COURSE CODE: SOS 314

COURSE TITLE: INTRODUCTION TO PEDOLOGY AND SOIL PHYSICS

NUMBER OF UNITS: 3 Units

COURSE DURATION: Two hours per week

COURSE DETAILS:

Course Coordinator: Dr. J. K. Adesodun *BSc., MSc., PhD*
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Other Lecturers: Dr. B.A Senjobi., Dr. G.A. Ajiboye; Dr. S.J. Akinsete; and Dr. M.A. Busari

COURSE CONTENT:

Factors and processes of soil formation; rock weathering and common minerals in soil; soil morphological characteristics and profile description; characterization of soils using diagnostic properties; soil survey, mapping and classification.

Soil texture and surface area of particles; volume-mass relationships in soil; bulk density; porosity; soil water; hydrological cycle; water balance; water content and water retention; field capacity and permanent wilting point; water flow in soils; energy balance; soil erosion and its control; conservation tillage.

Practical: Field: Soil profile description; morphology; texture by feel; colour; horizon designation; sampling soil profile for water content and bulk density determination; comparing soil texture by feel wit texture by particle size distribution, soil temperature measurement in the field

COURSE REQUIREMENTS:

This is a compulsory course for all students in 300 level of B. Agric program in the University. In view of this, students are expected to participate in all the course activities and have a minimum of 70 % attendance to be able to write the final examination.

READING LIST:

1. Fitzpatrick, E.A., 1980. Soils – Their Formation, Classification and Distribution. London: Longman, 353 pp.
2. Fitz Patrick, E.A., 1986. An Introduction to Soil Science, 2nd edn. Essex, England/ New York: Longman Scientific & Technical/Wiley, 255 pp.
3. Young, A., 1976. Tropical Soils and Soil Survey. Cambridge: Cambridge University Press. 468 pp.
4. Lal, R and Shukla M.K., 2004. Principle of Soil Physics. Marcel Dekker Inc. New York. Pp 716.
5. Leeper, GW and Uren, NC. 1993. 5th edn, Soil science, an introduction, Melbourne University Press, Melbourne

LECTURE NOTES

FACTORS OF SOIL FORMATION

There are five soil forming factors:- parent material, topography, climate, biological activity, and time.

Parent material

Parent material is the initial mineral substance that forms a soil. It is derived from the weathering of rocks and may reside at the site of its origin or be transported from somewhere else to its current location.

Material can be eroded from one place and transported to another where it becomes parent material for a soil at the new site.

Several forces can supply energy for the transportation of parent material: ice, wind, water, and gravity.

Ice

Glacial deposits occur at the front and sides of advancing ice.

Wind

Wind deposits two major types of material: eolian sands and loess.

Eolian sands are windblown deposits of material predominantly greater than 0.05 mm (0.05 to 2 mm) in diameter.

Loess, which is windblown silt-sized material (0.002 to 0.05 mm), once airborne, can travel several hundred kilometers before deposition. Windblown material tends to have sharp edges, a conchoidal shape, and surface etching.

Water

An alluvial or stream-borne deposit occurs in floodplains, fans, and deltas.

Gravity

Colluvium or hillslope sediments result from the force of gravity and runoff moving downslope.

Topography (relief)

Topographic relief, or the slope and aspect of the land, has a strong influence on the distribution of soils on a landscape. Two aspects of topography that influences soil formation are the altitude and the slope.

Slope affects soil depth, water infiltration rate and runoff while altitude modifies the microclimate.

Climate

Two aspects of climate that are important in the process of soil formation are rainfall and temperature. The total amount of rainfall as well as its intensity and distribution pattern affects the rate of soil development differently. Temperature affects the rate of biochemical and biophysical reactions taking place in the soil environment.

Climate also affects the type and amount of vegetation in a region.

Biological activity

Biological activity and climate are active forces in soil formation. Soil pedogenesis involves a variety of animals, plants, and microorganisms. Ants, earthworms, and burrowing animals, for example, mix more soil than do humans through plowing and construction

Time

Soils develop over time. Soil formation is a dynamic process, where a steady state is slowly approached but only rarely reached.

WEATHERING

Weathering is the physical and chemical processes by which rocks and minerals are disintegrated, decomposed, and re-synthesized into new compounds. Weathering encompasses both physical and biogeochemical processes, which generally occur simultaneously.

PHYSICAL WEATHERING

Physical weathering is the mechanical disintegration of rocks and minerals into smaller sizes. Some of the several mechanisms that work to break apart rocks include: temperature, water, ice, glaciers, erosion, wind, plants and animals.

Temperature

Seasonal and even day-to-night temperature changes cause the outer surface to separate and peel off.

Water

The force of raindrops beating down on soft rocks, and the scouring effect of suspended material in water flowing over rocks can wear the rocks away with time.

Ice

Water can infiltrate the cracks and pores of rocks and freeze. As the ice expands and thaws, the rocks break up.

Glaciers

Glaciers weather rocks in several ways. The weight of a glacier can crush rocks. As it moves over an area, a glacier can grind and pulverize rocks. As it recedes, the pressure release can cause rocks to expand and crack.

Erosion

Erosion causes pressure-release related weathering.

Wind

Wind suspends fine particles. As the particles are pushed and bounced over one another, they abrade the rock surfaces over which they pass, slowly wearing the rocks down.

Plants and Animals

The expansion and decomposition of roots growing in soil can alter the density and coherence of particles. The digging and burrowing of animals can have the same effect.

CHEMICAL WEATHERING

The process of chemical weathering changes the atomic makeup of a mineral.

Mechanisms of chemical weathering includes:-

Solution.....$CaCl_2 + H_2O \rightarrow Ca^{2+} + 2Cl^- + H_2O$

Hydration.....$2Fe_2O_3 + 3H_2O \rightarrow 2Fe_2O_3.H_2O$

Hydrolysis.....$KAlSi_3O_8 + H_2O \rightarrow HAlSi_3O_8 + KOH$

Carbonation.....$CaCO_3 + H_2O \leftrightarrow HCO_3^- + Ca^{2+} + H^+$

Oxidation/reduction.....$4FeO + O2 \leftrightarrow 2Fe_2O_3$

COMMON MINERALS IN SOILS

Soil minerals are also referred to as either *primary* or *secondary* minerals. They are usually derived from igneous or metamorphic rocks, but they can be inherited from sedimentary rocks as well.

Although different classification schemes could be used, mineralogists have classified soil minerals based on the dominant anion or anionic group. The classes include: (1) native elements, (2) sulphides, (3) sulphosalts, (4) oxides and hydroxides, (5) halides, (6) carbonates, (7) nitrates, (8) borates, (9) phosphates, (10) sulphates, (11) tungstates, and (12) silicates

The native elements, sulphosalts, nitrates, borates, and tungstates occur rarely in soil.

1. Halide, Sulphate, and Carbonate Minerals

The major soil minerals of this group are halite (NaCl), gypsum ($CaSO_4 \bullet 2H_2O$), calcite ($CaCO_3$), and dolomite [$CaMg(CO_3)_2$]. This group is characterized by minerals with relatively simple structures. The other minerals in this group have similar structures with cations such as Ca^{2+}, Mg^{2+}, or Fe^{2+} alternating with anions such as S_2^{2-}, SO_4^{2-}, or $CO_3^{\ 2-}$ The bonds between the cations and anions are predominantly ionic.

The minerals are highly soluble, easily leached and are therefore lost early during the weathering process. They are only present in appreciable quantities only in young soils or under arid conditions

2. Sulphides

Pyrite, FeS_2, the most common mineral in this group, does not occur extensively in soils, but when it is present it causes some unique problems. Pyrite often occurs in close association with coal. Pyrite is unstable under oxidizing conditions. Pyritic oxidizes in when waterlogged soils are drained or when mining leaves pyritic material on the surface to jarosite, $KFe_3(SO_4)_2(OH)_6$, and gypsum and sulfuric acid, H_2SO_4 causing high soil acidity. Soils affected by pyrite are referred to as acid-sulphate soils.

3. Oxides, Hydroxides and Oxy-hydroxides

Primary minerals break down during weathering and release cations and anions that recombine to form other more stable minerals. Several elements, in particular Al, Fe, and Mn, form oxide, hydroxide, or oxy-hydroxide minerals that are stable in the soil weathering environment.

a. Aluminum

Gibbsite, [$Al(OH)_3$] is the most common Al hydroxide mineral in soils. It is generally associated with the latter stages of weathering when leaching of silica has progressed to the point that phyllosilicate minerals no longer form. Gibbsite is common Oxisols, Andisols and weathering interface between igneous rock and saprolite.

b. Iron

Iron oxide minerals form from Fe released from primary minerals. Iron oxides are strong pigments and small amounts of these minerals account for most of the brown and red colors of soils. Goethite (FeOOH) is the most common mineral of this group and accounts for the brownish to yellowish color of many soils, while hematite (Fe_2O_3) is responsible for the red color of many soils. Large amounts of these two minerals occur in association with gibbsite and kaolinite in highly weathered soils

c. Manganese

Manganese oxides and hydroxides are commonly found in soils as brown or black nodules or as thin coatings on the faces of soil structural units. They are often associated with Fe oxides. Manganese occurs frequently as birnessite or lithiophorite in soils.

d. Titanium

Rutile and ilmenite occur in soils mainly as primary minerals inherited from igneous rocks. Anatase is less common and is generally considered a secondary mineral. Although frequently found in soils, these minerals do not occur in sufficient quantity to impact soil physical or chemical properties.

4. Silicates

The silicate mineral class is an extremely large and important group of minerals. Nearly 40% of the common minerals are silicates, as are most minerals in igneous rocks. Silicates occur as both primary minerals inherited from igneous or metamorphic rocks and as secondary minerals formed from the weathering products of primary minerals. The fundamental unit of all silicate structures is the SiO_4 tetrahedron. It consists of four O^{2-} ions at the apices of a regular tetrahedron coordinated to one Si^{4+} at the center. The individual tetrahedra are linked together by sharing O^{2-} ions to form more complex structures. Several different arrangements of the SiO_4 tetrahedra occur, partly accounting for the large number of silicate minerals and providing the basis for their classification. The tetrahedra may be present as single tetrahedra (nesosilicates), double tetrahedra (sorosilicates), rings (cyclosilicates), single or double chains (inosilicates), sheets (phyllosilicates) or three-dimensional frameworks (tectosilicates)

Soil Morphological Characteristics

This refers to the properties of the soil that can be observed either by sight of feel

COLOR

The most obvious soil characteristic is color. Although color is not used as a quantitative measure, it does give a good indication of organic matter contents, drainage conditions and mineralogical compositions. Black soil may indicate the presence of organic matter, red indicates the presence of oxidized iron while gray or bluish gray color indicates water saturation. Soil color is described by three attributes: hue, value, and chroma.

Hue: is the dominant spectral color. It is related to the wavelength of light reflected by soil particles.

Value: Value is the lightness or darkness of the color. It is a measure of the amount of light reflected.

Chroma: Chroma is the strength or purity of color. It indicates the degree of difference between white, black, or neutral color.

Munsell Soil Color Charts *is use for the determination of soil color a*nd contain several series of distinctively colored chips. Each page represents a different hue. The chart normally has 15 pages, each with a number (10, 7.5, 5, or 2.5) followed by a letter or letters indicating red (R), yellow (Y), green (G), blue (B), or combinations of these.

Value units range between 0 and 10. The numbers ascend vertically on the page from the lowest to highest numbers, indicating dark to light values.

Chroma units are arranged horizontally across the page from 0 to 10, increasing in numbers from left to right. Low numbers indicate an increase in grayness, while high numbers signify a pure color with little mixing with other hues.

Colour Mottles

The mottles must be described by their abundance, size, and contrast to the background.

Abundance: Abundance is the relative amount of mottling. Abundance can be classified as *few*; *common* or *many*.

Size: Size is a measure of the estimated average diameter of individual mottles along their greatest dimension. It could be *fine*; *medium*; or *coarse*.

Contrast: Contrast is an indication of the relative difference in color between the matrix and mottles. Mottle contrast may be described as faint, distinct or p*rominent*

MASTER HORIZONS

Horizontal layers of soil called horizons can be described by their different morphological characteristics. Capital letters designate master horizons, which are further subdivided by Arabic numerals.

O Horizon : O horizon is an organic horizon. It is a surface layer characterized by accumulation of organic matter which may be dominated by partially decomposed or undecomposed organic material.

A Horizon : The A horizon is the uppermost mineral layer. It may lie below the O horizon. An A horizon has a high concentration of humus and it is usually regarded as an elluvial surface horizon.

E Horizon : The E horizon is an elluvial surface horizon. It has experience the loss of clay, organic matter, iron and aluminum oxides with the resultant accumulation of quartz and other resistant minerals. It is also characterized by bleached appearance because of loss of materials.

B Horizon : The B horizon is a subsurface mineral horizon showing evidence of illuvial accumulation of silicate clay, iron, aluminum, gypsum, or silica; carbonate removal; residual concentration of sesquioxides and silicate clay; coating of sesquioxides, (etc.).

C Horizon : The C horizon is a layer of minimal alteration. Material may be similar to or unlike that from which the other horizons formed.

R Layer: An R layer refers to hard consolidated bedrock. The R layer is presumed to be the material from which the overlying horizons are developed. But if it is a different material from that of the overlying mantle, it is represented by IIR, indicating what is called LITHOLOGICAL DISCOUNTINUITY.

TRANSITIONAL HORIZONS

Transitional horizons are dominated by properties of one master horizon but have the subordinate properties of another. These are designated by two capital letters, for example, AB, EB, BE, or BC. The first letter represents the dominant horizon characteristics.

SUBORDINATE DISTINCTIONS

Master horizons are further divided by subordinate characteristics, which usually do not apply to transitional horizons. Subordinate distinctions are identified by lower-case letters, called suffix symbols.

- ***a.*** *Highly decomposed organic material.* ***b***. *Buried genetic horizon.* ***c.*** *Concretions or nodules.* ***d***. *Physical root restriction.* ***e.*** *Organic material of intermediate composition.* ***f.*** *Frozen soil.* ***g***. *Strong gleying.* ***h***. I*lluvial accumulation of organic matter.* ***i***. *Slightly decomposed organic matter.* ***k***. *accumulation of carbonates.* ***m***. *cementation or induration, km* . Cementation by carbonates; *qm* . Cementation by silica; *sm*. Cementation by iron; *ym*. Cementation by gypsum; *kqm*. Cementation by lime and silica; and *zm*. Cementation by salts more soluble than gypsum. ***n***. *Accumulation of sodium.* ***o***. *Residual accumulation of sesquioxides* ***p***. *Tillage or other disturbance.* ***q***. *Accumulation of silica.* ***r***. *Weathered or soft bedrock.* ***s***. *illuvial accumulation of sesquioxides and organic matter.* ***ss*** . *Presence of slickensides* ***t*** . *Accumulation of silicate clay* ***v*** . *plinthite.* ***w***. *development of color or structure.* ***x***. *fragipan character.* ***y***. *Accumulation of gypsum* ***z*** . *accumulation of salts more soluble than gypsum*

DIAGNOSTIC HORIZONS:

Master horizons describe a soil profile, while diagnostic horizons are used to classify soils. Whereas master horizons are based on appearance, diagnostic horizons are based on soil formation processes. There are two types of diagnostic horizons. These are surface (epipedon) and subsurface horizon (Endopedon).

EPIPEDONS

An epipedon is the surface, or uppermost soil horizon. They are not synonymous to the A horizon. They may be thinner than the A horizon, or include the E or part or the entire B horizon.

Histic epipedon

This organic horizon is water saturated long enough for reduced conditions to occur unless artificially drained. It is 40 to 60 cm thick and has a low bulk density often less than 1 g cm^3.

Mollic epipedon

This epipedon is a soft dark grassland soil. Its organic carbon content is 0.6 percent or more; its base saturation is 50 percent or more; It has a minimum thickness of 18 cmand contains less than 250 ppm P_2O_5.

Anthropic epipedon

While similar to the mollic epipedon, the anthropic epipedon contains greater than 250 ppm citric acid soluble P_2O_5 with or without a 50 percent base saturation.

Umbric epipedon

Mollic-like in thickness, organic carbon content, color, P_2O_5 content, consistence, and structure, this epipedon has less than 50 percent base saturation.

Ochric epipedon

Ochric epipedon is light in colour and low in organic matter and too thin to be any of the other five epipedons. Ochric epipedon is the most common epipedon in Nigerian soils.

Plaggen epipedon

This man-made horizon is 50 cm or more thick and has resulted from centuries of accumulation of sod, straw, and manure, for example. It commonly contains artifacts such as pottery and bricks.

DIAGNOSTIC SUBSURFACE HORIZONS

Diagnostic subsurface horizons can be categorized as weakly developed horizons, as horizons featuring an accumulation of clay, organic matter, or inorganic salts, as cemented horizons, or as strongly acidic horizons.

Agric

The agric horizon is an illuvial horizon that has formed under cultivation and contains significant amounts of illuvial silt, clay, and humus. It is usually formed after prolonged years of cultivation.

Albic

Albic (L. *albus*, white) materials are soil materials with a color that is largely determined by the color of primary sand and silt particles rather than by the color of their coatings.

Argillic (Bt)

An argillic horizon is normally a subsurface horizon with a significantly higher percentage of phyllosilicate clay than the overlying soil material. It shows evidence of clay illuviation.

Calcic

The calcic horizon is an illuvial horizon in which secondary calcium carbonate or other carbonates have accumulated to a significant extent.

Cambic

This horizon shows some evidence of alterations but is very weakly developed between A and C horizons. The cambic horizon has less illuviation evidence than found in the argillic and spodic horizons.

Gypsic (By) accumulation of $CaSO_4$; 15 cm or more thick 5% or more calcium sulfate.

Glossic (B/E) consists of an eluvial part (E - albic) and an illuvial part (Bt - argillic, or Bto- kandic or Btn-natric) sometimes referred to as tounging

Kandic (Bto) - fine textured subsurface horizon that has evidence of clay translocation and is composed mostly of low activity clays (low CEC and ECEC). The CEC (by the 1N NH_4OAC method at pH=7) is 16 cmol(+) or less per kg of clay and the ECEC (by the basic cations displaced by ammonium plus KCl extractable aluminum methods) is 12 cmol(+) or less per kg of clay.

Natric (Btn) - meets all the requirements of the argillic horizon and, in addition, has: a. either prismatic or columnar structure b. either (1) an exchangeable sodium percentage of 15 percent or more or (2) a sodium adsorption ratio (SAR) of 13 or more.

Oxic (Bo) - highly weathered horizon that consists of oxides of iron and aluminum, 1:1 clays and resistant minerals such as quartz. It has a thickness of 30 cm or more; less than 10 percent weatherable minerals; low CEC (≤ 16 cmol(+) per kg of clay

Salic (Bz) soluble salt accumulation - salts more soluble than gypsum 15 cm or more thick EC _>_ 30dS/m in a 1:1 soil water extract

Spodic (Bs or Bhs) - illuvial accumulations of sesquioxides and/or organic matter composed of spodic materials.

Other Diagnostic Soil Features

Abrupt textural change. Ochric or Albic overlies an argillic considerable increase in clay over a short distance in the profile usually double the clay content within a vertical distance of 7.5 cm

Glacic - (Bf). Ice in the form of ice lenses or wedges.

Lamellae - (Bt or Bw). Number of clay-enriched layers separated by coarser textured layers illuvial horizon less than 7.5 cm thick horizontal bands contain an accumulation of oriented clay bridging sand grains lamellae occur in a vertical series of two or more; each lamellae has an overlying eluvial.

Lithologic discontinuity. (Numerical prefix; e.g. 2Bt1) change in parent material geologic process rather than pedogenic possibly indicated by abrupt textural change, contrasting particle sizes, stone lines, mineral composition or orientation of rocks.

Plinthite - (Bv). Humus poor, iron-rich, ironstone hardpan hardens irreversibly after being exposed to repeated wetting and drying in place begins as soft, red iron segregations (mottled appearance) due to oxidation.

Slickensides - (Bss). Polished or grooved clay surfaces produced by one soil mass sliding against another common in shrink-swell clays indicates vertic.

Densic contact - (Bd or Cd). Boundary between soil and underlying densic material (plow pan, glacial till, etc).

Lithic contact - (R). Boundary between soil and consolidated underlying material digging with hand tools is impractical.

Paralithic contact - (Cr). Boundary between soil and weathered bedrock underlying material can be dug with hand tools.

CLIMATOLOGICAL DATA: A Source of criteria for soil classification.

Soil Moisture Regimes

The term “soil moisture regime” refers to the presence or absence either of ground water or of water held at a tension of less than 1500 kPa in the soil or in specific horizons during periods of the year.

Classes of Soil Moisture Regimes

Aquic moisture regime. The aquic moisture regime is a reducing regime in a soil that is virtually free of dissolved oxygen because it is saturated by water.

Aridic and torric moisture regimes. These terms are used for the same moisture regime but in different categories of the taxonomy. In the aridic (torric) moisture regime, the moisture control section is dry in all parts for more than half of the cumulative days per year.

Udic moisture regime. The udic moisture regime is one in which the soil moisture control section is not dry in any part for as long as 90 cumulative days in normal years.

Ustic moisture regime. The ustic moisture regime is intermediate between the aridic regime and the udic regime. Its concept is one of moisture that is limited but is present at a time when conditions are suitable for plant growth.

Xeric moisture regime. The xeric moisture regime is the typical moisture regime in areas of Mediterranean climates, where winters are moist and cool and summers are warm and dry.

SOIL TEMPERATURE REGIMES

Classes of Soil Temperature Regimes

Following is a description of the soil temperature regimes used in defining classes at various categoric levels in this taxonomy.

Cryic (Gr. *kryos*, coldness; meaning very cold soils). Soils in this temperature regime have a mean annual temperature lower than 8 ^{oC} but do not have permafrost.

Frigid. A soil with a frigid temperature regime is warmer in summer than a soil with a cryic regime, but its mean annual temperature is lower than 8 ^{oC} and the difference between mean summer and mean winter soil temperatures is more than 6 ^{oC}

Mesic. The mean annual soil temperature is 8 ^{oC} or higher but lower than 15 ^{oC}, and the difference between mean summer and mean winter soil temperatures is more than 6 ^{oC}.

Thermic. The mean annual soil temperature is 15 ^{oC} or higher but lower than 22 ^{oC}, and the difference between mean summer and mean winter soil temperatures is more than 6 ^{oC}.

Hyperthermic. The mean annual soil temperature is 22 ^{oC} or higher, and the difference between mean summer and mean winter soil temperatures is more than 6 ^{oC}.

ISO

If the name of a soil temperature regime has the prefix *iso*, the mean summer and mean winter soil temperatures differ by less than 6 ^{oC}.

SOIL CLASSIFICATION

International Soil Classification Systems

There are two major world soil classification systems. These are the United State Department of Agriculture (UDSA) taxonomic system and the World Food and Agricultural Organization (FAO) World Reference Base System (USDA, 2003; FAO, 2006). These are systems designed for universal application. They should classify any soil, and serve to **correlate** experiences on similar soils all over the world.

USDA SYSTEM OF SOIL CLASSIFICATION

The USDA classification system is a multi- categorical and hierarchical system. Thus the classes in the highest categories are divided into smaller classes in the lower one and continue to the lowest level, which is the soil series.

The USDA system comprise a hierarchy of 6 levels

- Orders (12) (surface and subsurface diagnostic horizons)
- Suborders (55) (Soil temperature. and moisture regimes)
- Great group (238) (subsurface diagnostic horizon)
- Subgroup (1243) (drainage, lithic contact, PM, clay type)
- Family (7504) (Texture of diagnostic surface horizon)
- Series (about 19,000) in U.S.

12 orders:

Alfisols

Andisols (*ando* – blacksoil)

Aridisols (*aridus* – dry)

Entisols (rec*ent*)

Gelisols (*gelid* – very cold)
Histosols (*histos* – tissue)
Inceptisols (*inceptum* – beginning)
Mollisols (*mollis* – soft)
Oxisols (*oxide*)
Spodosols (*spodos* – wood ash)
Ultisols (*ultimus* – last)
Vertisols (*verto* – turn)

FAO/UNESCO CLASSIFICATION SYSTEM

The FAO/UNESCO system was developed by a panel set up by UNESCO for providing the basic unit for the soil map of the world. This classification was compiled from diverse systems in term of category and nomenclature. The FAO system has two categories, a higher and a lower one. These categories have not been given name. From their definition, the higher category is equivalent to the great group of the USDA taxonomy while the lower category cannot be fitted into any category of the USDA.

The criteria for classification are similar to those of great group and sub group in the USDA taxonomy. The definition of diagnostic horizons in the FAO system is different from that of the USDA system, although there are many equivalent definitions. For example, argillic horizon in the USDA is the same as argic horizon in the FAO, while Albic, calcic, cambic, duric, histic, melanic, gypsic and nitric horizons has definition similar to those horizons bearing the same nomenclature in the USDA system.

There are 32 reference groups in the FAO (WRB, 2006) system:- Acrisols, Albeluvisols, Alisols, Andosols, Anthrosols, Arenosols, Calcisols, Cambisols, Chernozems, Cryosols, Durisols, Ferralsols, Fluvisols, Gleysols, Cypsisols, Histosols, Kastanozems, Leptosols, Lixisols, Luvisols, Nitosols, Phaeozems, Planosols, Plinthosols, Podzols, Regosols, Solonckak, Solonetz, Stagnosols, Technosols, Umbrisols and Vertisols.

Common group in Nigeria soils are Plinthosols, Ferralsols, Stagnosols (mangrove soils), Alisols (ultisols), Acrisols (ultisols), Luvisols, Lixisols (alfisols), Arenosols, Cambisols and Regosols.

The names of soils are indicated by adding prefix and suffix adjectives from the qualifier lists to the reference group, for example Gleyic Luvisol oxyaquic.

Local soil classification Systems

A number of soil classification systems exist within the country that is native of the country. These includes:-

- Smith and Montgomery (1962)
- Moss (1957)
- Jungerius (1964)
- Klinkenberg and Higgins (1968)

***SOIL* SURVEY**

Soil survey is a branch of soil science which involves the identification of the different types of soil in a given landscape and the location of their distribution to scale on a map. In addition, soil survey provides information on the quality of the land in terms of their response to management and manipulation.

Mapping Unit

A mapping unit is a geographical unit and it is an area of land within which the greater proportion is occupied by the taxonomic class after which it is named.

Principles of soil survey

The principles of survey can be discussed under five points

- A soil survey must have an objective.
- A soil survey is not the only basis for decision on land use and management, it is only an aid
- Land resources do not consist of soils alone
- A soil map must show soils.
- Soil map and report are complementary..

Type of Survey

Soil survey can be classified using the following criteria

Purpose of survey

Regularity of observation

Based on scale of mapping

Classification by purpose of survey

Based on the purpose of survey, there are two types of survey. These are general purpose and special purpose survey.

A general purpose soil survey is one that is done mainly to add to the already existing inventory of soil information.

A special purpose soil survey is done for specific purpose in mind, e.g. survey for irrigation or survey for citrus plantation.

Based on regularity of observation, three kinds of surveys have been distinguished: - free survey, rigid grid and flexible grid.

In **free survey**, there is no rigid pattern of observation.

In **rigid grid survey**, examinations of the soil are done at regular and pre-determined interval. **Flexible grid survey method** is a compromise between the free and rigid grid methods of survey. In this system of survey, the number of observation is fixed but the location of the observation points are not pre-determined and can be fixed at will.

Based on the scale of mapping, there are seven kinds of surveys:- compilation, integrated survey, exploratory survey, reconnaissance survey, semi-detailed survey, detailed survey and intensive survey.

Compilation: These are soil maps produced by abstraction from other soil surveys. And where they exist they are filled by inferences. The scale is usually at 1: 100,000 or smaller.

Integrated survey: This is also known as land system survey. It is based on mapping the total physical environment and the scale is 1: 250,000 or smaller.

Exploratory survey: They are usually rapid road traverse made to provide modicum of information about the area that are otherwise unknown. Scale of exploratory survey varies from 1: 2,000,000 to 1,500,000.

Reconnaissance survey: They are the smallest scale of survey where the whole area is still covered using remote sensed imageries and the scale is usually 1:250,000

Semi-Detailed survey: In a semi-detailed mapping units are usually soil association and the scale of mapping varies from 150,000 to 100, 000.

Detailed survey: Detailed surveys are executed using rigid grid method and are usually employed for small area. Scale of observation varies between 1: 10,000 and 1: 25,000. Mapping unit are usually soil series.

Intensive survey uses rigid grid approach and mapping units are soil series and phase of soil series. Scale of mapping varies from 1: 1,000 to 1: 10,000.

DEFINITION OF SOIL PHYSICS

Soil Physics is a branch of soil science that deals with physical properties of soil as well as measurement, prediction and control of physical processes taking place in and through the soil. Soil physical properties include soil texture, soil structure, soil colour, consistency, density thermal regime, soil water, porosity, infiltration, hydraulic conductivity etc.

Soil Physics could fundamentally be regarded as both basic and applied sciences. This is because, Soil Physics involves application of the principles of Physics to the characterization of soil properties and understanding of soil processes involving transport of matter or energy.

SOIL PRODUCTIVITY

Soil productivity is an economic concept and signifies the capability of the soil to produce specified plant or sequence of plants under well defined specified systems of management and environmental conditions. This suggests that productivity is not soil fertility alone but a function of several factors (e.g. climatic condition and soil factors). Soil productivity is measured in terms of output or harvest.

On the other hand, soil fertility refers to the inherent capacity of the soil to provide adequate amount and proper balance of nutrient for the growth of specified plant when other growth factors (e.g. light, water, temperature and favourable soil physical environment) are favourable.

In addition to chemical fertility i.e. presence of adequate nutrient in the soil and absence of toxic agents, the soil should also, be physically fertile. That is, the soil must be loose, soft and friable, possesses no mechanical impedance to root development, has pore volume and size distribution that allow entering, movement and retention of water and air to meet plant needs and has optimal thermal regime.

SOIL AS A DISPERSED SYSTEM

Soil is made up of 4 basic components: mineral matter; organic matter, soil water and soil air.

On the basis of these, there are three phases in the soil. These are solid phase, liquid phase and gaseous phase.

The dispersed nature of the soil and its constituent inter-phasal activities give rise to such phenomenon as:

adsorption of water and chemicals; ion exchange; adhesion and cohesion; dispersion and flocculation; swelling and shrinking and capillarity.

SOIL TEXTURE

Soil texture is the relative proportion of various soil separates in a soil. It is usually expressed on percentage basis.

The main textural classes are sand, silt and clay. These textural classes may be modified by addition of suitable adjective based on relative amount of each separate that make up the soil

Determination of Soil Texture

Soil texture may be determined on the field by textural feel and in the laboratory by soil mechanical analysis or soil particle size distribution. The mechanical analysis in the laboratory may be carried out either by Pipette or hydrometer method.

After the proportion of each of the soil separates are determination, the textural class of the soil is identified using a USDA Soil Textural Triangle.

Importance of soil texture

- It affects water and nutrient holding capacity of the soil
- It influences the type of crop to be grown
- It indicates type of management needed for crop growth and for engineering purposes.
- **Mechanical composition of soil**
- The mechanical composition of soil is a basic requirement in the soil physical investigation useful for land capability classification and in the study of soil morphology, genesis, classification and mapping.
- Soil mechanical analysis is the procedure for determining the particle size distribution of a soil sample.

Steps in soil mechanical analysis

- ❖ Sample collection
- ❖ Air dry the sample at room temperature
- ❖ Dispersion of the sample in an aqueous solution using Calgon solution (Sodium hexametaphosphate).
- ❖ If the sample contains high amount of organic matter remove the organic matter using H_2O_2.
- ❖ Carry out mechanical agitation by shaking or using ultrasonic vibration
- ❖ Determination/quantification of size fraction

(1) Sieving (for coarse fraction) – use net of sieve corresponding to the desired particle size
(2) Sedimentation (fine fraction)
The principles of sedimentation are that the velocity of fall of particle in a viscous medium is influenced by

(i) the viscosity of the medium

(ii) density difference between the medium and the falling particle

(iii) the size and shape of the material.

The law which govern sedimentation of particles is called Stoke's Law which states that resistance offered by liquid to the fall of a rigid spherical particles vary with the circumference of the sphere (and not its surface) **OR** the terminal velocity of a spherical particle settling under the influence of gravity in a fluid of a given density and viscosity is proportional to the square of the particle radius.
The Stokes' law consists of the factors contributing to the cause of settling and resistance to settling.

SURFACE RELATIONSHIP

The extent of the surface of dispersed soil system is described in terms of the soil specific surface.
The soil specific surface is defined as the sum of the surfaces of constituent dispersed soil particles referred to unit mass or unit volume.

Specific surface of soil (A_m) or (A_v) = $\frac{\text{Total surface area of soil } (A_s)}{\text{Mass or volume of soil } (M_s \text{ or } V_s)}$

That is, A_m or $A_v = \frac{A_s}{M_s \text{ or } V_s}$

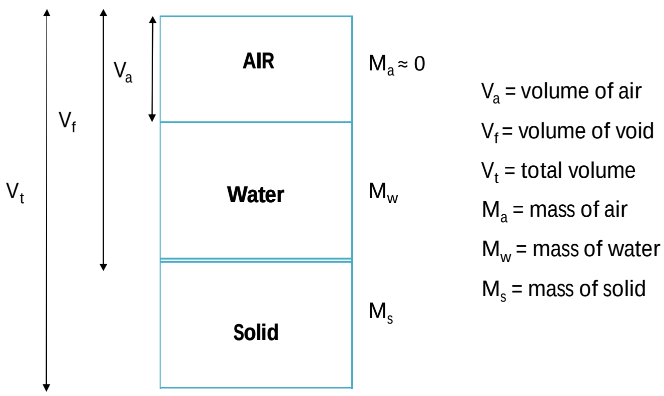
Therefore, on mass basis $A_m = \frac{A_s}{M_s}$ $\frac{cm^2}{g}$ or $\frac{m^2}{g}$ or $\frac{m^2}{kg}$

On volume basis, $A_v = \frac{A_s}{V_s}$ $\frac{cm^2}{cm^3}$ or $\frac{m^2}{cm^3}$

Soil specific surface depends on: i. Particle size, ii. Particle shape, iii. Mineralogy of the materials

VOLUME-MASS RELATIONSHIP

The volume-mass relationship among the three phases of soil could be diagrammatically represented as:



expressed in terms:

nd Air filled porosity.

me.

SOIL STRUCTURE

Soil structure is the arrangement of soil particles to form peds. Or, the arrangement of primary particles into secondary particles (aggregate).

Soil structure is strongly affected by changes in climate, biological activities and soil management practices.

Measurement of soil structure

There are direct and indirect methods of measuring soil structure.

The direct method involves measuring the size and shape of aggregate and pores of the soil. That is, three dimensional study of soil. This is done by thin section analysis with aid of powerful microscope e.g. scanning electron microscope, transmission microscope, petrographic microscope etc.

The indirect methods involve measuring soil properties that depend on soil structure. These properties include: aggregate size distribution, aggregate stability, bulk density, porosity, pore size distribution, permeability, infiltration etc.

Importance of soil structure

- It affects water and nutrient holding capacity of the soil
- It affects germination and root growth and development

- It affects water retention and transmission of fluid in soil
- It affects soil aeration
- It influences soil thermal properties

Measurement of soil structural stability

There are various methods: the two common methods that will be considered are sieving method and water drop impact technique

1. **Sieving method:** there are wet and dry sieving techniques. What is measured here is the Mean weight diameter (MWD). For wet soil it is called MWDW and for dry soil it is called MWDD

   The formula is given as

$$MWD = \sum_{i=1}^{n} X_i W_i$$

Where X = mean of diameter of particles size range separated by sieve

W_i = weight (proportional) of the aggregates in each size range

2. **Water drop technique:** this is done by studying the impact of rain drop on soil aggregate stability. This is done in the laboratory by using a rainfall simulator.

SOIL WATER

Soil water is the amount of water present in the soil available to crop. Water can enter into the soil by precipitation or by irrigation.

Forms in which water exist in the soil

Water exists in 3 forms in the soil

(i.) Hygroscopic water (ii.) Capillary water (iii.) Gravitational water.

Importance of water to crop

i. It is important in the absorption of mineral salts from the soil by plant.

ii. It helps in the transportation of plant nutrients from the root to other parts of the plant.

iii. Water is an essential raw material needed during photosynthesis.

Some terminologies in soil water include

The hydrologic cycle: Hydrologic cycle is the set of processes by which water moves through different reservoirs on earth. The hydrologic cycle can be thought of as a series of reservoirs, or storage areas, and a set of processes that cause water to move between those reservoirs. The largest reservoir by far is the oceans (Anne, 2003).

Water balance is an accounting of all water volumes that enters and leave a 3-dimensional space over a period of time (Burt, 1999).

The water balance equation is given as:

$\Delta W = P - (O + U + E_t)$. Where ΔW is change in water content between sampling; P is precipitation; O is the runoff; U is deep drainage and E_t is evapotranspiration.

Water content is the amount of water present in the soil. This is usually expressed as a percentage of oven dried weight of soil volume.

Water retention: The spaces that exist between soil particles, called pores, provide for the passage

strongly related to particle size; water molecules hold more tightly to the fine particles of a clay soil than to coarser particles of a sandy soil, so clays generally retain more water (Leeper and Uren, 1993).
Field capacity is the water content after the force of gravity has drained or removed all the water it can. FC is considered the upper limit of plant-available water (PAW).
Permanent wilting point (PWP): is the water content at which healthy plants can no longer extract water from the soil fast enough to recover from wilting. The PWP is considered the lower limit of PAW (Evans et al., 1996)

Ways by which soil loss water

i.) evaporation from the soil surface ii.) Transpiration from plant leaves, stem and fruit surface.

iii. drainage iv.) erosion

Sources of water in the soil

i.) Precipitation ii.) Irrigation iii.) High humidity

Methods of determining soil water content

1. Gravimetric method 2. Volumetric method 3. Neutron scattering technique

4. Gamma ray attenuation technique 5. Electric resistant method

6. Time domain reflectomery 7. Tensiometry method

Method of expressing soil water content

1. On mass basis 2. On volume basis 3. On depth basis

Forces acting on soil water

1. Matric force 2. Osmotic force 3. Body force

Water flow in soil

Flow of water in soil may take the following forms:

1. Saturated flow: this is when soil pores are filled with water. This normally occur immediately after rainfall or irrigation. The flow of water in this state is influenced by factors such as soil, fluid and moving forces. The soil factor is termed permeability, the fluid factor is termed fluidity while the moving force is known as the hydraulic gradient.

2. Unsaturated flow: Unsaturated flow is expectedly slower than the saturated flow and it takes place under normal field condition. The driving force under this flow is the suction gradient where water moves from the zone of lower suction (high water content) to a zone of high suction (low water content).

3. Vapour movement: Vapour pressure in soil varies with temperature. Therefore, under considerable temperature gradient, water vapour may move from warmer zone of the soil and condense at the cooler zone.

Energy balance

Net radiation is the sum of all incoming minus all outgoing radiation on the earth surface. According to Lal and Shukla (2004) steady state one-dimensional heat energy balance at the soil surface or crop canopy can be written as:

Net heat energy arriving at surface – net heat energy leaving surface = 0.

The net radiation received by the soil surface is transformed into heat which warms soil and air and vaporizes water. The total surface energy balance can therefore be given as:

$$(1-\alpha)Rs + R_{nt} - (H_c + J_H + L_*E) = 0$$

Where α is albedo, *Rs* is global solar radiation, R_{nt} is net long-wave thermal radiation, H_c convective heat flux, J_H is the vertical transport of heat into the soil, L_*E is the evaporation and subsequent transport of water from the soil surface.

Conservation tillage

Tillage practices that leave a high percentage of the residues from previous crops on the soil surface is referred to as conservation tillage. Examples include, stubble mulching, zero or no tillage system.

Soil Air and Aeration

- **Soil air -** is the air that fills the soil pore spaces not occupied by water. The gaseous phase of the soil not occupied by solid or liquid.

- **Soil aeration -** is the process of exchange of oxygen and carbon dioxide of soil air with the atmosphere.

Soil Air Composition

Soil Air Composition

Gas	Atmosphere (%)	Soil air (%)
Oxygen	21	10 to 20
Carbon dioxide	0.03	0.10 to 5
Nitrogen	78	78.8 to 80
Argon	0.94	
Hydrogen	0.01	

Factors Influencing Soil air Composition

i. Organic matter content ii. Microbial activity iii. Plant root respiration

iv. Texture v. Structure vi. Water content vii Crops

viii Drainage ix. Tillage x. Season

Soil Air Capacity

Definition:

- Is the fractional volume of air in the soil at field capacity.

- That is the quantity of air in the soil after soil has been saturated and allowed to drain for about twenty-four (24) hours.

Poor Soil Aeration

Poor soil aeration has adverse effects which could result in certain changes that are –

1. Morphological 2. Physiologic

3. Anaerobic conditions in soil induce series of reduction reactions

Soil Thermal Properties

Soil thermal regime determines:

1. The rates and directions of some physical processes.
2. The rates of energy and mass exchange with the atmosphere.
3. Governs the type and rates of chemical reactions taking place in the soil e.g. weathering.
4. Influences biological processes such as:

i) Microbial activity ii) Soil germination iii) Plant growth

Major Aspects Of Soil Thermal Regime

The major aspects which characterize the soil thermal regime are:

1. Soil heat intensity: This describes mainly the soil temperature (˚C, degree Celsius; K, Kelvin).
2. Soil heat capacity (gravimetric): The amount of heat required to raise the temperature of a given mass by one degree Celsius (1˚C)

Mode of Heat Energy Transfer in Soil

Mode of heat energy transfer in soil include:

i) Conduction – This is the primary mode of heat transfer in soil.

ii) Convection iii) Radiation

Factors Influencing soil Temperature Variation

1. Factors that influence the amount of heat available at the soil surface are:

i) Soil colour ii) Soil mulch

2. Factors that influence dissipitation of available heat (i) Water content of the soil

Types of Soil Temperature Variation

1. Diurnal 2. Seasonal 3. Variation due to soil depth

Solar Radiation

Solar Radiation is the major source of soil heat. Only a portion of the emitted solar radiation reaches the earth's surface. Part of the solar radiation may be:

1. Reflected by the clouds
2. Scattered into the atmosphere by atmospheric gases.
3. Absorbed by the ozone and water vapour.

Management of Soil Heat

These methods includes:

1. Covers 2. Mechanical manipulation of soil surface

3. Others (indirect effects) i) Irrigation – reduces temperature ii) Drainage – increases temperature iii) Weed control iv) Plants/trees

SOIL EROSION

Definition

Soil erosion can be simply defined as the wearing away of soil materials from place to place by the agents of erosion such as water, wind and ice.

In general soil erosion is broadly divided into

1. Geological Erosion

Soil erosion that occurs naturally, without the influence of human activities.

2. Accelerated Erosion

Soil erosion resulting from human interference with the natural environment.

Mechanics of Soil Erosion

a. **Detachment** of soil aggregates into particles

b. **Transportation** of the detached particle by floating, rolling, and dragging.

c. **Deposition** of the transported materials where the energy of force dissipates.

Soil erosion by water and wind erosion involves the three processes listed above. However, the method of soil movement in wind erosion defers.

Factors causing soil erosion

1. Climatic factor 2. Soil factors 3. Topography 4. Vegetation cover

5. Human activities e.g., *Tillage, Overgrazing, Fires, Lowering of the water table (water use in excess of replenishment rate)* - these accentuates wind erosion

Types of Soil Erosion by water

- **Sheet Erosion:** The removal of a fairly uniform layer of soil from the land surface by runoff water.
- **Rill Erosion:** As sheet flow is concentrated into tiny channels (*called rills*), rill erosion occurs.
- **Gully Erosion:** When the volume of runoff is concentrated, the rushing water cuts deeper into the soil, deepening and fusing the rills into larger channels called gullies.

Measurement of Soil Erosion by Water

The **Universal Soil Loss Equation** (USLE), was designed by Wischmeier and Mannering, (1969), to predict annual soil loss by water in the USA but has been adapted and modified in some cases for prediction around the world. The USLE equation is as follows:

$$A = R\ K\ L\ S\ C\ P$$

A - predicted soil loss (kg m^2 s^{-1}); R - rainfall erosivity

K - soil erodibility; L - slope length; S - slope gradient or steepness C - cover and management P - erosion control practices

Wind Erosion

Types of soil movement

1. Saltation 2. Soil Creep 3. Suspension

Factors affecting Wind Erosion

1. Wind velocity 2. Soil characteristics / properties 3. Vegetation / mulch

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