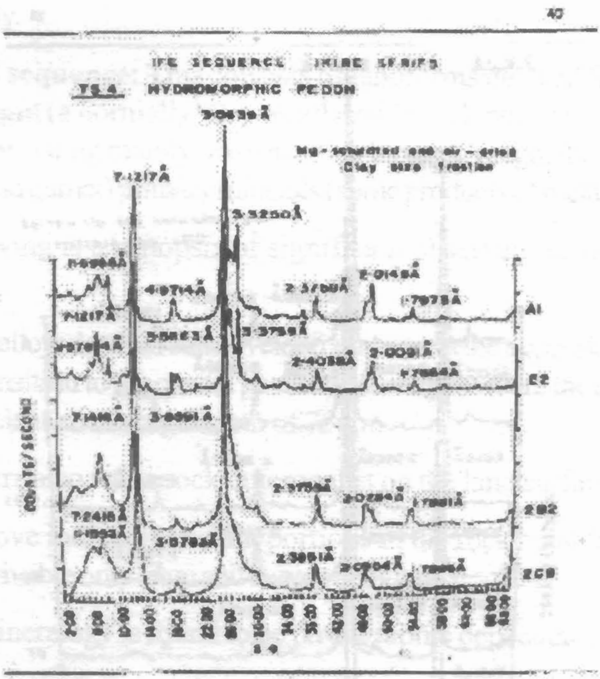


Figure 9. Clay Mineralogy in a Valley Bottom Soil Profile

iv Itagunmodi sequence:

In conjunction with my postgraduate students, the soil-landscapes relationships of soils formed in ultramafic (amphibolites) parent rock derived parent materials were studied (Osei,1990 and Muda, 1999) to bring out the soils' characteristics for technological transfer and land use potential determination through characterization studies anchored on the soil-slope (soil series-slope) relationships. The essence of this sequence is captured in the introductory statements in Muda (1999, P.2) which states that Ultrabasic rocks encountered in south western Nigeria formed part of the amphibolite complex (de'Swardt, 1953). This rock group includes a variety of different rock types all of which are rich in ferromagnesium minerals, particularly amphibole (Smyth and Montgomery, 1962).

Significant contributions from the properties of these soils include:

- the detailed variabilities expressed in soil-slope relationships.
- the fine sand mineralogy, an index of available weatherable nutrient elements/resistant mineralswhich was dominantly quartz and opaque minerals (Muda,1999) or quartz, feldspar, zircon, hornblende, tourmaline and opaque ores (Osei, 1990), and
- mean potential productivity index of 0.40 for selected arable crops (cassava, yam and maize) which is considered to be moderately productive with soil effective depth, texture/structure and slope as potential constraints to arable crop production.

- <u>**The Alluvial Landforms**</u> were unique in places of extensive occurrence. They occurred in both the flood plains and the terraces especially in Central Nigeria. Most of the soils studied formed on the Niger-Benue alluvial landforms and are considered to be relatively young because of their clay mineralogy suite. The parent materials could be heterogenous or homogeneous. The variability could be well expressed by their clay mineralogy (a mixture of kaolinite, smectite and some hydrous mica) and the resultant soil classification of Ustifluvents, Tropaquepts, Plinthaquults and Argiaquolls to mention some in landforms that obliquely seemed to be plain and homogeneous (Okusami et. al. 1987a). See Figure 10 below.

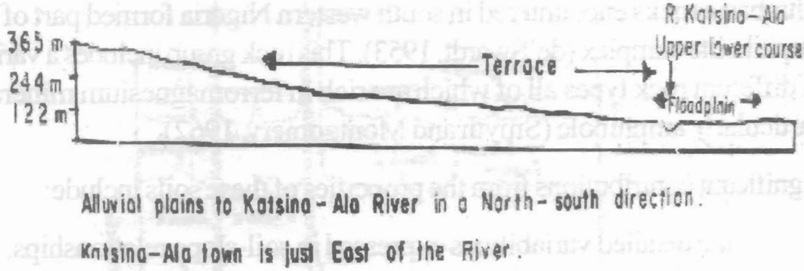


Figure 10 Alluvial Plain to River Kastina-Ala in Benue State of Nigeria

Some generalised pedogenetic statements could be derived from the clay mineralogical studies (Table 2) of these soils formed in selected alluvial landforms within the Niger-Benue trough:

(i) most of these soils are relatively young.

(ii) clay mineralogy could be taken to be a good key to the weathering environments in these alluvial but hydromorphic landforms.

- presence of vermiculite and illite could suggest juvenile stage of weathering.

- ferrolysis (a chemical process that destroys clay minerals in-situ) as postulated by Brinkman (1978) is actively in progress in these hydromorphic soils on.

- ferrolysis (a chemical process that destroys clay minerals in-situ) as postulated by Brinkman (1978) is actively in progress in these hydromorphic soils on.

Table 2: X-ray diffraction analysis (net peak count intensities)

Depth (cm)	Horizon	Chlorite 2:1:1	Muscovite Feldspars	Illite (hydrous mica) mica	Vermiculite 2:1	Smectite 2:1	Kaolinite 2:1	1:1	Quartz	Geothite	Otherst	Amorphous
Profile 2 (somewhat poorly drained)												
0-12	Ap	- ++	-	-	x	x	-	xxx	xx	x	Gib	x
15-56	E	- -	-	x	x	-	xxx	xx	x	Gib	x	
115-130	2Ab2	- -	-	x	-	x	xxx	xx	-	Gib	x	
150-170	ND	- -	-	xx	-	-	xxxx	xx	x	-	x	
170-220	ND	- -	-	xx	-	-	xxxx	xx	x	-	x	
Profile 3 (somewhat poorly drained)												
0-20	Apl	-	x	x	x	-	-	xx	xx	-	-	x
36-63	Ec1	-	-	x	xx	-	-	xxxx	xx	-		
H	xx											
81-88	BEc	-	-	x	xx	-	-	xxxx	xx	-	-	
	x											
107-130	Bwc2	-	-	x	xx	-	xx	xxxx	xx	-	-	
	xx											
170-210	ND	-	-	x	xx	-	xx	xxxx	xx	x	-	
	x											
Profile 5 (poorly drained)												
0-10	A1	-	-	-	x	-	xx	xxxx	xx	-		
-		xx										
10-17	A2	x	-	-	x	-	xx	xxxx	xx	x	-	
xx												
17-30	BAg	x	-	-	-	-	xxx	xxxx	xx	-	-	
-												
54-72	Btg2	-	-	-	-	-	xxx	xxxxx	xx	-	-	
xx												
85-127	Cg2	x	-	-	-	-	xxx	xxxxx	xx	-	-	

Source: Okusami et al. 1987

alluvial landforms especially those with perched water-table (the pseudogleys).

presence of goethite is considered to be an excellent indicator of the forward boundary of ferrolysis process.

Al saturation is an index of in-situ weathering of clay minerals and a possible index to differentiate between the hydromorphic conditions of (i) high groundwater table and (ii) perched water –table with higher values expected in the latter.

Total free iron oxide (Fed) is also a possible index to demonstrate weathering and the transportation of weathered soil materials in hydromorphic soils. The accumulation of Fe in well-drained soils has been associated with lessivage in well-drained soils (Asamao, 1973) but in contrast a zone of Fe accumulation is due to water-table movement in these alluvial but hydromorphic soils.

Wetland/Hydromorphic Landforms-Soils

These group of soils have always had significance in both pedological (agricultural inclusive) and ecological contexts. The group consists of all landforms/soils with excess water.

The following dendogram (Okusami 1995, Okusami et al., 1995, and Okusami et al., 2004) was an attempt to bring into perspective the role of wetland/hydromorphic soils in pedological and soil utilisation studies in Nigeria. Since a section above has discussed the pedology on alluvial plains (also a wetland/hydromorphic landform), this section will dwell more on soils of ***inland valley (non-alluvial)*** and other general considerations about hydromorphic soils on all possible landforms (Figure 11).

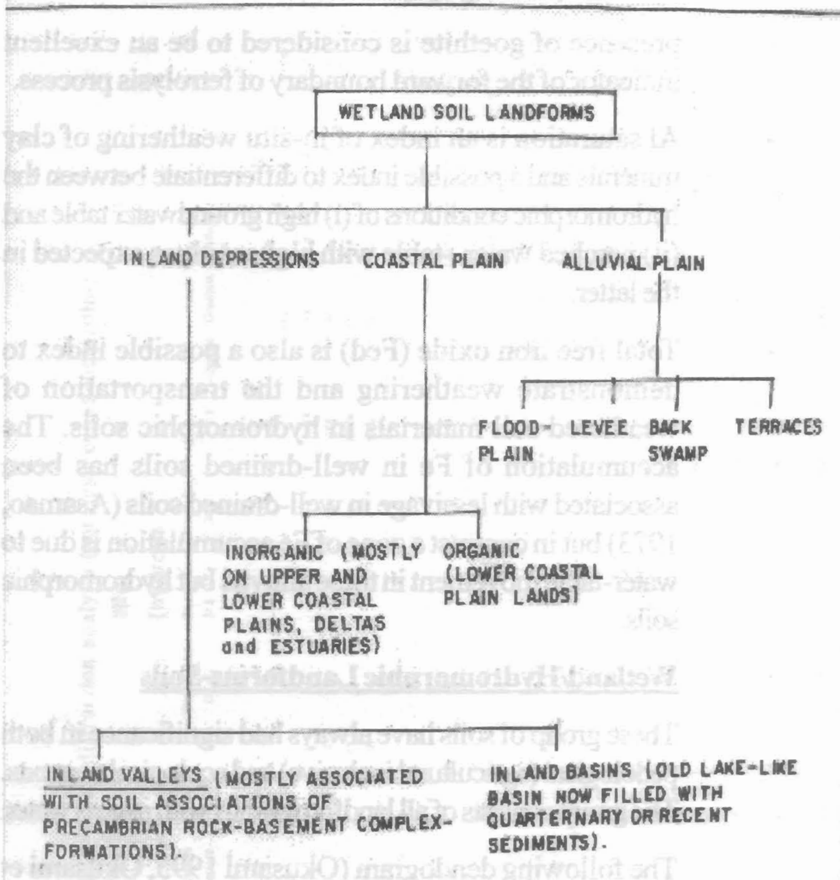


Figure 11. Wetland Soils Landforms in Sub-Sahara Africa (Okusami1995).

In Okusami (1981)

> "All inland valley (the foot-slope/valley bottom positions) are repository, on a seasonal basis, of water input from direct rainfall, overland flow and seepage. Also in all ecosystems, it is the wetland soils of the inland valley type that is underutilised in all situations. In the subhumid and semiarid regions of Nigeria, wetland soils of the inland valley type are more cultivated to a rice-based cropping system than observed in the wetland soils of the inland valley type of the humid zones because the farming system /culture of the latter is not geared towards wetland soil cultivation. Although there is now increasing use of these wetland ecosystems for dry season cropping within the humid ecoclimatic zone. There is therefore an enormous potential in Nigeria (and sub-Sahara Africa in general) for increased production by expanding the area of cultivatable land to wetland rice. Garrity (1985 quoted by Spencer 1991) indicates that only about 2% of wetlands are used in sub-Sahara Africa."

With the awareness generated towards the last two or three decades of the 20th C the percentage might have gone up at least in some other sub-Saharan African countries if not for Nigeria.

Additional Diagnostic Characteristics (of wetland/hydromorphic soils):

Morphological. Typical Diagnostic morphological features for the establishment of soils with aquic moisture regimes include mottles, presence of coated soil materials (quartz grains), and concretions (Pomerening and Knox, 1962; Vepraskas and Bouma, 1976); colour of chroma 2 or less, Veneman et al., 1976) as cited in Okusami and Rust (1992). In addition, where the hues of hydromorphic soils are redder than 10YR then it indicates iron accumulation zones which reflect the wet/dry soil moisture regime (Okusami and Rust 1992); a hue of 10YR has also been found to be typical of all the hydromorphic soils studied (Okusami and Rust, 1992) in contrast to a redder hue of 7.5YR or even 5YR observed on adjacent well-drained soils (Okusami et al., 1983, 1985; and Oyediran, 1987).

Still on the efforts towards qualitative (and quantitative) diagnostic features of hydromorphic soils, a definition by Okusami (1985) on hydromorphic soils was given as any

> "wetland soil that will not support crops (or plants), with aerobic requirements, during the peak of groundwater recharge. The influence of the water-table is largely controlled by the texture of the profile. This is of significance because the capillary fringe of any water table may be as saturated as those horizons under the water table, and this tends to increase the apparent height of the groundwater. A depth of 100cm to a saturated zone is suggested as the depth below which a pedon ceases to become aquic or show features associated with hydromorphism that could limit the environment to anaerobic crops. For a general land use purpose, a probable depth of 150cm is suggested as the depth beyond which a pedon ceases to become hydromorphic."

Other significant morphological features include clay (or soil) coatings and silt-like coatings on the sand grains and concretions of some hydromorphic soils respectively.

The texture in alluvial materials are more silty and loamy, those in coastal Cretaceous sediments are predominantly clay and sandy clay loam whereas those in inland valley (lowlands) pedons are predominantly sandy and loamy with more than 60% sand.

Chemical. On a landform basis, the chemical attributes indicate that,

- Alluvial plains has cationic distribution of Ca>Mg=Al>Na>H>K
- Coastal plains (wet) has cationic distribution, Al>Mg>Ca>H>Na>K
- Inland Valley (lowland-wet) has cationic distribution, Ca>Al=H>Mg>K=Na
- Non-hydromorphic Pedon has Mg>Al>Ca>H>K>Na

Horizons with appreciably high total extractable free iron (Fed) seem to indicate an aerobic-anaerobic zone – a confirmatory analytical test.

There seems to be a relationship between the Easily Reducible Mn

(ERMn) and intensity of hydromorpism in porous soil media.

ERMn is very low or non-existent in the former in contrast to what is obtainable in finer textured wetland soils especially those with perched water table.

Mineralogical. Highlights of clay (Table 3) and silt (Table 4) mineralogical investigations are that,

- Types of water table influence the clay mineral suite-pedons that formed in shale (materials with poor permeability) demonstrate two trends. Pedon 040, a very poorly drained soil under high regional ground water, has a dominating kaolinitic (1:1) clay mineralogy whereas pedon 020 (also formed in shale) is poorly drained but under perched water table hence richer in smectite (2:1) clay minerals with depth.

- Clay mineralogy of the soils of Inland Valley lowlands are dominantly kaolinite with higher probability of smectite clay minerals occurring in deep subsoil horizons.

Table 3: Clay mineralogy, pH soil and cation saturation for selected hydromorphic soil

Depth .(cm)	C	F	M	I	V	S	K	Q	G	L	H	R	A	pH_{H20}	AIS	BS
															........%....	
COASTAL PLAINS																
Pedon 020 - Ibese: Poorly Drained																
0-12	-	-	-	-	2	-	2	2	1	1	-	-	-	4.6	14.5	79.0
12-33	-	-	-	-	2	2	3	2	1	1	-	-	-	4.7	48.8	42.2
33-45	-	-	-	-	-	2	3	2	1	2	-	-	-	4.7	67.7	19.1
45-63	-	-	-	-	-	3	3	2	-	2	-	-	-	4.7	76.7	16.5
63-120	-	-	-	-	-	3	3	-	1	-	-	-	-	4.9	70.8	24.6
120-160	-	1	-	-	-	4	3	-	1	-	-	-	-	4.8	38.2	59.8
160-180	2	-	-	-	-	5	2	-	-	-	-	-	-	4.7	25.9	72.1
Pedon 040 - Atan Otta: Very Poorly Drained																
7-16	1	-	-	-	-	-	4	2	-	-	-	-	-	5.0	3.0	94.4
16-43	2	-	-	-	-	-	4	2	-	-	-	-	-	4.7	11.1	86.5
43-63	1	-	-	-	-	-	4	2	-	-	-	-	-	4.4	63.8	32.6
97-140	-	1	-	-	-	-	4	2	-	-	-	-	-	4.2	85.1	8.0
Pedon 080 - Itoikin: Poorly Drained																
48-66	-	-	-	-	-	-	4	1	1	-	-	-	-	3.9	93.7	6.3
66-89	-	-	-	-	-	-	4	1	1	-	-	-	-	4.0	80.6	6.6
89-120	-	-	-	-	-	-	4	1	1	-	-	-	-	3.8	78.9	8.3
120-190	-	-	-	-	-	-	4	1	1	-	-	-	-	4.1	73.3	15.0

INLAND DEPRESSIONS/VALLEYS

Pedon 050 - Osara: Somewhat Poorly Drained

37-47	-	-	1	-	-	-	3	2	-	-	-	-	-	5.1	8.0	88.4
47-56	-	-	1	-	-	-	2	1	-	-	-	-	-	5.1	3.9	92.2
56-90	-	-	1	-	-	1	3	2	-	-	-	-	-	5.1	2.7	91.7
90-110	-	-	1	-	-	1	3	2	-	-	-	-	-	5.3	0.0	92.6
110-130	-	1	-	-	-	-	2	2	2	-	-	-	-	5.2	0.2	99.0
130-152	-	-	-	-	-	4	3	2	-	-	-	-	-	5.3	0.1	99.0

Pedon 180 - Kabba: Poorly Drained

0-17	-	-	1	2	-	-	4	2	-	-	-	-	-	5.1	ND	41.3
17-33	-	-	1	1	-	-	3	2	1	-	-	-	-	5.2	ND	39.9
33-54	-	-	-	1	-	-	3	2	2	-	-	-	-	5.3	ND	37.8
54-80	-	-	-	1	-	-	3	2	1	-	-	-	-	5.5	ND	45.2

ALLUVIAL PLAINS

Pedon 130 - Adani: Poorly Drained

0-11	-	-	-	-	2	-	5	1	-	-	-	1	1	4.5	41.7	50.7
11-25	-	-	-	-	-	1	5	1	1	-	-	2	1	4.5	62.5	27.6
25-60	-	-	-	-	1	1	5	1	1	-	-	1	1	4.5	72.0	20.3
60-100	-	-	-	-	-	1	5	2	1	-	-	1	1	4.6	72.9	19.8
100-115	-	-	-	-	-	1	2	5	1	-	-	1	1	4.6	74.6	19.6

Pedon 140 - Adani: Moderately Well Drained																
0-10	-	-	-	-	2	-	5	2	2	1	-	-	1	5.0	0.6	99.0
10-27	-	-	-	1	2	-	5	2	2	-	-	-	1	4.6	11.8	86.5
27-43	-	-	-	1	2	-	5	2	2	-	-	-	-	4.7	18.9	79.5
43-53	-	-	-	-	-	2	5	2	2	-	-	-	1	4.6	20.2	80.9
53-70	-	-	-	-	-	1	3	3	-	1	1	-	2	4.7	23.5	74.5
70-100	-	-	-	-	1	-	4	4	2	-	-	-	2	4.6	27.0	70.6
Pedon 3 -River Kaduna on Mokwa – Bida Road: Poorly Drained																
0-20	-	1	1	1	-	-	2	2	-	-	-	-	-	4.7	22.4	71.3
36-63	-	-	1	2	-	-	4	2	-	-	1	-	-	5.0	16.8	81.0
81-88	-	-	1	2	-	-	4	2	-	-	-	-	-	5.4	16.3	81.5
107-130	-	-	1	2	-	2	4	2	-	-	-	-	-	6.8	0.0	99.2
170-210	-	-	1	2	-	2	4	2	1	-	-	-	-	8.1	0.0	99.8
Pedon 5 - Bacita: Very Poorly Drained																
10-17	1	-	-	1	-	2	4	2	1	-	-	-	-	7.1	0.0	99.5
17-30	1	-	-	-	-	3	4	2	-	-	-	-	-	6.3	0.0	99.5
54-72	-	-	-	-	-	3	5	2	-	-	-	-	-	7.0	0.0	99.6
85-127	1	-	-	-	-	3	5	2	-	-	-	-	-	7.0	0.0	99.7

Pedon 200 - Edozighi on River Kaduna: Very Poorly Drained

0-15	-	-	1	1	-	-	5	1	-	-	-	-	-	4.2	ND	8.4
15-30	-	-	1	1	-	-	5	1	-	-	-	-	-	4.2	ND	6.7
30-45	-	-	-	1	-	-	5	1	1	-	-	-	-	4.6	ND	19.3

Abbreviations: C = Chlorite; F = Feldspar; M = Muscovite; I = Ilite;

V = Vermiculite; S = Smectite; K = Kaolinite; Q = Quartz;

G = Goethlite; L = Lepidocrocite; H = Hematite; R = Rutile;

A = Anatase; AIS = Aluminium saturation; BS = Base saturation.

l, small (0-100); 2, moderate (101-500); 3, large (501-1000);

4, Abundant (1001-2000); 5, dominant (>2000)

Source: Okusami and Rust. 1992

- Evidence for neoformation process (a resynthesis process for the formation of clay minerals)-Smectites or the micaceous clay minerals are not geochemically compatible with rutile and/or anatase.

- The presence of goethite reinforces the capability to classify hydromorphic soils into drainage classes. Presence of goethite in hydromorphic soils has been associated with a highly oxidising environment (Kawaguchi and Kyuma, 1969 in Paramananthan, 1978).This could be a function of soil texture (sandy) and/or duration of water-table and its fluctuation or a combination of the two.

- The presence of goethite in clay fraction of pedons 020,080,130 and 140 (Table 3) suggests that these pedons are not as intensely reduced during saturation as for example, pedon 040 , which has no detectable goethite. Pedon 040 was permanently wet/moist at the time of visit.

- Lepidocrosite is an iron oxide that is diagnostic for a reducing environment. It occurs up to greater depth in pedon 020, confirming its poorly drained and anaerobic status. Although pedon 140 is considered to be non-hydromorphic, the presence of lepidocrocite in the surface horizon indicates that it undergoes sufficient wetness to cause hydromorphism,

- Rutile and anatase are some of the most resistant minerals. The presence of either mineral suggests that some of these soils are formed in pre-weathered sedimentary parent materials (Okusami and Rust, 1992).

- Silt fraction (Table 4) mineralogy with the presence of heavy minerals and their oxides confirm the pre-weathered status of these sediments.

Table 4: Silt mineralogy of selected pedons

					———Oxides———				
Depth (cm)	Horizons	K	I	Q	G	H	L	A	R
Pedon 040									
7-16	E	1		5				1	1
16-43	Bg1	1		5				1	1
43-63	Bg2	1		5				1	1
97-140	Cg	1		5				1	1
Pedon 080									
10-48	BA	1		5				1	1
48-66	Bw	1		5				1	1
120-190	Cg2	1		5	1	1		1	1
Pedon 130									
0-11	Ag			5				1	1
25-60	B	1		5			1	1	1
60-100	Bcx1			5				1	1
100-115	Bcx2	1		5				1	1
Pedon 140									
0-10	A			5				1	1
27-43	B1			5				1	1
53-70	Btc2	1	1	5	1	1		1	1
70-100	Btc3			5	1	1		1	1

* See abbreviation under Table 3

Source: Okusami and Rust, 1992.

Tables 5 and 6 contain the summaries of some of the characteristics of selected wetland soils in Nigeria (Okusami and Rust 1992). Oyediran (1987,1990), as my postgraduate student, studied wetland soils of the savanna ecosystem to characterize them for genesis, classification and potential productivity index for lowland rice (Oryza sativa L.) cultivation.

The formation of Inland Valley Consortium headquartered in Ivory Coast (West African Rice Development Authority) was to assist the continuous research and development into the Inland Valleys in West Africa especially the inland valley lowlands for rice crop production. I was one of the representative members from Nigeria with responsibilities for southwest coordination. Not much has been heard/done in recent years from the Nigerian end. The National Cereals Research Institute at Badagri as a NARI (National Agriculture Research Institute) is a coordinating center for Nigeria as required in regional studies with external funding. My pioneer work on wetland soils characterization and utilization made me to be a contributor (Okusami et al. 2004) "The Nigeria Rice Memorabilia.

Table 5: Selected Soil morphological, physical and chemical properties

Depth (cm)	Horizon	Colour (dominant, moist) matrix	Colour (dominant, moist) mottles	>2mm % of whole soil (conc.)	Sand %	Silt %	Clay %	Texture	Org. C %	Fed %	ERMn mg kg⁻¹	ECEC cmol(+) kg⁻¹ clay
COASTAL PLAINS												
Pedon 020 Poorly Drained - Ibese												
0-12	A	10 YR 3/2	-	0.0	49.0	40.6	10.4	1	1.52	0.66	3.0	39
12-23	Ag	10 YR 3/2	10 YR 3/5	0.0	76.5	17.1	6.4	1fs	0.32	0.35	0.1	47
33-45	BAg	10 YR 3/3	10 YR 3/6	NS	77.5	13.5	8.0	1fs	0.30	0.66	0.1	41
45-63	2Bg1	10 YR 3/2	7.5 YR 5/6	NS	66.5	11.5	22.0	scl	0.57	1.21	0.2	41
63-120	2Bg2	10 YR 4/1	2.5 YR 4/8	NS	60.1	12.9	27.0	scl	0.34	3.11	0.2	52
120-160	2Bg3	10 YR 7/1	10 YR 3/6	4.8	48.0	8.8	43.2	sc	0.10	6.08	0.3	54
160-180	2Cg	10 YR 6/1	10 YR 7/8	16.6	10.1	13.9	76.0	c	0.13	3.18	0.8	70
Pedon 040 Very Poorly Drained – Atan-Otta												
0-7	A	10 YR 4/2	-	0.0	27.5	32.6	39.9	cl	2.43	0.10	6.9	36
7-16	E	10 YR 5/2	10 YR 7/6	0.0	22.7	22.3	55.0	c	0.83	0.24	2.1	15
16-43	Bg1	10 YR 4/1	10 YR 6/5	0.0	10.8	16.7	72.5	c	0.61	0.38	0.6	13
43-63	Bg2	10 YR 5/2	10 YR 4/6	0.0	10.7	21.3	68.0	c	0.37	1.31	0.1	12
63-97	Bcg	10 YR 4/2	10 YR 4/6	0.0	14.4	20.1	65.5	c	0.30	0.31	0.1	12
97-140	Cg	10 YR 6/2	2.5 YR 4/2	0.0	4.0	16.3	79.7	c	0.27	0.17	0.1	10
120-190	Cg2	10 YR 6/2	5 YR 3/8	3.8	50.0	15.0	35.0	scl	0.54	3.32	0.1	12

INLAND DEPRESSIONS/VALLEY

Pedon 050 Somewhat Poorly Drained – Osara

0-30	Ap1	10 YR 3/3	-	0.0	78.4	17.6	4.0	lfs	0.37	0.17	1.1	37
30-37	Ap2	10 YR 5/2	10 YR 4/6	0.0	81.8	14.4	3.8	lfs	0.30	0.10	0.4	36
37-47	A	10 YR 5/2	10 YR 4/6	0.0	90.3	7.7	2.0	fs	0.15	0.07	0.1	35
47-56	2Ab	10 YR 4/2	10 YR 4/6	0.0	80.5	19.5	3.0	lfs	0.27	0.34	0.4	47
56-90	2BAb1	10 YR 6/4	7.5 YR 5/8	0.0	80.1	12.9	7.0	lfs	0.18	0.13	0.5	29
90-110	2BAb2	5 YR 6/2	7.5 YR 5/8	4.7	86.2	8.3	5.5	ls	0.18	0.13	0.4	47
110-130	3Bb1	10 YR 6/2	7.5 YR 6/8	40.0	54.5	3.6	42.0	gr.sc	0.26	5.76	12.7	30
130-152	3Bb2	7.5 YR 7/0	few, faint	10.7	61.0	9.0	30.0	scl	0.18	0.84	39.0	54

Pedon 100 Poorly Drained – Nteje

0-25	Ap	10 YR 5/3	5 YR 4/6	0.0	63.5	26.8	9.7	sl	0.87	1.35	10.5	30
25-38	A	10 YR 5/2	2.5 YR 4/6	0.0	63.2	27.1	9.7	sl	0.40	1.75	4.3	27
38-102	Bg	7.5 YR 6/2	5 YR 5/6	0.0	64.0	17.8	8.2	scl	0.26	1.12	0.8	32

ALLUVIAL PLAINS

Pedon 2 Poorly Drained – Katsina Ala

0-12	Ap	10 YR 3/3	faint	0.0	3.5	46.5	52.0	slc	1.57	3.33	56.7	18
12-56	E	10 YR 4/2	10 YR 3/6	0.0	5.2	48.8	46.0	slc	0.75	4.36	5.2	19
56-77	BA	10 YR	10 YR 3/6	0.0	5.0	53.0	42.0	slc	0.68	4.34	8.4	20
77-98	Bt	10 YR 5/2	10 YR 5/2	0.0	5.5	51.5	43.0	slc	0.54	5.06	20.0	23
98-115	2Ab	10 YR 4/2	10 YR 5/2	0.0	10.2	44.1	45.7	slc	0.71	5.35	51.5	21
115-130	2Abc	10 YR 4/2	10 YR 4/4	0.0	9.5	49.0	59.5	slc	0.83	4.81	29.4	20
130-150	2Ebc	10 YR 5/2	10 YR 4/6	0.0	15.3	43.7	41.0	slc	0.57	4.90	27.3	21
150-170	ND	ND	ND	0.0	24.0	37.6	38.4	cl	0.48	7.49	258.3	30
170-220	ND	ND	ND	0.0	10.2	31.0	58.8	cl	0.27	4.20	80.9	33

Pedon 5 Very Poorly Drained – Bacita

0-10	Ag1	10 YR 3/1	-	0.0	35.5	41.6	22.9	l	1.67	0.33	14.9	80
10-17	Ag2	10 YR 3/1	-	0.0	29.1	49.5	21.4	l	0.99	0.14	4.0	66
17-30	ABg	10 YR 3/2	faint	0.0	33.0	35.1	31.9	cl	0.61	0.35	1.0	35
30-54	Bg1	10 YR 4/1	10 YR 4/6	0.0	23.5	29.8	46.7	c	0.32	0.38	1.0	32
54-72	Bg2	10 YR 5/1	-	0.0	24.2	24.8	51.0	c	0.27	0.33	4.5	33
72-85	Cg1	10 YR 5/1	-	0.0	54.2	15.8	30.0	scl	0.18	0.16	4.3	36
85-127	Cg2	10 YR 6/1	-	0.0	58.2	16.0	25.8	scl	0.15	0.35	6.5	35

Texture: s = sand; c = clay; si = silt; l = loam; gr = gravelly; ND = Not Determined: concs. = concretions; co-coarse

Others: ND = Not Determined

Table 6 : Statistics for reactive properties of studied hydromorphic soils

	pH_{H20}	Ca	Mg	Na	K	Al	H	ECEC	ECEC	AIS	BS
		cmol (+) kg^{-1} soil							cmol (+) Kg^{-1}clay	%	
Coastal Plain N = 19											
Min.	3.60	0.07	0.06	0.03	0.01	0.00	0.15	2.87	10.00	0.00	5.40
Max.	5.70	10.43	29.17	1.66	0.70	13.80	1.26	53.34	104.00	93.7	98.9
X	4.45	1.85	3.03	0.21	0.12	4.09	0.48	9.75	32.21	53.83	38.86
C.V. (%)	11.2	154.3	218.8	181.4	141.0	84.5	57.3	114.9	71.0	56.6	82.8
Inland depressions/valleys. N = 15											
Min.	4.50	0.41	0.18	0.01	0.01	0.00[a]	0.03[a]	0.69	23.00	0.00[a]	37.3[a]
Max.	5.50	10.68	5.01	0.23	0.19	6.18	6.18	16.28	54.00	54.8	99.00
X	5.05	2.26	1.13	0.04	0.08	1.47	1.32	4.95	36.13	13.92	80.77
C.V. (%)	5.6	127.2	122.0	128.8	76.0	140.6	159.5	92.1	24.9	122.7	23.2

Alluvial plain N = 38											
Min.	4.20	0.17	0.05	0.01	0.03	0.00	0.01	2.30	18.00[b]	0.00[b]	19.60[b]
Max.	8.10	13.38	5.43	6.92	1.33	5.53	4.23	19.60	80.00	74.60	99.90
X	5.59	4.30	1.73	0.87	0.24	1.70	0.46	9.03	33.2	22.16	73.99
C.V. (%)	19.8	83.6	73.7	149.69	100.6	108.4	191.2	50.1	42.1	112.6	36.68
All samples. N = 72											
X	5.18	3.23	1.95	0.52	0.17	2.23[c]	0.63[c]	8.37	33.57[d]	30.02[c]	64.87[c]
C.V.(%)	18.9	107.2	187.4	197.5	120.6	116.0	188.5	85.7	50.6	99.9	49.81

[a]N = 11; [b]N = 35; [c]N = 65; [d]N =69; AIS = Aluminium Saturation; BS = Base Saturation

Concluding Remarks: Hypotheses/Models.

- A supporting evidence to the significance of the dominating role of physiography (landforms/landscape/topography) in soil variabilities, is manifested in for instance:

  · the lack of chemical/mineralogical differences demonstrated in some of the existing red soils formed on upland positions and in different parent rocks/parent materials (Okusami et al. 1997) where the clay mineral suite in all the soils is dominated by kaolinite with traces of 2:1 and 2:2 clay minerals, goethite, hematite, anatase, magnetite and rutile.

  · the study of Iwo series (Typic Paleustult/Ferric Acrisols) in southwest Nigeria, where it was concluded (Okusami and Oyediran, 1985) that:

"the statistical hypotheses tested in this study have supported that no significant differences exist between soil profiles formed in similar parent material occupying different aspects of physiographic units of the landscape.— ————groundwater table exerted a strong influence on relict features of soil profiles but this may not be sufficient to delineate different series. Chemical variabilities as observed through pH and ECEC also have shown that irrespective of physiographic characteristics, these soils that are exposed to identical climatic parameters weather identically."

- Another significant contribution under characterization studies is the model developed from soil samples that are mostly from "aqu" suborders and aquic subgroups (Okusami et al., 1987). Table 7 shows the different multiple regression equations for the determination of ÄpH, ÄCEC, and specific surface area (SA). And also that the regression equation is significant and can therefore be extrapolated to other newly sampled soils.

Table 7: Multiple regression equations for ?pH, ?CEC, and specific surface area (SA).

Equation	df	r^2	P value*
ÄpH = -1.58 + (-0.189 ExNa) + (0.007 sand) + (0.38 organic C)	101	0.56	0.005
ÄCEC = 3.118 + (0.345 clay) + (-23.96 ExK) + (10.1 organic C)	101	0.83	0.005
SA = -3.96 + (0.647 clay) + (-4.03 pH)	102	0.94	0.005
(N = 105)			

* p value = the probability of accepting the null hypothesis that there is no significant regression

Source: Okusami et al; 1987b

Soil Survey Activities – Significance

At this juncture, the term Land Use Planning can creep into the discussion for the purpose of highlighting in context the significance of soil survey activities.

According to Wikipedia – the free encyclopaedia (http://www.en.wikipedia.org/wiki/Landuse planning)

> "Land use planning is the term used for a branch of public policy which encompasses various disciplines which seek to order and regulate the use of land in an efficient and ethical way",

and that

> "despite confusing nomenclature, the essential function of land use planning remains the same whatever term is applied."

The Canadian Institute of Planners offers a definition that:

> "[Land Use] planning means the scientific, aesthetic, and orderly disposition of land, resources, facilities and services with a view to securing the physical, economical and social efficiency, health and well-being of urban and rural communities "(http://www.cip-icu.ca/English/about plan/what.htm).

In whatever way Land Use Planning is Conceptualised, soil survey (soil science/pedology sub-discipline) has been considered as a tool (see functions under [http:/.en.wikipedia.org/wiki/landuse planning]) that provides extensive land use planning information (therefore by inference, sustainable land use) such as limitations for dwellings with and without basements" (not yet common with us in Nigeria – my comment), "shallow excavations, small commercial buildings and septic tank adsorption" (rural land use inclusive).

The usefulness of a soil survey report is a function of the level of detail (Baumgardner et al. 1983) contained in the report and the accompanying soil map.

To buttress the significance of soil survey report (non-agricultural) I discuss briefly, as an example, an advert placed in the Punch of April 14, 2009 by the Ministry of Works and Transport of Osun State Government of Nigeria titled **"GEOTECHNICAL INVESTIGATIVE STUDIES OF OSOGBO-IWO ROAD"**, with the following "Project Objective/Scope of Works".

The project aims at conducting investigative research into the main cause/causes of the incessant failures of the road towards raising a Bill of

Engineering Measurement and Evaluation (BEME) for reconstruction / rehabilitation of identified defective portions of the road.

"Briefly the scope of works includes but not limited to the following:

(1) To carry out geotechnical investigation into the causes of perennial failure of the road pavement;

(2) To investigate perceived high water table occurrences along the road corridor;

(3) To ascertain availability of suitable road construction materials;

(4) To investigate soil conditions for the formation; and

(5) To carry out other necessary geotechnical/geophysical investigations and tests on the road."

My first reaction was to think of a consortium of the Departments of Soil Science, Geology and Civil Engineering. My discussion with a colleague/ friend towards initiating this consortium however did not encourage it. The motivating force behind my interest being that the bulk of the fundamental work requested for is actually derivable from a soil survey study. I refer, as example, to my early work as a postgraduate student and subsequent follow-up study on soils of the Shasha River Basin i.e., Origo Association Soils in Osun State (Okusami et. al., 1974; Okusami and Ojanuga 1984). In addition, Smyth and Montgomery (1962) devoted a chapter to the "Use and Management of the Soils" including a discussion on "Soil Quality for Engineering Purposes" (Smyth and Montgomery, 1962. 206-210).

SOIL SURVEY INTERPRETATIONS/LAND EVALUATIONS (Antidote for unsustainable land use and management)

- **Why?**

This exercise has been part of soil survey activities, i.e., describing, mapping, inventorying and evaluation of soils for their capabilities and limitations for both agronomic and non-agricultural purposes. The concluding remarks in the preface to the book titled "Soil Surveys and Land Use Planning" (Bartelli et. al. (eds) 1966) says:

"Soil Science is still a new tool for most planners, but I believe that the soil capability analysis soon will be as basic to our art, and science, as the land use inventory, the traffic count and the population projections".

This 'prophetic' statement has come to pass in the United States of America (Soil Survey Division Staff, 1993, Chapter 6, 281-325).

Agricultural lands could be rated for their Land Capability Classes (Klingebiel, and Montgomery, 1961) and/or Land Suitability Classes (FAO, 1976). These are ratings that group soils into their capabilities for different uses; arable, tree crop, (forestry), wetland, grazing, recreation, wildlife etc. Each capability could then be further evaluated for the different land utilization types (LUT) into Land Suitability Classes.

It is a multidisciplinary approach that requires information on the soils from soil survey report and the requirements/characteristics of the intended use from literature or subject matter specialists.

The essence here (in evaluation) is to point out the limitations for particular usage ranging from lands with no/minimal limitations to those with maximum limitations for arable land use for instance or even as foundation information for engineering works on land.

Therefore to mitigate the effects of soil degradation on soil/agricultural productivity, a combination of land evaluation methodologies need to be applied for land use type delineation and subsequent land management with Land Capability Classification studies and Land Suitability evaluation respectively. Examples from my studies include the following:

- **Wetland/Hydromorphic Utilization Study**
  - **Origo Association Soils:** I have been a pioneer in the pedological investigation into the utilization potential of wetland/hydromorphic soils and especially that of the potentials of Origo Association Soils which predominantly occupy the middle/lowland sections of Shasha river basin and part of Osun river basin both in present Osun State (Okusami et. al. 1974) of southwest Nigeria. Soils of Origo Association in both areas of occurrence/survey occupy an area of 8,430ha as determined in a survey (Okusami et. al. 1974).

The soils typically belong to the "soils with impeded drainage" because of the presence of 2:1 clay minerals (i.e. montmorillonite) in the subsoil horizons.

  - The dominant soil series, Origo and Majeroku, are classified as Vertic Tropaquepts and Vertic Haplaquolls respectively (Okusami and Ojanuga, 1984). Agronomic field trials, indicated that rice (Oryza sativa) could be grown profitably (Table 8) during the rainy season with proper soil and water management and that sorghum (Sorghum vulgare) should be successful as a late season crop (Okusami et. al. 1974).

Table 8: Summary of Results of Rice Production Trials at Asipa (in Osun State of Nigeria)/Yield Trials

Rate	Yield of Rice Kg per ha								
Kg/ha	1969		1970		1971			1972	
	OS-6	Offada	OS-6	OS-6	IR-20	OS-6	IR-20	IR-20	OS-6
					Effect of Nitrogen				
0	1805	1569	1749	3689	2759	2825	2063	-	-
33.6	2051	1647	1715	3453	3363	2590	2130	-	-
67.2	1715	1737	1961	2872	3823	3207	2489	-	-
100.8	1569	1513	1637	3531	4193	2631	2390	-	-
					Effect of Phosphorus				
0	1950	1770	2017	3440	3229	-	2825	2063	-
14.6	1737	1720	1659	3420	3677	-	3093	2510	-
56.4	1647	1371	1627	3677	3677	-	2825	1973	-
					Effect of K, Mg, Cu, Zn, Fe				
Without	1805	-	1805	-	-	3453	-	-	2320
With	1591	-	1749	-	-	3700	-	-	2635

The inherently poor drainage of the soil of this Origo Association automatically brings it into Land Capability Class V reserved for soils/ land with wetness (high water table) limitation and so adapted only for rice cultivation. Improved soil-water management and wetland (lowland) rice varieties could now bring the yield to an optimum expected.

- **Others:** The collection of empirical data on other wetland soils in Nigeria and Liberia was to evaluate their potentiality for rice-crop production (Okusami 1981, Okusami et. al. 1985;

Okusami et. al., 1987a; Okusami, et. al. 1987b; Okusami, 1986; Okusami and Rust, 1992; Ojanuga et. al. 1996; Okusami et. al. 1995; and Olaniyan et. al. 1995). These include those of Oyediran (1987, 1990) as my postgraduate student.

- **Landforms On Basement Complex/Quartzite Ridges: Upland Rice Cultivation**

Erio Ekiti and other surrounding cities are located on quartzite ridges sufficiently high and sloppy to warrant attention because of the slopes cultivated to rice (upland) and intercropped on a rotational basis with yam (Dioscorea allata) and cassava (Manihot esculenta). In the introductory remarks (Okusami, 1991) to the Abstract, it was stated that

> "The scenery on the rolling/hilly landscape of central southwest Nigeria has always generated the curiosity as to its capability to sustain crop yields under low resource input farming system. This had necessitated studies of the soil types, their actual productivity under a low resource input level and the soils' evaluation to ascertain their suitabilities for cultivated crops. A transect on Eiye watershed (a tributary to River Osun) was established and the soil sequence studied. Soils in the immediate environment were also examined."

Field estimates were taken by randomly selecting plots of mature crops in the fields of farmers (Table 9).

Table 9: Summary of Rice and Yam Yield from Selected Farmlands

	Rice (N = 10)		Yam (N = 9)
	With Shell	Without Shell	
	Kg/ha		
Min	61.9	30.9	3068.5
Max	2090.0	1045.0	3068.5
X (Mean)	892.8	446.2	5603.9
C.V.(%)	67.4	67.3	35.5

Source: Okusami, 1991

In conclusion it was observed that

(a) Lands of all physiographic units on the quartzite ridges were cultivated irrespective of the hazard of being susceptible to erosion (because of the slope)

(b) Soil management practices for all land utilization types (rice, yam and cassava) especially those of upland rice and yam indicated that there were three technical constraints against sustainable land use (Table 10):

- Erosion hazard
- Low soil fertility status and
- Water management problems

(c) Soils of these quartzite – derived parent materials are more suitable to upland rice cultivation (Table 10) than to tuber/ root crops or even to tree crops, although appropriate farming system techniques would have to be worked out to meet the needs of these low input farming communities.

(d) The traditional way of maintaining soil fertility was observed to be in the use of the Siam weed (Chromoleana odorata) as fallow crop which had a prolific growth and therefore a high turnover of organic matter (presence of thick organic matter) even within a three year fallow.

(e) Table 10 contains suggested land use and land use management requirements.

Table 10: Suitability evaluation of identified soil units (Okemessi Soil Association)

Series FAO/UN USDA	Suitabilities Upland Rice	 Yam	 Cassava	Suggested Land Use/Land Management
Omo Series *Dystric Leptosols* *Typic Ustorthentic*	S3t s/3	N2	N2	Forest cover for soil/ water conservation
Iwaji Series *Dystric Leptosols* *Typic Ustorthent*	S3t s/2b	S3t s/2b	S3t s/2b	Forest cover for soil/ water conservation
Erinoke Series - *Ustoxic Dystropeps*	S3t f/1	S3t s/2b f/1	S3t s/2b	Forest cover for soil/ water conservation
Etionni Series *Rhodic Ferralsols* *Rhodic Haplustox*	S2t f/1	S2t f/1	S2t f/1	Contour planting with leguminous tree-crops to improve on the physical and chemical properties of the soil
Etionni Series *Rhodic Ferralsols* *Eustruustox*	S3s/3 f/1	S3s/3 f/1	S3s/3	Tree crops for soil/water conservation
Ipele Series *Rhodic-Haplic Ferralsols* *Eustrustult*	S2b/f/1	S3s2/b f/1	S3s2/bf/1	Intercropping with melon and alternate rice variety/fallow
Apomu Series ? *Fluventic Dystropepts*	S2w2/b f/1	S2w2/b f/1	S2w2/b f/1	Rotational cropping, appropriate rice variety/fallow
Jago Association *Dystric Gleysols* *Aquents*	N1w2/bs2/b	N1w2/b	N1w2/b	Forest to stabilise the stream banks

Class Levels: S1 = no/slight, S2 = moderate; S3 = severe; NI, N2 = very severe limitations
Limiting factors: t = topography, s = physical characteristics of soils, w = wetness, c = climate
f/1 = fertility limitation (ECEC); s/3 = solum depth or depth to impermeable layers, s/2b = coarse fragments

Source: Okusami. 1991

Landforms On Basement Complex/Granites

This example (in Figure 13) is cited because its map is very amenable to reproduction due to the small land area. It is an example of an exercise carried out after cultivation had been initiated before an appraisal for land suitability or otherwise.

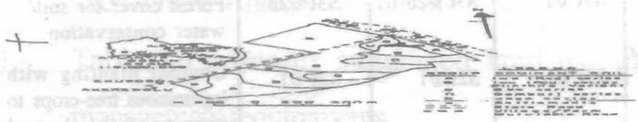


Figure 13. Soil Distribution in Pre-Cambrian Rock Derived Parent

Material in Onikoko Village in Ile-Ife Suburb

In conclusion, it was stated (Okusami, 1990) that wrong land use has been responsible for the loss of productive agricultural lands. No matter how small a land is, it is still beneficial to ensure that it is evaluated and put to sustainable use. Table 11 indicates the suggested Land use.

The suggested land use on Gambari series (Petroferric Haplustults/Dystric Leptosols) (Table 11) has been coroborated on the studies (Orimoyegun and Okusami 1995) on factors that influence Teak (Tectona Grandis) which indicated that tree growth also varied with soil types indicating highest volume production on ironpan soils (Gambari series).

Landforms On Coastal Sediments

Landforms on the coastal belt represent the soil formed in sedimentary derived parent materials. The lithology is as variable as the marine environment under which they were deposited. And except for the current River Niger Delta, other sediments are represented in an East-West fashion.

The recent global concern on climate change influence on coastal lands (especially inhabited locations) make the studies of the soils' land use capabilities very retroactively significant and contributively to the characteristics and their use potentials.

Of interest was the study (Okusami, 1997) on the Land Suitability ratings of a 5000ha land for upland rice cultivation in the upper coastal plain area of Lagos State (Table 12).

Table 11: Land Suitability Evaluation for Dominant Soil Types Identified in Onikoko Area

Group	Dominant Soils - Local - Soil Taxonomy - FAO Unesco Legend	Land Suitability Ratings For Maize	Cowpea	Suggested Alternative Land Use and Advantages
A (16.1 HECTARES)	Iwo (Red) Series Typic Paleustults Ferric Acrisols	S1	S1	——
B (17.71 HECTARES)	Iwo (Red) Series Plinthite variation Plinthustults Plinthic Acrisols	S2es	S2es	Oil Palm-will afford a permanent cover while yielding oil/kernel S2s
C (8.05 HECTARES)	Oba Series Plinthic Kandiustults Plinthic Ferralsols	S2es	S2es	Oil Palm-will give a permanent cover and also give a good crop yield
D (11.27 HECTARES)	Gambari Series Petroferric Haplustults Dystric Leptosols	S3esm	S3esm	Bush cover and Oil Palm on soils <50 cm and <90 cm respectively
E (38.64 HECTARES)	Jago Association soils Aquents, Aquepts Gleysols	S3w	S3w	Early maize (S2w) followed by swamp rice (S2) and vegetables during the dry season

S = Suitability; 1,2,3 = Highly, Moderately, and Marginally; w = wetness, e = erosion hazard, s = soil depth problem; m = moisture limitation

Source: Modified after Okusami 1990.

Table 12: Soil Classification and Suitability Ratings for Studied Pedons on Upper Coastal Plains in Lagos State

Soil Classification			Suitability Ratings for Upland Rice	
Soil Series	Soil Taxonomy	FAO-UNESCO	Class	Sub-Class
Oteyyi	Typic Kandiustults	Haplic Ferralsols	S3	S3s/3
Alagba	Typic Kandiustults	Rhodic Ferralsols	S1	
Asaba	Typic Kanhaplustults	Haplic Ferralsols	S3	S3s/3
Ugbolu	Typic Kanhaplustults	Xanthic Ferralsols	S3	S3ts/3
Owode	Typic Kandiustults	Xanthic Ferralsols	S2	S2t
Agege	Typic Kanhaplustults	Xanthic Ferralsols	S2	S2ts/3
Ibeshe	Typic Kanhapludults	Xanthic Ferralsols	S2	S2t
Ipajo	Typic Kandiustults	Xanthic Ferralsols	S2	S2t
Iju	Typic Hapludox	Xanthic Ferralsols	S2	S2l
Atan	Tropic Fluvaquents	Gleyic-Dystric Fluvisols	S3	S3w/2
Mesan	Humaqueptic Psammaquents	Dystric Gteysols	N1	N1w/1

Source Okusami, 1997

Classes: SI= highly suitable, S2= moderately suitable, S3 = marginally suitable : N= Not suitable

Limiting Factor: S/3 = solum depth, t = erosion hazard/slope w/1, w/2 = flooding hazard.

Highlights of the observations were that:

- Lands were potentially erodible so would not sustain upland rice (or crop with similar physiognomy) cultivation and so will the effective soil depth.

Soil morphological properties of the different pedons and their classification will assist with sustainable land use management practices

The good news was that based on negative assessments, the plan to use the land for upland rice cultivation was abandoned. I am not sure of the status now.

Similar evaluation (Okusami, 1996) on the lower coastal acid sand of Lagos State (Lekki Peninsula) revealed that these sandy soils were only moderately suitable for cassava, pineapple and cashew. The nutrient status contributes the most limiting factor against sustainable use.

* **<u>Land In Sao Paolo, Brazil</u>.**

During my TWAS (Third World Academy of Sciences) Visiting Associate stay in Brazil, I was requested, as part of my Scientific assignment, to provide the land suitability classification of the soils of ESPIRITO SANTO do TURVO COUNTY in SAO PAOLO STATE OF BRAZIL. This study was a necessary complement to the soil map to complete the soil survey report and therefore conclude an inventory/ advisory assignment given to the Institute of Agronomy. The latter is the research arm of the government of Sao Paolo state in Brazil.

The suitability rating study was on coffee- Coffea Arabica; maize-Zea mays, sugar cane- Saccharum officinarum, and cassava-Manihot Esculenta. Table 13 indicates the outcome of the study/exercise.

Table 13: Land Suitability Classification (approximate) for soils of Espirito Du Turvo County in Sao Paolo

Mapping Units	Land Utilization Types: Coffee Arabica	Maize	Sugar Cane	Cassava
LEa1	S3nxe	S3nxe	S3ne	N2
Lea2	S3nxe	S3nxe	S2nxe	N2
PEa	S4nxe	S4nxe	S3ne	N2
PEd	S3nxe	S4nxe	S3ne	N2
PEe1	S3nxe	S4nxe	S3ne	N2
PEe2	S3ne	S4ne	S3ne	N2
PEaba	S3ne	S4nxe	S3ne	N2
PEabe	S3ne	S4nxe	S3ne	N2
PVa1	S4nxe	S4nxe	S4ne	N2
PVaba	S3nxe	S4nxe	S4ne	N2
PVabe	S3ne	S4ne	S3ne	N2
Others	NR	NR	NR	NR

Notes

1. Source of Mapping Units and other related properties:

   Menk, J. R. F., M. Rossi, F. C. Bertolani, and M. R. Coelho. 2000. Levantamento Semi Detalho Dos Solos Do Municipio De Espirito Santo Do Turvo (SP). Governo Do Estado De Sao Palolo Secretaria De Agricultura E Abastecimento. Instituto Agonomico. Campinas. ISSN 0102-2032.

2. SI- highly suitable; S2- moderately suitable; S3- Marginally suitable1; S4- Marginally suitable2; N2- Not suitable (Climatic-temperature limitation)

   n-nutrient availability and/or nutrient retention capacity limitation; x-toxicity limitation; e-erosion hazard limitation.

   Within couple of days after the conclusion of the study, I was informed that the weather forecast for the county authenticated Land Suitability Class established (as in the Table 16).

· **Concluding Remarks:** land use evaluation on some soils of Nigeria.

The following limitations to sustainable land use seem to be recurring on almost all landforms;

- topographic/erosion hazard
- flooding hazard (wetland/hydromorphic)
- physical characteristic of soils
  - texture (sandy and/or waste fragments)
  - solum depth
  - depth to impermeable/petrified layers
  - soil moisture limitation
- chemical characteristic of soils
  - nutrient availability/nutrient retention capacity limitation
- toxicity limitation

LAND USE POLICY IN NIGERIA

There is currently no Land Use Policy in Nigeria. The Land Use Act Decree of 1978 was enacted basically to shift ownership control of land from communal to state. The only element of significance under the Act is the possibility of acquiring land (contiguous) to the extent of 500ha or 5000ha for agricultural and grazing purposes respectfully. And it is obvious that this has only worked to the advantage of the very few in the society.

The closest to a Land Use Policy in Nigeria was the suggestion by Aladejana (1982) in his article titled "Guidelines on National Policy on Agricultural Land Resources".

Some of his recommendations need to be quoted here as they are relevant to the topic of this inaugural lecture. These are that the Nigerian Land Use policy, within the frame work of national development should:

(i) articulate approximate area of land to be reserved for food production,

(i) articulate area of forest land to be retained as a resource base for raw material

(ii) articulate areas to be permanently kept under forest cover for purpose of soil conservation, erosion control or water resource management,

(iii) that forest land should be classified as parks, game reserves and nature sanctuaries, etc.

A slight modification to the Land Use Decree is the Agricultural Land Policy Statement (Department of Agricultural Sciences, 1997, P.13) whose objectives

> "include establishing an acceptable land tenure system to discourage land fragmentation and make land accessible to all persons; and to ensure that land allocation procedures promote optimal use and land conservation".

A fundamental suggestion/requirement to be able to attend to the above was that the Nation should urgently carry out a detailed soil classification so as to be able to plan efficient land use.

The last statement is the closest to what is expected in a Land Use Policy and this cry continues till today.

THE WAY FORWARD: TOWARDS SUSTAINABLE LAND USE

This section is strictly with reference to pedological studies required to sustain soil mapping works needed that will produce soil survey reports, the foundation document for evaluation towards a sustainable land use.

· **Past Attempts (20th Century):** Soil map/survey production in Nigeria from the mid-20thC was basically, for instance, to establish "the soils and land use of some 16,000 square miles of that part of the cocoa growing area of Western Nigeria which is underlain by metamorphic rocks"(Smyth and Montgomery, 1962, page vii).

The Foreward in Smyth and Montgomery (1962) went further to say that

> "the manual is not final or complete in itself but it provides the framework for the further studies at large scales which are necessary to supply the detailed information for effective land planning on all types of farming projects".

In the same vein, Moss (1957) expressed similar sentiments in the introduction to the Report on the Classification of the soils found over Sedimentary Rocks in Western Nigeria, which is,

" - that certain gaps in the classification will also be obvious, and cannot be filled until work has been done in the large areas of Benin, Ijebu and Delta Provinces still un-surveyed. New series will undoubtedly be found, and ideas concerning those already described will inevitably change as new evidence is obtained from further field work."

Obihara et al., (1963) did some illuminating soil studies (1:50,000) on Anambra-Do River Basin (a tributary to River Niger, South of Lokoja) and this was closely followed by Jungerius' (1964) published exploratory soil map of the old eastern Nigeria (all lands east of River Niger but excluding the lands immediately south of River Benue). The British Ministry of Overseas Development has done a lot of soil resources inventory studies in the northern part of Nigeria, mostly at reconnaissance/small scale levels. It also extended its soil studies southward into the Derived Savanna of western state of Nigeria (Murdoch et. al., 1976).

At the national level, the studies of Doyne et. al., (1938) on soil types and fertility experiments in Nigeria evolved into a provisional soil map in 1944 and was based on the geology and parent material types (FDALR, 1982). Vine's (1951) provisional soil map of Nigeria was based on the degree of leaching, mechanical composition and organic matter content. This was considered as an improvement over that of Doyne et. al. (FDALR, 1982). FDALR (1990) released a soil map of Nigeria at 1:1,000,000 a compilation from its soil survey studies published at 1:250,000.

Smyth and Montgomery (1962) referred to studies at large scales carried out on many projects such as the Farm Settlements and Farm Institutes which supplied "the detailed information for effective land planning on all types of farming projects". I (Okusami) have contributed to studies on large scales that could be beneficial towards correlation and upgrading as suggested by the above authors. These include for instance,

- the detailed reconnaissance map of Origo Association and Associated Soils (1:50,000) – Okusami, 1971.
- the soil survey of the Soil Science Section of the Teaching and Research Farm of the University of Ife, Ile-Ife: 1:2,500.- Okusami 1986, and
- the detailed Soil Survey and Qualitative Land Evaluation of Folawiyo Farm in Ibeju/Lekki Local Government Area of Lagos State. 1:10,000. (Okusami 1989).

· **Contemporary (21st Century):** There has been a call for detailed soil survey studies for the country so that Nigeria can have good supporting soils information required for land use planning and management.

CIAT (International Center for Tropical Agriculture in Colombia) a CGIAR centre, is currently funded (In Brief, 2009) to produce digital maps for sub-Sahara Africa including Nigeria. This sounds embarrassing to me as a Pedologist, an African and a Nigerian that there goes again an opportunity to lay claim to "intellectual property rights" of one of our esteemed natural resources inventory and use potential.

At a recent Inception Workshop with the theme of Revitalizing Agricultural Research in Nigeria (organised by the Agricultural Research Council of Nigeria – International Food Policy Research Institute) the news that fund has been set aside to initiate studies on the detailed soil survey of Nigeria was very cheery.

CONCLUDING REMARKS

Moving Forward: Sustainable Use of Land.

Mr. Vice-Chancellor, I have the following suggestions/recommendations:

A. Resources Base Inventory

(1) Intensification of the production of detailed soil survey reports amenable for use for sustainable land use planning and its management–for both agricultural and non-agricultural land use.

(2) Correlation studies between already identified soil series/types especially within agro-ecological zones or even between those zones with identical geological history are urgently needed.

(3) Definition and delineation of agricultural prime lands and marginal lands are overdue.

B. Land Use Models for Sustainability.

Assumption: Availability of detailed soil survey report with strong write-up on soil-landscape relationships and variabilities.

The following models are recommendations for evaluation:

1. Parallel/Linear Land Use:

- On the Coastal Plain Sand. Lack of a hilly/rugged landscape and the presence of the dominant sandy soil morphology means linear type of agricultural land use could be practiced with trees (cash crops) most adjacent to the Atlantic shore line for wind protection. Other precaution will be according to the closeness of groundwater to the surface, acidity and possibility of salinity.

- On Alluvial Floodplains/Terraces:

Control of flood water if economically and physically feasible will be needed.

2. Centripetal Land Use (Figure 14): this is a radial type of land use to ensure groundwater recharge, minimal soil loss and therefore non-silting of the inland valley lowlands.

- Lands on Pre-Cambrian Formations
    - Inland Valley Systems
    - Quartzite Landscapes
    - Igneous/Metamorphic Landscapes
- Lands on Upper Coastal Plains

The physiography of all the above are typically hilly/rugged and sometimes on slopes as steep as 20% (e. g., Iwaji Series, Okusami 1991).

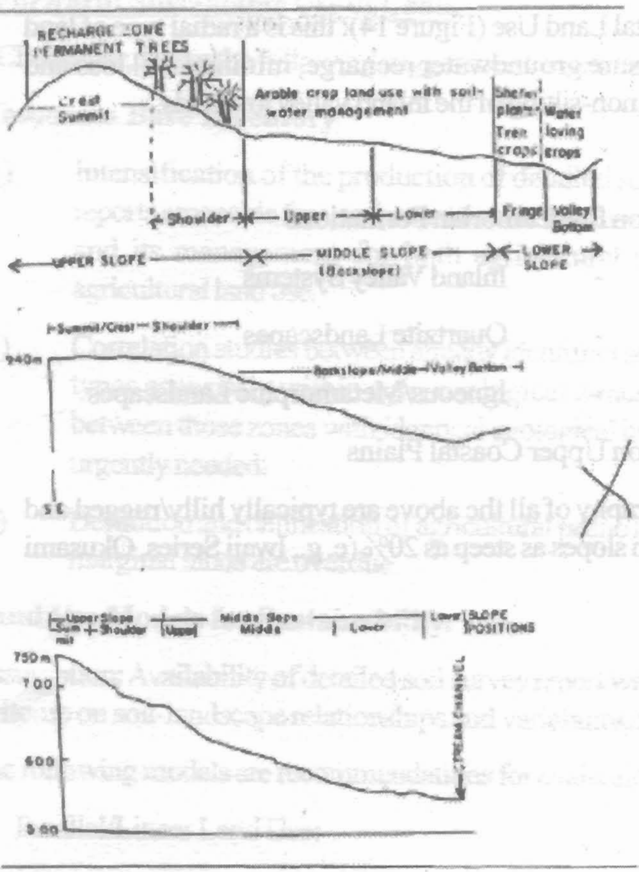


Figure 14. Soil Landscape/Soil Landuse Model (Centripetal)

Figure 14. Soil Landscape/Soil Landuse Model (Centripetal)

C. Institutional Participation and Development:

- Education for Sustainable Land Use and Management

1. Obafemi Awolowo University

- Infrastructure – grossly inadequate for Soil Science Curriculum implementation and sustainability- inadequate laboratories by type and space.

  While I was the Head of Department sometimes in 2003/2004, I prepared a floor by floor space requirement for the Department of Soil Science which could be accommodated by the I.A.R.&T blocks of building. Mr. Vice-Chancellor, we need to support this vision to bring the Department of Soil Science and Land Resources Management to levels comparable with similar facilities in Institutions within and without Nigeria. SOIL IS LIFE, SUSTAIN IT!

- Laboratories need to be well equipped to perform their roles for sustainable land use research and development.

- Curriculum Development: still deficient/lacking in implementation for a 21st century land use management programme.

2. **Governments at all Tiers:** their roles.

Pedological research is capital intensive but rewarding in the preservation of our soil resources and landscape.

- Tripartite (National, state and local governments) funding for Soil Resources Inventory, Evaluation and Development.

- Formulation of a Land Use Policy based on the heterogeneity of the landscapes/soils of Nigeria.

- Legislation especially at the Local Government level to avoid unsustainable Land Use practices:

- Commission large scale soil studies for all aspects of Land Use
- Penalty for State/Local Government misuse of land especially those within urban and immediate surroundings of urban land, e.g. misuse of wetlands especially those located within and immediately surrounding urban areas for houses and similar structures.

Thank you for your attention and God bless.

REFERENCES

Aladejana K. 1982. Guidelines on National Policy on Agricultural Land Resources in Ezedinma et al. (ed.). Efficient use of Nigerian land Resources. Proceedings of the First National Seminar on Agricultural Land Resources. September 13-18, 1982. Federal Department of Agricultural Land Resources. Kaduna.

Asamao, G.K. 1973.Particle size and free iron oxide distribution in some latosols and groundwater laterites of Ghana. Geoderma 10:285-297.

Bartelli, L.J.A., A.A. Klingebiel, J.V. Baird and M.R. Heddleson. 1966. Soil Surveys and Land Use Planning. Proceedings at the Annual Meetings of the Soil Science Society of America and the American Society of Agronomy. Columbus, Ohio. Nov. 1-5, 1965.

Baumgardner, Marion et al. 1983. Soils. P.250. In Conant Francis et al (eds.). Resource Inventory and Baseline Study Methods for Developing Countries. American Association for the Advancement of Science.

Beatty, M.T., G.W. Petersen, and L.D. Swindale (eds) 1979. Planning the Uses and Management of Land. Agronomy No. 21. Wisconsin, USA.

Brewer, R. 1964. Fabrics and mineral analysis of soils. John Wiley & Sons, New York.

Brinkman, R. 1978. Ferrolysis: Chemical and mineralogical aspects of soil formation in seasonally wet acid soils and some practical implications. Pages 295-306 in International Rice Research Institute. Soils and Rice, IRRI. Los banos, Philippines.

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

Cremens David L., Randall B. Brown, and J. Herbert Huddleston (eds.) 1994. Whole regolith pedology: proceedings of a symposium sponsored by Committee S880, Divisions S-5 and S-9 of the Soil Science Society of America and the Clay Minerals Society in Minneapolis, Minnesota. 3 Nov. 1992. SSSA special publication No. 34, Soil Science Society of America. Madison, USA

Crocker, R.L., 1967. The plant factor in soil formation: 179-190. In J.V. Drew (Editor). Selected Papers in Soil Formation and Classification. SSSA Special Publication Series No.1. Soil Science Society of America. Madison, USA

Department of Agricultural Sciences. 1997. National Agricultural Research Strategy Plan: 1996-2001-. Edited and Compiled by Bukar Shaib, Adamu Aliyu and J.S. Bakshi. Federal Ministry of Agriculture and Natural Resources, Abuja, Nigeria.

De' Swardt, A. M. J. 1953. The geology of the country around Ilesa. Geological Survey of Nigeria. Lagos No. 23

Editorial Staff. 1940. Obituary Notice. Soils Fertilizers. 3: 147-48.

F.A.O. 1976. A Framework for Land Evaluation. Soils Bull. 32. Rome. FAO.

Garrity, D. P. 1985. Rice in Eastern and Southern Africa: The role of international testing. 29-45. In: Rice Improvement in Eastern, Central and Southern Africa. Proceedings of the International Rice Workshop, Lusaka. Zambia. April 9-19, 1984. IRRI. Los banos. Phillipines.

Gibbs, H.S. 1955. What use is Pedology? Soils Fertilizers 18:188-90.

Gibbs, H.S. 1966. The Soil factor in the assessment of Land resources. Publication No. 347: 1-8. Department of Scientific Soil Bureau and Industrial Research. Reprinted from New Zealand Agricultural Science. May 1966.

Grove, A.T. 1951. Land use and soil conservation in parts of Onitsha and Owerri Provinces. Bulletin No. 21. Geological Survey of Nigeria.

Hole Frank. 2009. Drivers of unsustainable land use in the Semi-Arid Khabur River Basin, Syria. Geographical Research 47(1): 4-14.

Ilawi, M.,Abdelgawad, and E. Jabour. 1992. Syria: human induced soil degradation. 42-45. In N.T. Middleton, and D.S.G Thomas (eds) World Atlas of Desertification. Edward Arnold. London.

In Brief. 2009. Mapping African Soils. Spore (140):7

Jeje L.K. 1978. A preliminary investigation into soil erosion on cultivated hillsides in parts of Western Nigeria. Geo-Eco-Trop. 1:175-187.

Klingebiel, A.A. and P.H. Montgomery 1961. Land Capability Classification. Agric. Handbook 210. Washington DC. Department of Agriculture.

Lal, Rattan. 1999. World soils and the greenhouse effect. Global Change Newsletter 37: 4-5.

Leeper, G.W. 1953. What use is pedology? Soils Fertilizers 16: 241-42.

Leeper, G.W. 1955. What use is pedology? Soils Fertilizers 18: 375-76.

Marbut, C.F. 1935. The soils of the United States. In USDA Atlas of American Agriculture, Part 3, Advance Sheets, No.8.

McCarthy James J. and Nancy M. Dickson 2000. From Friibergh to Amsterdam: On the Road to Sustainability Science. Global Change Newsletter 44:6-8

Moss, R.P. 1957. Report on the Classification of the Soils found over Sedimentary Rocks in Western Nigeria. Ibadan. February 1957

Muda, S.A. 1999. Characterization of Soils in landforms ultrabasic rock origin in southwest Nigeria. M.phil. Thesis (un published) Obafemi Awolowo University Library. Ile-Ife. Nigeria. 103pp

National Geographic 2008. Our Good Earth. The Future rests on the soil beneath our feet. National Geographic 214(3):80-111.

Northcote, K. H. 1954. The place and function of pedology in soil science. Soils Fertilizers 17:305-10.

Ofomata, G.E.K. 1964. Soil erosion in the Enugu region of Nigeria. African Soils, IX(2):289-248.

Ofomata, G.E.K. 1965. Factors of soil erosion in Enugu area of Nigeria. Nigerian Geographical J. 8:45-59.

Ofomata, G.E.K. 1981. Actual and potential erosion in Nigeria and measures of control. Paper presented at the 9th Annual Conference of the Soil Science Society of Nigeria. Owerri, December 6-10, 1981.

Ofomata, G.E.K. 1982. Use and misuse of Nigeria's agricultural land resources. PP.119-130. In Federal Department of Agricultural land Resources (FDALR). Proceedings of the First National Seminar on Agricultural Land Resources, Kaduna. September 13-18, 1982.

Ojanuga, A.G. and T.A. Okusami. 1975. Soil Map of Okaka Farm, Okaka. Oyo State. 1 Sheet. Department of Soil Science. University of Ife, Ile-Ife.

Okusami, T.A. 1971. Detailed Reconnaissance Map of Origo Association and Associated Soils. Ede. I sheet Osun Division. Western State. Department of Soil Science. University of Ife, Ile-Ife.

Okusami, T.A. 1972. Increasing Available Subsurface Water for Agriculture. Project Paper. International Post-graduate Course on Hydrological Methods for Developing Water Resources Management. Research Institute for Water Resources Development (VITUKI). Budapest, VIII. Hungary.

Okusami, T.A. 1985. Hydromorphism: Its definition and correlation between three major classification systems with reference to West Africa. Ife J. Agric. 7:26-34.

Okusami, T.A. 1986. Soil Survey of the Soil Science Section of the Teaching and Research Farm of the University of Ife, Ile-Ife. Mimeo. p.39 plus 4 Figures.

Okusami, T.A. 1989. Detailed Soil Survey and Qualitative Land Evaluation of Folawiyo Farm in Ibeju/Lekki Local Government of Lagos State. Nigeria. UNIFECS Consultancy Services Centre. Obafemi Awolowo University, Ile-Ife. Iv + 76p and 2 Figures.

Okusami, T.A. 1990. The roles of soil morphology and land characteristics in rapid land evaluation for sustainable agriculture in some soils of Southwest Nigeria. Niger. J. Agric. Sci. 5(1): 15-27.

Okusami, T.A. 1991. Quartzitic sloping landscapes of humid tropics: Soils and land evaluation studies of an upland rice-based cropping systems in Upper Osun River Basin of Southwest Nigeria. African Soils. 24: 49-84.

Okusami, Temitope A. 1994. 'Characteristics and Genesis of Soils Formed in Landscapes of Biotite Gneiss Origin from the Humid Tropics of Nigeria. Volume 6b. pp. 82-83 in World Congress of Soil Science. July 10-16. 1994. Acapulco. Mexico.

Okusami, T.A. 1995. The potential for sustainable use of inland valleys in sub-Sahara: Contributions to the status report on Nigeria. Presented at the National Unit of the Consortium on Inland Valley Research in Sub-Sahara: Membership and First National Workshop. January 7-20.1995. National Cereals research Institute. Badeggi. Niger State.

Okusami, Temitope Abayomi. 1981. Land and Pedogenetic Characterization of selected Wetlands in West Africa with Emphasis for Rice production. Ph. D. Thesis. Univ. of Minnesota, St. Paul. Univ. Microfilms #313130. Ann. Arbor.Mich.

Okusami, T.A. 1996. Acid sand soil on Atlantic coastal plain landforms of southwest Nigeria. Property variabilities and land evaluation for agricultural use. Ife J. Agriculture 18: (1 & 2: 112-126).

Okusami, T.A. 1997. The characterization, classification and evaluation of acid soils on upper coastal plains of Lagos State. Ife J. Agric. 19:92-116.

Okusami Temitope A. 2006. Catena/Toposequence/Soil Association: Unifying Concept in Soil Classification, Soil Genesis and Land Use in the West Africa Sub-Region – Nigeria. (An Oral Presentation). 18th World Congress of Soil Science. July 9-15. 2006. Philadelphia. Pennsylvania. USA.

Okusami, T.A., E.A. Aduayi and A. A. Jayeola. 1988. Soil Survey, Soil Fertility and Land Suitability Evaluation for Upland Rice Production at Igbodu-Ketu in Epe Local Government Area of Lagos State. UNIFECS Consultancy Services Centre. Obafemi Awolowo University. Ile-Ife. V + 75p and 4 Figures.

Okusami, T.A., R.B. Corey and E.E. Schulte. 1974. Production potentiality of Origo soils in Ife-Ilesha and Osun Divisions of Western State. Niger J. Agric. 11(3): 23-34.

Okusami, T.A. and A.G. Ojanuga. 1984. The characteristics and classification of some montmorillonite soils in Central Western Nigeria. Niger. J. Sci. 18:43-48.

Okusami, T.A. and G. O. Oyediran. 1985. Slope-soil relationships on an aberrant toposequence in Ife area of south western Nigeria: Variabilities in soil properties. Ife J. Agric. 7(1&2): 1-11.

Okusami, T.A., G. Olaniyan, and E.O. Ajayi. 1995. Soil characteristics of Inland Valley, agro-ecosystems in humid and sub-humid agro-ecologies of Nigeria. 291-299. In J.Y. Jamin, and P.N. Windmeijer (eds). Characterization of Inland Valley Agro-ecosystems: a tool for their sustainable use. Proceedings of the 1st Scientific Workshop of the Inland Valley Consortium. Nov. 6-10. 1995. WARDA. Boake. Ivory Coast

Okusami, T.A., D.A. Osiname and A.O. Olaleye. 2004. Producing and Potential rice fields in Nigeria: Prospects and Constrains. The Nigeria Rice Memorabilia. Abuja.

Okusami, T.A. and R.H. Rust. 1992. Occurrence, characteristics and classification of some hydromorphic soils from South Nigeria. 185-197. In: Kimble J.M.(ed). Proceedings of the Eighth International Soil Correlation Meeting (viii ISCOM.). Characterization, Classification and Utilization of Wet Soils. USDA SCS, National Soil Survey Centre, Lincoln. NE. USA.

Okusami, T.A., R.H. Rust, and A.O. Alao. 1997. Red Soils of different origins from southwest Nigeria. Characteristics, classification and management considerations. Can. J. Soil Sci. 77:295-307.

Okusami, T.A., R.H. Rust and A.S.R. Juo. 1985. Characteristics and classification of some soils formed on post-cretaceous sediments in Southern Nigeria. Soil Sci: 140(2):110-119.

Okusami, T.A., R.H. Rust and A.S.R. Juo. 1987a. Properties and classification of five soils on alluvial landforms in central Nigeria. Can. J. Soil Sci. 67:249-261.

Okusami, T.A., R.H. Rust and A.S.R. Juo. 1987b. Reactive characteristics of Certain Soils from south Nigeria. Soil Science Society of America. 51(5):1256-1262.

Orimoyegun, S. O. and T. A. Okusami. 1995. Landscape and soil factors influencing Teak (Tectona grandis L. F.) growth at Gambari Forest Reserve in Oyo State Nigeria. "The proceedings of Third African Soil Science Society in conference. Special Edition African Soils. XXVIII(28):467-473.

Osei, B. A. 1990. Characterization and classification of soils formed in amphibolite-derived parent material in southwestern Nigeria. M. Phil. Thesis (unpublished). Obafemi Awolowo University Liabrary. Ile-Ife. Nigeria. 118pp.

Oyediran, G. O. 1987. Characterization of soils in selected inland valleys of Bida area, Niger State of Nigeria. M.Phil. Thesis. (Unpublished). Obafemi Awolowo University Library. Ile-Ife. Nigeria. 175 pp

Oyediran, G. O. 1990. Genesis, classification and potential productivity of selected wetland soils in the Savanna ecosystem of Nigeria. Ph.D. Thesis (Unpublished). Obafemi Awolowo University Library. Ile-Ife. Nigeria. 335 pp.

Planetearth. 2005. Soil-Earth's living skin.

Prospectus for a key theme of the international year of Planet Earth. Earth Sciences for Society Foundation, Leiden. The Netherlands

PUNCH NEWSPAPER. 2009."Yar'Adua Inaugurates Committee on Land Reform". Friday, April 3, 2009. NEWS. Page 7.

Sada, P.O., and G.E.D. Omuta. 1979. Auchi Urban Area. A preliminary report on Erosion and Environmental Problems and Planning. Pp 130-152. In P.O. Sada and G.E.D Omuta (eds)., Spatial Perspectives in National Development. Proceedings of the 2nd Annual Conference of the Nigerian Geographical Association, Benin, March 28-April 01, 1979.

Sigmund, A.A.J. de. 1938. The principles of soil science.(Transl. from Hungarian by A.B. Yolland: edited by G.V. Jacks).T. Murby and Co., London.

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

Smyth, A.J., and R.F. Montgomery. 1962. Soils and Land Use in Central Western Nigeria. The government of Western Nigeria. Ibadan. 265 p.2 Maps and One Paper Disc.

Spencer, S. C. Dunstan. 1991. A farming system research strategy for the development of inland valleys for increased food production in west Africa. Agricultural Systems in Africa. 1(2): 5-14.

Stamp, L.D. 1938. Land utilisation and soil erosion in Nigeria. Geographical Review 28:32-45.

Steffen Will, Joãn Morais and Wendy Broadgate 2000. The Challenge of Amsterdam 2001: Binding Towards a New Science for Global Sustainability. Global Change Newsletter 44:1-2.

Sykes, R.A. 1940. A history of anti-erosion work at Udi. Farm and Forest 1:3-6.

Tiessen, H., and D.W. Anderson. 1992. Concepts and Methodologies for Measuring the Sustainability of Managed Ecosystems .Presented to Sustainable Land Management. International Board for Soil Research and Management (IBSRAM). Chiang Rai. Thailand.

United Nations Environment Programme (UNEP) 1997. Global Environment Outlook. Oxford University Press. New York. P. 236.

Vilenskii, D.G 1957. Soil Science. (Transl. by A. Birron and Z. S. Cole) Israel Prog. for Sci. Trans. Jerusalem, 1960. Available U.S. Dept. Commerce, Washington.

World Resources Institute – 1992 (In http://www.wri.org)

APPRECIATION

§ I heartily thank the following for assisting with my tertiary education:

- Western State/Ogun State–Undergraduate programme at the University of Ife, Ile-Ife; and Ph.D programme at the University of Minnesota, St. Paul, Twin Cities, Minnesota, U. S. A., and

- USAID (United States Agency for International Development) for the award of Postgraduate Fellowship for my M.Phil programme at the University of Ife, Ile-Ife and

- International Institute of Tropical Agriculture, Ibadan, for the funding of my one year research fellowship towards my Ph.D programme, and financial support (Netherlands/Japanese Governments agencies) towards the two theses of Oyediran (1987 and 1990) under my supervision

  I equally appreciate the confidence reposed in me through the award of Federal Government scholarship for my Ph.D programme although unutilised. I acknowledge the award of Commonwealth Fellowship which I could not use because of the suspension of Nigeria from the Commonwealth at the material time.

§ I benefitted immensely from Professional Development Programmes sponsored through:

- UNESCO/Hydrological Decade Fellow and (ii) the United Nations University Institute for Natural Resources in Africa

§ I benefitted from Research Grants by Western Nigeria Marketing Board based in the Faculty of Agriculture; Obafemi Awolowo University/University Research Committee; Social Science Research Council/American Council of Learned Societies: Project Development Grant; and United Nations University Institute for Natural Resources in Africa (UNU/INRA). AND

Travel Grants by: the International Centre for Theoretical Physics, Trieste, Italy; the United Nations Development Programme; the Social

Science Research Council/American Council of Learned Societies; the German Academic Exchange (DAAD) Visiting Fellow; the United Nations Environmental Programme; the Japan International Cooperation Agency (JICA); the Third World Academy of Science (TWAS)/Institute of Agronomy, Campinas, Brazil; the 15th World Congress of Soil Science Organizing Committee/International Soil Science Society; and the Rockefeller Foundation

§ And the University of Ife (now Obafemi Awolowo University) for providing the enabling environment for my academic and social life.

§ My teachers/mentors at all levels: Mr. Grillo (possibly Prof.) – Primary; Late Chief Oshuneye (Secondary); Prof. R.B. Corey and Prof. R.H. Rust at Tertiary Institutions. I cannot forget Late Prof. Wilkinson and others of the USAID/Wilkinson team.

§ My parents (both late), MR. Simeon J. Adekanbi. Okusami and MRS. Dorcas EbunOluwa Okusami are very much appreciated for laying the foundation.

§ AND the GREATEST!; "LORD OF HOSTS"