Soil science and soil productivity in agriculture

Soil

This is a mixture of weathered rock materials, air, water, organic matter and living organism.

Importance of soil

- It is a medium within which plants grow.
- It provides water to the plant.
- It is a medium for microbial activities.
- It provides air for respiration of plant root.
- It is a medium for anchorage of plant it absorbs and decomposes waste material, thus keeping environment clean.

Soil formation

Soil is formed through the process of weathering.

Weathering

This is the process of breaking down or the disintegration of rocks to form soil.

The rocks that form soil are of three types i.e. igneous rocks, sedimentary rocks, and metamorphic rocks.

Igneous rocks

These are rocks formed by the cooling and solidification of molten magma (Larva) extracted at high temperature from the interior regions of the earth's crust near on the surface of earth.

The main types of igneous rocks are:-

Granite, diorite, and basalt and gabbro. The minerals present in these rocks are mica, feldspar, quarts, iron oxides and biotite.

Sedimentary rocks

These are formed by the deposition of weather minerals which are derived from igneous rocks. E.g. shales, sand stone, and limestone. The minerals in these rocks are clay minerals, quartz, calcium, phosphate, dolomite, iron oxides.

Metamorphic rocks

These are formed by the action of heat, pressure and chemical changes on igneous and sedimentary rocks e.g. gneiss, schist, slate, and quartzite

Types of weathering

There are three main types of weathering i.e. physical weathering, chemical weathering and Biological weathering.

Physical weathering

This is the mechanical disintegration of rocks which is caused by heat, roots of trees, ice, wind and rain.

Temperature

When rocks are heated, they expand unevenly between their layers. A change in temperature will set up stresses which will result into breaking of rocks. The alternative heating and cooling results into rapturing of rocks.

Ice

When water cools to form ice, it expands. Therefore the presence of water in rocks cracks can lead to the breaking of rocks when it cools to form ice

Rain

Rainfall particularly that with hail stones falls on rocks surfaces crashing and removing some particles from them which are carried by the running water.

Wind

As strong wind, blows it carries away tinny rock particles to different places from the mother rock.

Plant roots

As roots penetrate through the rock cracks, they will cause further cracking as they increase in size through growth.

Chemical weathering

It is the breakdown of rock with accompanied with a change of chemical composition.

Process of chemical weathering

This includes hydrolysis, hydration, oxidation, carbonation, reduction, and solution.

Hydration

This occurs when water combines with minerals like silicates, oxides of iron or aluminum to form hydrated compounds e.g.

$2Fe_2O_3 + 3H_3O \rightarrow 2Fe_2O_3 . 3H_2O$

The hydrated compound are softer than the original rock and therefore easily worn away.

Oxidation

It is the addition of oxygen to mineral rocks to form compound that decompose or dissolve easily.

$2Fe\ (s) + 3O_2(s) \rightarrow 2Fe_2O_3(s)$

Hydrolysis

This is the use of water to break up chemical bonds of a particular compound e.g

Calcium silicate + water → silic acid + calcium hydroxide

$CaSiO_3 + 2H_2O \rightarrow H_2SiO_3 + Ca(OH)_2$

Reduction

It involves the removal of oxygen from minerals, e.g.

$Fe_2O_3 \rightarrow 4FeO + O_2$

Solution

It is the dissolution of solid mineral compound in water.

$NaCl\ (s) + aq \rightarrow Na^+(aq) + Cl^-\ (aq)$

Carbonation

Water and carbon dioxide combine to form a weak carbonic acid which reacts with oxides and hydroxide of calcium and magnesium to form carbonate and bi-carbonates.

$CO_2\ (g) + H_2O\ (l) \rightarrow H_2CO_3\ (aq)$

$Ca(OH)_2 + H_2CO_3 \rightarrow CaCO_3 + 2H_2O$

Biological weathering

It is a type of weathering where rocks are broken down by living organisms, for instance

- Roots of trees grow in the cracks widen the cracks causing the rocks to split
- Burrowing animals e.g. rodents breakdown soft rocks and help in soil profile mixing.
- Living organisms like bacteria and fungi carry out decomposition of dead plants and animals remain leading to soil formation.
- Animal hooves break the rock surface that they walk on.
- The termites are able to convert wood into soil because they have the cellulose enzymes in their guts which act on cellulose in wood.
- The vegetative cover protects the soil surface from soil erosion hence minimizing soil loss.
- Living organisms die and decompose to form soil
- Earth worms grind up mineral particles important in soil formation
- Fungi and algae colonize the rocks and secrete chemicals which dissolve rocks.
- Man's activities such as cultivation, quarrying breakdown rock

Factors affecting soil formation

These are responsible for the types and nature of soil formed in an area

(a) Nature of the parent rock

It refers to the material from which soil is formed

- It determines the type of soil formed for example sand stone gives rise to sandy soil while volcanic ash give rise to very fine soils.
- Parental material affects the colour of the soil formed
- Parent material determines the ease of weathering i.e. soft rocks such as igneous rocks are easier to breakdown.
- Parent material influences the rate of soil profile development
- Parent material determines the depth of soil formed. For example, soft igneous rocks produce deeper and more fertile soils than hard sedimentary rocks

(b) Climate

Climatic factors that influence soil formation include temperature, rainfall and wind

(i) Effect of temperature

- Alternate expansion and contraction of rock surfaces due to temperature changes of day and night cause cracking of rocks to form soil
- Increase in temperature results in evaporation of soil moisture of soil moisture to form rain which is a weathering agent
- Increase in temperature promotes activities of soil organisms that cause biological weathering
- High temperature causes peeling of the rock surface (exfoliation)
- Low temperature at high altitude cause solidification water into ice that exert pressure and cause rocks to crack

(ii) Effect of rain

- Rain drops dislodges particles from rocks to form soil
- Flow of rain water carry solids that knock particle from parent rocks.
- Rain dissolves carbon dioxide and sulphur dioxide forming acid solution which dissolve rocks.
- Rain provide water used by soil organisms in decomposed organic matter.
- Running water helps to remove accumulated materials from rocks surface thus exposing rocks to agents of weathering.

(iii) Effect of wind

- Wind blows sand particles against rock causing abrasion of the rock surface

- Wind remove accumulated material from rock surface exposing rocks to agents of weathering

(c) Topography (relief)

- This influences the amount of rainfall received in an area,
- Surface erosion which determines soil depth by removal and deposition of soil
- Water infiltration into the soil.
- It also influences vegetation through its influence on rainfall hence affecting soil formation.

(d) Time

- It requires a lot of time for a soil to develop up to full maturity. A mature soil will contain all the required nutrients needed by plants.
- The longer the time the rock is exposed to agents of weathering, the deeper and more fertile the soil will be
- Clay content of the soil increase with time
- Organic matter soil content increase with time.

(e) Human influence

Humans tend to disrupt soil formation through disturbing soil profiles during the cultivation, and construction of buildings, roads and dams.

Man can transform soil in the following ways;

- Natural vegetation is destroyed in getting land for agriculture
- Fertilizer application interferes with the chemical nature of soil
- Topography is altered through constructions of roads and buildings
- Application of pesticides changes chemical soil properties
- Soil cultivation destroys soil structure
- Irrigation may interfere with soil nutrient composition and structures
- bush burning destroys organic matter and raises soil temperature, slowing down the process of soil formation

The stages of soil formation

Soil formation involves 3 stages of disintegration, decomposition and translocation.

- **Disintegration**; breaking up of parent material
- **Decomposition**; process of decomposing organic materials
- **Translocation**; removal of soil or vertical movement of particles and dissolved solids with in a profile and often into the ground
- **Deposition**; the soil particles carried away by water and wind are deposited to another area.

Properties of soil

These include soil drainage, water holding capacity, plasticity, aeration, fertility, structure, density texture, porosity, colour, soil fauna, PH, and productivity.

A. Soil structure

It refers to the overall arrangement of soil particles or the compactness or looseness of soil particles

Classes of soil structure

(i) Structure less or single grained: these are single separate grains that do not stick together
(ii) Massive: these are less cemented fine particles with limited pores.
(iii) Aggregated: occurs when particles stick together to form secondary and larger particles leaving air space within.

Types of soil structure

(i) Crumb structure

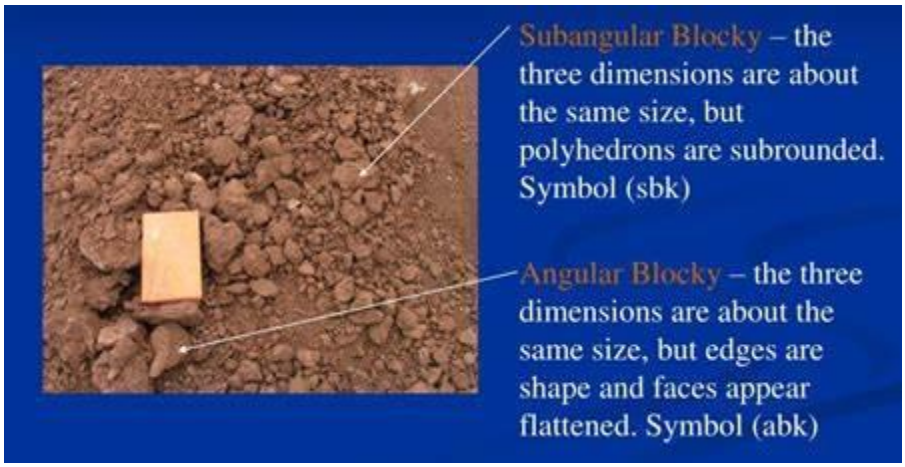
- It is bread-like textured
- It is found in top soil
- It has a lot of organic matter which makes it good for growing crops such as vegetable
- It is very porous and well drained

(ii) Granular structure

- Here the particles are in form granules but grouped together
- It is common in top soil
- It is porous

(iii) Blocky structure

- The particles are arranged in form of cubes or block
- They are hexagonal in apperance with sharp edges
- Common in subsoil of some heavy clay soil



(iv) Columnar soil structure

- The aggregates are arranged in form of column-like structures

(v) Prismatic structure

- The soil particles are arranged on form of prisms with leveled tops
- It is found in subsoil of arid and semi-arid regions.

(vi) Planty soil structure

- Soils particles are arranged on top of each other to form thin horizontal plates

- They are common at the soil surface or as surface crust. Water mostly moves laterally.

Importance of soil structure

- It controls passage of water through the soil (soil drainage). The bigger the particles the easier the penetration of water.
- Controls soil aeration. Soil with big particles contains more air than that with small particles.
- Controls soil temperature through its control of aeration.
- Control soil water retention
- Control soil pH through controlling aeration. High level of carbon dioxide lowers soil pH.
- It controls workability of the soil i.e. single loose grained soils are easily worked on than sticky soil.
- It control the ability plant root penetration into the soil.
- It influences the availability soil nutrients.
- Control soil erosion; loose soil erodes faster.

Factors that influence the formation of soil structure (aggregation)

- Organic matter content: organic matter is sticky and binds soil particles together.
- Soil water: moist soil are plastic than dry soil and so are easy to bind together. Too much moisture causes dispersion of the particles.
- Living organism: produce substances such mucus that cement soil particles together e.g. earthworm.
- Compaction: this is the formation of the platy structure which comes as a result of destruction of other structure
- Soil texture: soils with large particles e.g. sandy soil are not plastic enough and its particles are not easily bound together.
- Liming: liming encourages formation of soil aggregates due to favorable effect of calcium on the soil

Activities that can lead to destruction of soil structure

- Pollution of the soil such as application of fertilizers and insecticides. Also pollution kills microorganisms.
- Ploughing soil at high moisture content results into mingling of the soil especially those that contain high clay content
- Excessive leaching especially calcium and iron oxides that bind soil particles
- Continuous cultivation/tillage of the soil break up soil aggregates
- Bush burning destroy the organic matter and expose the soil to agents of erosion
- Soil erosion erodes the aggregates destroying their shape
- Use of heavy machinery compact the soil and destroy soil structure.

- Water logging prevents organic matter from decomposing encouraging crumbling of soil structure
- Mining breaks soil particles
- Removal of soil cover expose soil to soil erosion
- Over grazing exposes soil surface to soil erosion
- Poor harvesting practices that do not add organic matter in the soil
- Water logging that leads to dispersion of soil particles

How soil structure can be maintained

- Minimum tillage
- Growing cover crops that minimize soil erosion
- Application of organic manures to bind soil particles together
- Mulching to control soil erosion and add organic manure
- Bush fallowing involving grass to bind soil particle
- Afforestation to control soil erosion
- Draining to remove excess water that cause dispersion
- Liming to bind soil particles together
- Controlled irrigation to provide soil moisture
- Controlled grazing to maintain grass cover

B. Resistance to crushing

- Loose; separate and non-coherent soil particles
- Friable; lumps that can be crushed into small crumbs with gentle pressure
- Compact; dense lumps of soil that can be crushed with a lot of difficulty
- Slightly compact; lumps that can be crushed into fragment with moderate pressure
- Cemented; soil materials that cannot be broken in hand
- P**lastic**; soil that can be moulded when wet without breaking

C. Soil texture

This is the roughness or smoothness of soil. It is due to the proportion of sand, silt, and clay in a particular soil.

Effects of soil texture

(a) **The circulation of air in the soil (soil aeration):** In fine textured soils, there is limited movement of air due to the small spaces.

(b) **Water holding capacity:** this is higher in fine textured soils like clay than coarse textured soil like sand.

(c) **Root penetration:** this is easier in coarse textured soils and difficult in fine textured soils since the fine particles resist root penetration.

(d) **Response of plants to fertilizers:** poor root penetration means limited response to fertilizers hence fine textured soils are not good when it comes to movement of nutrients.

(e) **Rate of chemical reaction in the soil:** Poor textured soils would limit soil reaction like carbonation, hydration and hydrolysis.

Types of soil textures

Soil	**Appearance of particles**	**Behavior when moist**	**Feeling**
Sand	Loose and single grained	No ribbon formed Not plastic	gritty
Loam	Soft clods	Weak ribbon formed Slightly plastic	Gritty
Clay	Hard lumps and highly cemented	Long flexible ribbon Formed Highly plastic	Smooth

Soil textual classes

This is done according to the United States Department of Agriculture and the international soil science system.

USDA classification

Soil separate	**Particle diameter (mm)**
Very course sand	2.00 – 1.00
Course sand	1.00 – 0.50
Medium sand	0.50 – 0.25
Fine sand	0.25 – 0.10
Very fine sand	0.10 – 0.05
Silt	0.05 – 0.002
Clay below	0.002

Soil textual classes (soil types)

There are three main textual classes (types) i.e. clay soil, Sandy soil and loam soil.

These three give rise to other classes depending on the percentage of sand silt and clay present in a particular soil e.g. sandy clay, clay loam, silty clay loam, sandy clay loam, loamy clay sand and silty clay.

Properties of textual classes

Clay soil

- It has a high water holding capacity
- It has a high nutrient holding capacity.
- It has small air spaces
- It is not gritty
- It is not smooth
- It forms extremely cohesive balls and long threads which bend into rings easily when wetted.

Sandy soil

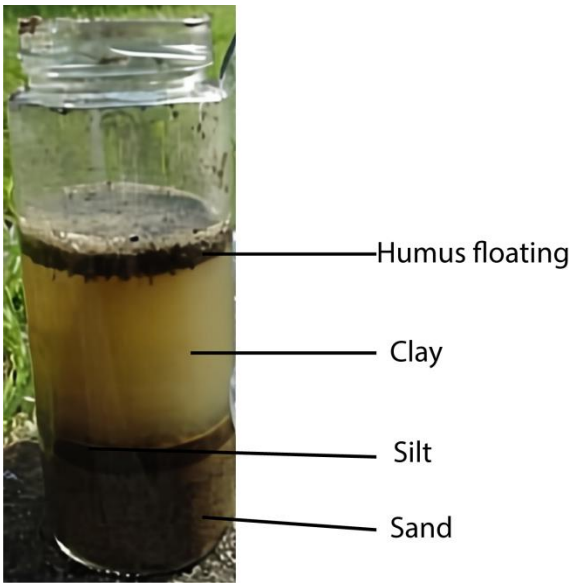
- It is extremely gritty
- It is not smooth
- Its not plastic
- It forms non cohesive balls which collapse easily
- It has a low water nutrient holding capacity
- It has big air spaces
- It has big soil particles.

Loam soil

- It is moderately gritty
- It is slightly smooth
- It is slightly sticky
- It is slightly plastic
- It forms moderately cohesive balls
- It forms long threads which bend into rings with difficulty.
- It has a moderate water holding capacity
- It contains 5 – 10% organic matter
- Loam soil is an optimum mixture of sand, silt and clay.

Experiment to determine the different sizes of particles present in the soil:-

- Place 40g of soil in 100cm3 measuring cylinder
- Fill the cylinder with water up to ¾ of it
- Cover the open end firmly with land and shake the content of the cylinder vigorously
- Stand the cylinder on a land flat surface and observe how the suspension settles down.



Results

- Some bubble escape from the container indicating the presence of air.
- After shaking, the largest particles fall to the bottom (sand) followed by fine sand, silt, clay and finally organic matter.

Conclusion

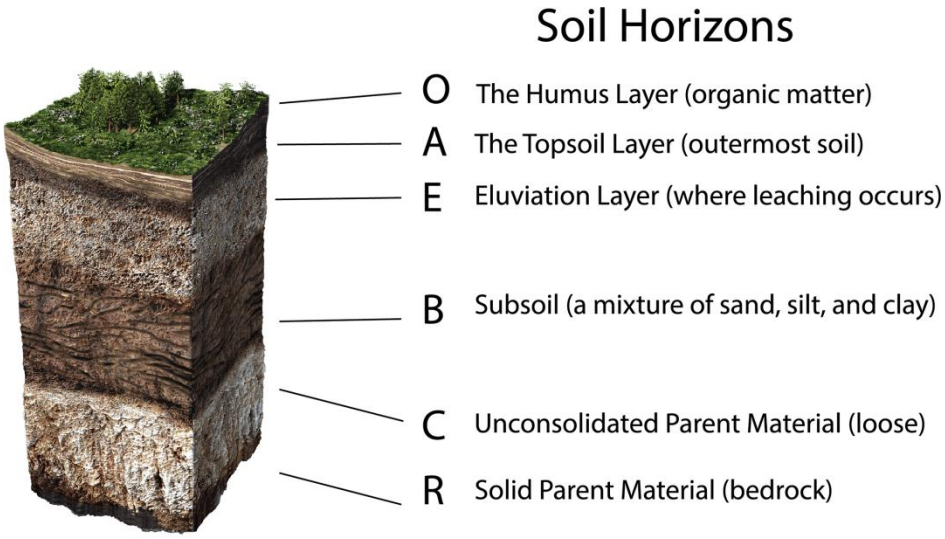
Soil is made of different sized particles which when subjected the experiment sediments settle according to sizes

Importance of soil texture

- It controls the passage of water through the soil i.e. granular structure enables are more rapid downward flow of water than planty structure
- It controls aeration of soil
- It controls soil temperature
- It regulate water holding capacity
- Controls soil pH by controlling air passage
- It controls workability of the soil; single, loose grained soil is easier to work than sticky heavy soils.
- It control root soil penetration
- Control soil erosion; loose soil is easily eroded.
- Controls the ability of soil to hold nutrients

D. Soil profile

This is a vertical section from the top of soil to the unchanged parent material beneath showing the various horizons



An individual layer in a soil profile is called a horizon.

Change in a horizon is characterized by change in soil colour. There are two types of soil profiles.

a. Podzol profile
b. Ferralsol profile.

A **podzol profile** displays sharp contrast between the horizons and its widely distributed in humid temperate areas.

Ferralsol: It is an example of soil that has developed under humid tropical conditions through progressive weathering of rock.

N.B. Soil catena is the sequence of soil developed from a similar parent rock material under similar climatic conditions but whose x-tics differs due to difference in relief and drainage.

E. Soil temperature

This the degree of hotness or coldness of the soil

Importance of soil temperature

- Affects the rate of weathering
- High soil temperature promotes activities of soil organisms such as nitrogen fixation
- High soil temperature promotes active uptake mineral soil
- High soil temperature promote decomposition and release of nutrients from organic matter
- High soil temperature increases water uptake
- Optimum temperature promote germination
- high temperature encourage drying of the soil
- alternate hot and cold temperature promotes weathering of soil
- influences root growth
- influences water loss from the soil through evaporation

Factors that influence the temperature of the soil

- Amount of soil radiation: high solar radiation increase soil temperature
- Soil colour: dark soil color absorbs heat and increases soil temperature
- Crop cover: plant cover lowers soil temperature
- Organic matter increases soil moisture retention and give a darker color to the soil increasing heat retention in the soil
- Soil moisture: retains heat in the soil
- Compositing release heat increasing soil temperature

How to maintain soil temperature

- mulching keeps the soil cold
- shading cools the soil during day
- irrigation lowers soil temperature
- planting cover crops
- application of organic matter
- drainage to remove excess water

F. Soil color

Soil color is determined by the color of the parent rock, iron and organic matter

Significance of soil color

- Can be used to determine the age of the soil
- Indicates presence of organic matter in the soil for i.e. dark color indicates presence of organic matter.
- Demarcates soil profile horizon
- Indicates the extent of mineral loss through leaching

Effect of soil color on soil properties

- Affects soil temperature: for instance black soil increases the soil's ability to absorb heat and hence causes a rise in soil temperature.
- Affects soil moisture levels: for instance black soil absorbs heat and increase the rate of water loss through evaporation
- Influences microbial activities: high temperature of black soil activates microbial activity.

G. Bulk density

This is the mass per unit volume of un disturbed soil dried to consistent weight at 105^0C.

Bulk density = $\frac{Weight\ of\ oven\ dry\ soil\ (g)}{The\ volume\ of\ the\ oven\ dry\ soil\ (cm^3)}$

Effects of bulky density

- Water holding capacity
- Soil aeration
- Crop root development
- Seed germination

Factors that influence soil bulk density

- **Organic matter content:** organic matter is very light and spongy and so increase in organic matter content lowers bulk density of the soil.
- **Soil particle size:** clay soil with tiny particles have higher bulky density than sand with large particles
- **Porosity of the soil:** porous soil has lower bulky density than non-porous soil
- **Soil depth:** bulk density tends to increase the deeper one goes into the soil profile due to lower organic matter and high density of the underlying rocks.
- **Level of cultivation:** intensive cultivation increases bulk density because it causes rapid break down of organic matter and cause compaction of the soil
- **Systems of soil management:** addition of manure in large amounts to soil lowers its bulk density.
- **Cropping systems:** continuous cropping reduces the amount of organic matter in the soil and increases the bulk density.
- **Amount of air in the soil:** the higher the air in the soil, the higher the bulk density
- **Soil structure:** the more compacted the soil structure, the higher the bulk density
- **Mechanization:** use of heavy machines such as tractors during cultivation compact the soil increasing its bulk density.

Particle density

It's the ratio of weight of solids to volume of solids in soil (g/cm^3). The solids in soil are organic matter, inorganic matter, and living organism. In the calculation of particle density, volume of air should be excluded.

H. Soil plasticity

This is the capacity of the soil to be molded without breaking or rupturing.

The terms used in describing the degree of plasticity are non-plastic, slightly plastic, plastic and very plastic.

I. Soil consistency

This is the degree of cohesion of soil or the resistance of the soil to deformation is measured by filling and manipulating the soil by hand or pulling tillage equipment through it. The classes of consistence include:-

J. Soil porosity

This is the measure of the size of pore space in soils. In soils where the particles are closely together, there is limited pore space and therefore less air in such soils and poor plant root development.

Factors that affect soil porosity

- Soil texture: very fine soil texture such as clay soil lead less porous soil
- Level organic matter in the soil: high organic matter content increase soil porosity by promoting soil aggregate
- Frequent tillage promotes soil porosity by breaking up soil particles
- Soil organisms like earth worms burrow and levels tunnels in the soil improving soil porosity.
- Soil depth: soil porosity tends to decrease and the soil depth increase.

K. Soil fertility

This is the ability of the soil to supply plant nutrients in adequate amount and right proportion for better plant growth.

Characteristics of productive soil

- It should be well drained.
- It should be of a sufficient depth for good root penetration and growth.
- It should be well aerated.
- It should have a good water holding capacity.
- It should have enough nutrients which must be the right proportions.
- It should be fee from crop pests and diseases.
- It should have a right PH for the particular crop to be grown on it.
- It should have a good structure and texture.

The causes of low soil productivity/fertility

- Soil erosion leads to loss of crop nutrients
- Leaching leads to inaccessibility of soil nutrients
- Poor drainage may lead to water logging and hence poor soil aeration and unfavorable soil temperature.
- Poor tillage destroys soil structure leading to leaching
- Unfavorable pH
- Soil capping i.e. development of impervious layer on the soil surface
- Development of hard pans or impervious layers below the soil surface
- Lack of required soil nutrients
- Presence of pests and disease causing organisms in the soil
- Presence of weeds which compete which compete with plants for nutrients
- Lack of adequate soil moisture.
- Mono-cropping cause soil exhaustion and buildup disease causing organisms
- Burning of vegetation destroys soil living organisms

- Excessive irrigation cause leaching
- Excessive drainage lead to loss nutrients
- Salinity of the soil

Maintenance of soil fertility

The fertility of the soil can be maintained through the following ways:-

a. Crop rotation: Is the growing of different crops on the same piece of land in a particular sequence season after season for proper utilization of nutrients
Follow the guide lines.

- Legumes should alternate with other crops since they increase soil fertility by fixing nitrogen
- Crops with high nutrient requirement should come first on a newly cultivated piece of land to utilize a high content of nutrients present at this stage.
- Deep rooted crops should alternate with the shallow rooted crops since deep rooters bring nutrients to the upper layers of soil for shallow rooters to use
- Cover crops should be included in the rotation to control erosion.
- A fallow period should be included in the rotation to preserve soil structure and restore the lost nutrients.
- Crops that are easy to weed should alternate with those that are difficult to weed.
- Crops attacked by similar pests and diseases should not succeed one another in the rotation to reduce spread

Importance of crop rotation

- There is maximum use of soil nutrients since different crops with different nutrients requirements are involve in the rotation.
- Pests and diseases are easily controlled by breaking their cycle and starvation.
- Parasitic weeds like string spp in sorghum are easily controlled under crop rotation.
- The nitrogen content of the soil can be improved more especially if legumes are included in the rotation.
- Good rotation evens out labor requirement throughout the year.
- It spreads financial risks over several crops
- Some deep rooted crops in the rotation will recycle nutrients.
- Soil erosion can be controlled during the fallow period when grasses are allowed to grow on the land or by the binding action of the plant roots.

The role of crop rotation in maintaining soil fertility

- Rotating crops of different rooting system enables plants to absorb nutrients at different soil layers
- Different crops prefer different nutrients which prevent soil exhaustion.
- Some plants like legumes fix nitrogen to the soil
- Crops rotation improves soil structure such as those with fibrous roots.

- Crop rotation controls pests and diseases by breaking their life cycles
- Crop rotation controls some weeds such as striga
- Resting helps regain fertility
- Nutrient recycling i.e. deep rooter against shallow rooter
- Conserve soil moisture when cover crops are planted
- Control soil erosion by maintain soil structure or planting cover crops,

An example of a four year crop rotation

Year	Plot 1	Plot 2	Plot 3	Plot 4
1	Sweet potatoes	Beans	Cassava	Millet
2	Millet	Sweet potatoes	Beans	Cassava
3	Cassava	Millet	Sweet potatoes	Beans
4	Beans	Cassava	Millet	Sweet potatoes
	Fallow	Fallow	Fallow	Fallow

NB After the fourth year the farmer can decide to have a fallow period

Limitations of crop rotation

- Shortage of land due to an increasing human population
- Presence of permanent building that cannot be rotated
- Introduction of perennial crops with a long gestation period
- Merits of the practice cannot be easily recognized by farmers hence difficult to convince them

b. Proper weed control: weeds compete with crops for soil nutrients. A high population of weeds **will extract a lot of nutrients from the soil making it infertile in the long run.**

c. Mulching: Is the covering of top soil with dry plant materials or artificial substances like polythene papers. Apart from conserving the soil moisture and suppressing weeds, mulches also rot and add fertility to the soil.

d. Minimum tillage: Minimum disturbance of the soil will conserve its organic matter content and moisture hence maintaining fertility.

e. Soil pH control: At different pH some macro and micro elements are present while others are absent. The soil pH can be maintained through liming and addition of fertilizers.

f. Addition of manure: The addition of both organic and inorganic manure will increase the amount of soil nutrients therefore maintaining the fertility. However, over use of artificial manure can cause acidic conditions in the soil that may lower soil fertility.

g. Soil erosion control: The washing away of he most fertile top soil leads to loss of soil fertility as well. Methods of controlling soil erosion like terracing, mulching, contour ploughing etc should be used.

h. **Improving on soil drainage**: This will eliminate water logging with all its disadvantages like increased leaching
i. **Improving on the water holding capacity of the soil**: Water is needed by plants in the absorption of soil nutrients and in photosynthesis therefore water holding capacity of the soil should be improved to maintain the soil fertility through the addition of organic manures.

Loss of soil fertility

Soil can lose fertility through:-

- Change of soil PH: some plants nutrients are available to the plants at low PH e.g. iron, Mg, A1, Zn, K and Boron while others are favored by a high PH e.g. phosphorous and molybdenum
- Buildup of pests and diseases in the soil
- Burning that destroy useful microorganisms and also destroy soil structure
- Formation of hard pans which restricts root development and access to water and nutrients. Hardpans also impede water drainage which can lead to waterlogging above the hardpan and drought conditions below it.
- Soil compaction by heavy machinery and overgrazing that may reduce the soil's ability to hold water and nutrients
- Deforestation that lead to soil erosion
- Monoculture practices/over cultivation leading to nutrient depletion
- Crop removal during harvesting carries away all the nutrients concentrated in their tissue and seeds.
- Leaching: washes out of soil nutrients in both solution and suspension to the deeper layers of the soil where plants cannot utilize it.

The factors that affect leaching in the soil

- Soil structure; weak structure encourages leaching
- Soil texture; coarse texture encourages leaching
- Rainfall intensity; high rainfall water encourages leaching
- Vegetation cover minimizes leaching
- Soluble nutrients are easily leached
- Tillage removes vegetation cover and encourages leaching
- Cation exchange capacity of the soil; high exchange capacity increases leaching
- Level of humus in the soil; high content of humus reduces the rate of leaching

- Large number of weeds competes with plant for nutrients.
- Overuse of fertilizers and pesticides that can alter soil pH and kill beneficial microorganisms
- Salinization due to irrigation
- Over cultivation causes rapid oxidation of organic matter by microorganisms leading to loss of fertility

Effects of over cultivation of arable land

- Destroys Soil structure making the land more prone to erosion
- Increases production costs by engaging more labor in cultivation
- Can destroy crop roots
- Can increase evaporation of moisture from soil by increasing surface area for loss.
- Increases oxidation of crop nutrient hence loss of fertility

- Soil erosion: carries away the more productive top layer of soil leading to loss of fertility

How soil productivity can be improved

- Through application of manure and fertilizers
- Practicing crop rotation to promote usage of different nutrients
- Irrigation to provide water in the soil.
- Drainage of excess water
- Modifying soil pH
- Prevention of soil erosion
- Control pests and diseases
- Proper cropping like preventing overcrowding
- Applying effective method of water conservation

Components of soil

Soil is composed of living organisms (micro and Macro), air, mineral elements, organic matter and water.

(a) Living organisms

These include microorganisms like bacteria, fungi, protozoa, etc. It also includes macro living organisms like earth worms and some insects.

Importance:

Positive importance

- Decompose plant and animal remaining into humus
- They are used for nitrogen fixation
- Help in soil aeration e.g. earthworm
- Mix up soil particles
- Produce mucus causing aggregation of soil particle e.g. earthworms
- Improve soil drainage
- Improve soil aeration

Harmful effects of soil organism to crop

- Some organism destroy plant tissue e.g. millipedes
- Some organisms such as fungi cause disease
- Termites burrow deep and bring to the surface poor unfertile soil which reduces soil fertility.

- Soil organism e.g. nematode suck plant sap and block the transport tissues thereby hampering growth.

Factors that influence abundance of soil living organisms

- Temperature of the soil: different organisms prefer different temperature ranges
- pH influences enzyme activities in microorganisms; very high and very low pH hinder multiplication of microorganisms
- Aeration / oxygen for respiration
- Presence of organic matter in soil that act as food to microorganisms
- Presence of certain minerals such as iron II which provide respiratory energy.
- Presence of pollutants that poison microorganisms.
- Depth of the soil: deep soil provides space for microorganism to live.
- Soil moisture: soil organisms require moisture is essential for life and for enzyme activity and metabolism and, is a solvent for biological nutrients and other chemicals. Also moist soil facilitates movement of organisms in the soil.
- Light require by phototrophic microorganisms immediately below or on the surface of the soil. Light also warms the soil while some sunlight component (uv) skills microorganisms.
- Type of plant grown e.g. legumes house nitrogen fixing bacteria
- Tillage not only kill soil organisms but also destroy their microhabitats
- bulk density, dry weight, porosity affect burrowing of macro-organisms in the soil
- Soil salinity: high salinity reduces microbial growth

Factors that affect symbiotic nitrogen fixation in the *soil*

- Presence of nitrogen fixing bacteria (**of** the genus **Rhizobium)**
- Presence of root legume roots in whose root nodule bacteria live
- Presence favorable temperature
- Presence of oxygen in the soil for respiration of bacteria
- Presence of nitrogen in the soil to be fixed
- Presence of zinc in the soil: zinc is necessary for nitrogen fixation acting as a secondary signal for nitrogen fixation
- Presence of antimicrobial agents in the soil

(b) Soil air

Soil contains air, the biggest portion being CO_2 and O_2. Soil air is used by living organisms in respiration and also the plant roots.

N.B. Water and air occupy the same position and therefore high level of water in the soil will reduce the amount of air in that particular soil.

Importance of soil air

- It is required for root respiration and root development
- Supports nitrogen fixation in root nodules

- It required for respiration of soil microbe
- Required for oxidation in weathering

Effects of poor soil aeration

- Reduced microbe activity
- Reduced root growth and expansion
- Increased denitrification
- Wilting and yellowing of plants due to reduced absorption of salts
- Anaerobic conditions leading to formation of harmful acids

How to improve soil aeration

- Turn over the top layer of soil through tilling.
- Drain water logged soil
- Use additives such orchid bark, perlite, coarse sand, vermiculite, and agricultural charcoal.
- Create holes for oxygen to penetrate the ground using spike aerator.
- Add wetting agents to improve oxygen levels.
- Incorporate organic matter such as compost, leaf litter, or manure to improve soil texture
- Cover crops like clover or rye can help break up compacted soil and improve its structure over time
- Limit foot traffic not to compact soil
- Broad forking manually loosen the soil without turning it over can help improve aeration while preserving soil structure
- Practice crop rotation to prevent soil compaction

(c) Soil water

It is found in the macro and micro pores of the soil

Importance of soil water

- It a medium/solvent through which mineral nutrients are absorbed by the plant
- Promote weathering and soil formation
- Soil water is absorbed and used for photosynthesis,
- Absorbed soil water is used transpiration and cooling of the plant.
- Helps biological decomposition of dead plant remaining into humus
- Regulates soil temperature i.e. evaporation of water from the soil cools it
- Soften soil and ease root penetration and cultivation
- Promote seed germination

Ways of improving water retention in the soil.

- Increase organic matter like compost and peat moss in your soil.
- Till less frequently.
- Keep your soil covered or mulched.

- Use soil amendments like perlite, vermiculite or biochar
- Plant cover crops like clover or legume to improve soil structure and reduce soil erosion
- Plant windbreaks to reduce wind erosion
- Remove weeds that would compete with the plants for water

Dangers are associated with excess moisture in the soil or waterlogging

- Insufficient supply of oxygen, which slows or stops plant growth.
- Accumulation of carbon dioxide, which impedes the growth of plant roots.
- Inhibition of aerobic respiration, limiting energy metabolism and restricting growth and developmental processes.
- Promotes denitrification leading loss of soil fertility
- Leads to accumulation of toxins in the soil
- Promotes rotting of roots
- Photosynthesis decline due to closure of stomata, degradation of chlorophyll

Soil drainage

Drainage is the removal of excess water from the soil

Ways by which drainage affects agricultural production

- Improves soil aeration
- Prevents buildup of toxic substance from decomposition of organic matter.
- Cause favorable soil temperature that promote germination and plant growth
- Frees soil of excess water
- Make the soil lighter and easy to till
- Helps control pests and diseases
- Discourage leaching
- Facilitate growth of plants that do not require water logged conditions
- Reduces soil erosion
- Prevents rotting of roots.

Problems that may result from draining agricultural land

- May lower water table
- May lead to death of water loving organisms such as frogs
- Lead to loss of dissolved nutrients
- May dry up soil
- May cause unfavorably high temperature
- Salinization of the soil surface
- Upset ecosystem

Signs of poor drainage

- Stagnant water present on the soil
- A wet spongy soil surface
- Accumulation of organic matter on the soil surface
- Presence of short shallow rooted vegetation

Factors to consider choosing a method of draining

- Topography of the area. A slopping area can easily be drained by surface method
- Affordability
- Skill
- Level of drainage required
- Soil properties e.g. sand soil require surface drainage
- Economic returns anticipated determine the investment in drainage
- Climatic factors such as heavy rainfall require permanent drainage
- Farmer's preference
- Type of crop to be grown: whether it requires a lot of water or not
- Government policy: government may subsidize the cost of pipes promoting sub-surface drainage.

Methods of drainage

(i) Surface drainage (open ditch drainage)

Land is excavated and a ditch is dug at the low lying part of the field. The ditches facilitate collection of excess water which flows freely from agricultural land.

Advantages of surface drainage

- It is cheap to establish
- Blockage can easily be seen
- It is easy to maintain

Disadvantages of using surface drainage channels in draining land

- Waste land since channels are constructed on the soil surface
- Ditches interfere with agricultural operations and livestock movement
- The open channels are prone to silting
- Expensive to maintain
- Promote gulley erosion
- Require **leveling** before water can flow into the drains
- Ditches may become hiding places for dangerous animals

Maintenance of surface drainage

- Plant the channels with vegetation for stability and efficiency of drainage
- The dimensions of the ditches should be maintained by removing silt
- Do not allow people or livestock to use channels or edges of the channels as walk ways.

(ii) Sub-surface or underground drainage

Tiles or pipes are established beneath the soil surface. These trap excess water and carry it away from farm land.

Procedures for sub-surface drainage

- Land is cleared
- Ditches are constructed where pipes are to be laid
- Pipes are then laid in the channels
- The pipes are covered with soil

Advantages of sub-surface drainage

- The field is free from surface obstruction and thus does not interfere with movement of animals and machines
- They do not encourage gulley erosion since water flows inside the pipes
- No need to level land to facilitate drainage
- It removes only excess water and not water required by the plant

Disadvantages of sub-surface drainage

- It may lead to excessive leaching in areas of heavy rainfall.
- It has high initial cost
- Requires skilled labor
- Pipes may be blocked or damaged by crops or animals
- Blockade is difficult to trace

Maintenance of sub-surface drainage

- Control soil erosion to prevent exposure of pipes
- Replace old and damaged pipes
- Construct silt traps to prevent pipe blockage
- Avoid compaction of soil

(iii) Sub-soiling

It done by a sub-soiler a tillage implement that penetrate soil up to 60cm. The operation cracks and loosens the subsoil facilitating water movement and root penetration

(iv) Use of deep-rooted crops

Deep rooting crops as lucerine and eucalyptus can be planted; their roots penetrate compacted subsoil facilitating movement of water to subsoil.

(d) Organic matter

It is the non-mineral portion of soil solids from decayed and partial decayed plant and animal's residue. It is composed of carbohydrates, proteins, fats, pigments, lignin, bones

Classes of organic matter

- **Litter** which includes relatively undecomposed dead parts of plants and animals and their waste that have just been deposited on the soil surface.
- **Residues** which include the dead parts of plant and animals which are actively decomposing
- **Humus** which is the well decomposed and stable organic matter; it is the final product of organic matter decomposition

Importance of organic matter

- Provide food and shelter for soil living organism
- Source of plant nutrients
- Buffers pH
- Reduce soil erosion by binding soil particles together
- Provide attachment sites for mineral ions
- The organic acids released during the process of organic matter breakdown promote weathering
- Promote soil drainage
- Improve soil texture

Properties of humus

- Dark brown
- Odorless
- Colloidal
- Insoluble in water
- soluble in dilute alkali giving a dark colored solution
- contains modified plant residues and synthesized microbial compounds
- has high cation exchange capacity
- has high water absorbing capacity about 5-7 that of clay
- has high relative molecular mass
- light amorphous material with very low bulk density(0.2 -0.5mg/g)

Uses of humus in the soil

- it is a source of N, P, S and most micro-nutrients

- It increases cation exchange capacity (CEC) of the soil because organic matter is negatively charged.
- Source of food for soil organisms
- It increases water holding capacity especially of sand soil
- It improves soil structure by binding soil particles together
- Ti reduces the impact of compaction and capping in soil
- It buffers pH change
- It promotes root penetration into the soil because it keeps soil soft

Experiment to find the percentage of humus in the soil

- **Dry the soil sample (w g) in an oven at 1050C to a constant weight x g**
- **Heat the soil until red hot to a constant mass y.**
- **Percentage** of humus =$\frac{x-y}{w} x100\%$

Factor that affect the rate of decomposition of organic matter

(a) Biological factors

- Age: young plant decompose faster than old ones because of high moisture content, they are less fibrous, and have low C:N ratio.
- Moisture content: succulent plants decompose faster than those which are non-succulent
- Carbon: nitrogen (C:N) ratio: legumes with low C:N ratio decompose faster than cereals.
- pH of the material: plants e.g. pine give acidic residue which are very difficult to breakdown.

(b) Climatic factors

- Temperature: very low temperature hinder decomposition because microorganisms are inactive, increase in temperature promotes decomposition due to activation of microorganisms, high temperature hinder decomposition because of death of microorganisms. Very high temperature accelerates chemical degradation of organic matter.

(c) Soil factors

- Soil moisture: influences activity of soil living organisms
- Soil temperature influences activity of bacteria
- Mineral content
- Presence of living organism

How organic matter level can be increased

- Application of organic manures e.g. farm yard manure (FYM), compost and green manure
- Minimum tillage
- Mulching
- Ploughing back crop residue into the soil
- Liming to increase the living organism
- Proper drainage to encourage the soil microorganisms

How organic matter contributes to soil conservation

- Bind soil particles together reducing soil erosion
- Add nutrients to the soil
- Provide food to soil microorganisms
- Bind soil particles improving soil texture
- Increase water retention in sand soil
- Buffer soil pH
- Impart dark color to the soil that increase soil heat absorption
- Increase cation exchange capacity of the soil

The factors that affect the rate of decomposition of organic matter in the soil

- Age of the plant- young plant materials decompose faster than old ones
- Amount of water in the material: wet materials decompose faster than dry ones
- Carbon: nitrogen ration – legumes decompose faster than cereals because they have high percentage of nitrogen.
- Presence of putrefying organisms; for instance sterilizing soil with heat delays decomposition
- Soil temperature: rate of decomposition increases with soil temperature
- Soil aeration: adequate oxygen in the soil encourages growth of microorganism and promotes decomposition.
- Soil pH between 6 and 8 promotes growth of microorganisms and thus promotes decomposition
- Pollution kills microorganisms and delays the rate of decomposition
- Climatic factors such as rainfall that provides water necessary for rotting

L. Soil permeability

This is extent to which a soil allows water to pass and spread through it. However sometimes soil permeability and soil drainage are considered to be the same.

M. Capillarity in soil

It is the ability of water to rise through the small pores of the soil buy the forces of cohesion and adhesion.

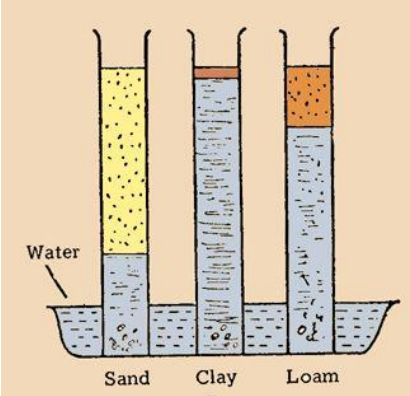
Importance of capillarity

- It makes water available to the plant
- Enable plants access nutrients dissolved in soil

Experiment to investigate soil capillarity

- Get three tube open on both ends and plug one side with cotton wool.
- Fill one tube with dry clay soil and another with dry loam soil and the third with dry sand soil

- Place the tube with soil in cold water bath with the plugged sides immersed in water as shown below



Observations

- Water rises fastest in sand soil but highest in clay soil.
- The level of water increase from sand soil to loam soil and highest in clay soil.

Factors affecting soil fertility

Soil depth, soil structure, soil drainage, soil PH, soil aeration, water holding capacity, availability of plant nutrients, presence of pests and diseases, soil compaction, living organisms, accumulation of salts, soil capillarity, hard pans, soil capping and presence of polyethene materials in soil.

Soil depth

Soil depth is associated with the maturity of the soil and it also influences the amount of water retained in it for plant use.

Soil structure

This affects the amount and movement of air and water within the soil and also the transfer of heat. Therefore a good soil structure gives ideal conditions for plant growth.

Soil drainage

This refers to the ease with which excess water drains out of the water logged soils. There is poor aeration, low temperature, poor soil structure, and low PH in water logged soils. All the above will interfere with normal crop growth.

Soil aeration

Adequate air in the soil particularly oxygen improved water and nutrients uptake and also encourages better root development. The air is also needed by the soil organisms during the decomposition of plant or animal remains.

Polyethene materials in soil

Affects soil aeration, root development and water infiltration which all affect soil fertility

Soil capping

This affects soil drainage which determines pest attack, soil Ph and root development in crops and hence soil fertility.

Hard pans

This impedes water infiltration hence affecting soil fertility.

Availability of plant nutrients

Plant nutrients are needed by plants and therefore a soil which contains most of the nutrients and can easily supply them is said to be fertile.

Soil pH (soil reaction)

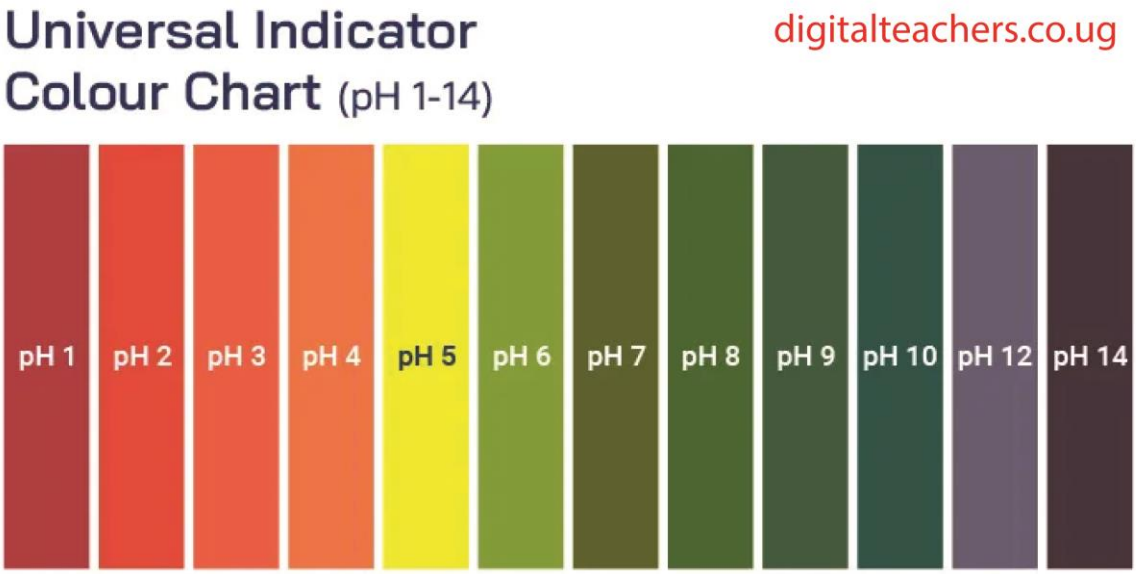
This is the acidity or alkalinity of the soil.

Importance of soil pH

- It affects the presence of certain plant pathogens like bacteria and fungi are not common at low PH but fungi are common
- At very low PH the concentration of certain nutrients such as iron and Aluminium in the soil becomes toxic to plants.
- Soil PH has a strong influence on the availability of various plant nutrients.
- Very low or very high PH inhibits the activity of the soil micro-organisms more especially the nitrifying bacteria.
- It influences the (ability) availability of plant nutrients e.g. at lower PH (acidic) phosphorous and molybdenum are not available but iron, Mg, Zn, K and Boron are available yet unavailable again at high PH (alkaline)

Testing for soil pH

- Place a sample of soil in a dry test tube
- Add barium Sulphate / ammonium Sulphate to the soil sample
- Add distilled water to the mixture and shake gently
- Add 3 drops of the universal indicator and allow the contents to settle for about 45 minutes
- Use the pH chart to find the pH of the soil by relating with the color of the contents in the test tube



Acidity of the soil

An acidic soil has pH less than 7

Causes of acidity in soils

- Soil formed from acid rocks: Rocks such as granite contain an excess of silica (Quartz) which combine with water to form acids.
- Presence of humus: Humus may react with iron and aluminum to form complexes which undergo hydrolysis to yield hydrogen ions responsible for acidity.
- Presence of soluble salts: These may be acidic, neutral, or basic arising from fertilizers mainly.
- Water lodging: This causes hydrolysis of some of cautions in the soil which may release hydrogen ions leading to soil acidity
- Rain water: atmospheric carbon dioxide combines with rain water to form a weak carbonic acid responsible for soil acidity.
- Cultivation of crops: The growing of crops can cause acidity when the plant absorbs cations that can be replaced by hydrogen ions.
- Fertilizers application: Application of fertilizers increases cations and anions content in the soil. When the nitrates are leached they move along with cations leaving the H+ behind
- Biological activities in the soil: Anaerobic decomposition of organic matter leads to formation of weak acids in the soil e.g. lactic acids, ethanoic acids (Organic acids)
- The presence of sulphides in the soil: The sulphides in the soil can also cause soil acidity due to the production of H^+ ions.
- Presence of sulphides: These can cause acidity to the production of H^+.

Ways of raising soil pH

- Addition of lime

Examples of liming materials

- Calcium carbonate (Calcite)
- Calcium magnesium carbonate (dolomite)
- Calcium oxide(quicklime)
- Wood ash
- Paper mill
- Magnesium carbonate.
- Sugar factory lime
- Calcium hydroxide

Characteristics of a good liming material

- It should have a mild balkanizing effect
- It should have a favorable effect on soil
- Should be cheap and readily available
- Should not affect soil microbes
- Should not affect availability of crop nutrients

Factors considered before liming

- Soil pH; very high or low pH may require amending
- Buffer capacity of the soil i.e. ability to resist change in pH after addition of lime
- Amount of bases in the exchange complex.
- Type of crops to be grown i.e. each crop requires a different pH
- Fineness of the materials to be used for liming
- Amount of manganese present in the soil

Importance of liming

- It increases the use of nutrients by crops leading to increased yields.
- It increases the microbial activity in the soil
- Organic matter decomposition in the soil is accelerated
- It increases the availability of plant nutrient and their supply like phosphates.
- Make soils easy to cultivate more especially clay soil
- Ensures sufficient utilization of soluble acidic manures such as phosphates
- Keeps the soil in good condition for crop growth.

Negative effects of liming

- It can lower the yields of crops in later years if the PH is allowed to increase continuously.
- It is expensive therefore can increase the production.
- It decreases the future supply of plant nutrients
- Accelerated organic matter (OM) decomposition causes a decline in organic matter content of the soil.

Soil alkalinity

An alkaline soil has a pH greater than 7

Causes of soil alkalinity

- Weathering of limestone
- Addition of bases e.g. lime
- Irrigation using saline water
- Drought condition
- Underground water

Ways of lowering soil pH

- Addition of acidic organic matter e.g. organic matter from pine needle
- Addition of acidic fertilizers e.g. Sulphate of ammonia.

Cationic exchange

This is interchange between positively charged ions in the soil solution with the adsorbed positively charged ions on the soil colloids such as clay or humus.

A cation is positively charge ion of a metal

Soil cation exchange capacity (CEC)

CEC is the total sum of the exchangeable cations adsorbed per unit weight of soil at a particular pH. CEC measures the number of adsorption sites per unit weight of a soil at a particular pH. It measured in centimols per kilogram of soil, ($cmolkg^{-1}$)

Importance of CEC in the soil

- Help to fix mineral nutrients into the soil due to the negative charges
- Store nutrients for the plants
- Minimize leaching and retains plant nutrients
- Influence pH of the soil
- Helps soil stability

Factors which affect the rate of cation exchange in the soil

- Concentration of cations in the soil solution. Concentrated cations in soil solution replace the less concentrated ones
- The speed of movement of hydrated ions: movement of hydrated ions is slow compared to those not hydrated
- The amount of charge: ions with more charges replace more ions with fewer charges less number of charges.
- The type of colloid: humus has a higher cation exchange capacity than clay.
- The number of charge on the exchange complex: monovalent charged elements have higher cation exchange than divalent charged elements.
- Soil type, the soil pH and the soil organic matter content.

- Influences absorption of nutrients: nutrient uptake from soil is achieved when root hairs pump hydrogen ions into the soil through proton pumps. The hydrogen ions displace cations attached to negatively charged particles (micelles) so that the cations are available for uptake by the roots through root hairs.

Plant nutrients

Plant nutrients can be divided into two major groups i.e. Macro and Micro nutrients.

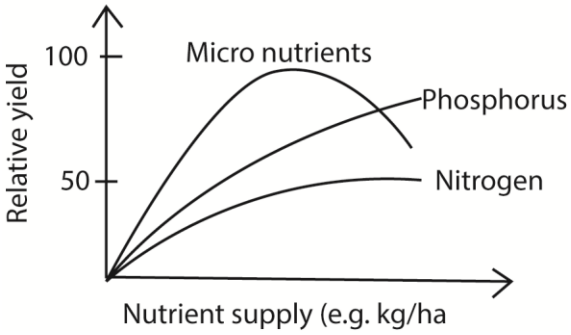
Macro nutrients (major elements)

These are nutrients needed by plants in large quantities e.g. carbon, oxygen, hydrogen, nitrogen, phosphorous, potassium, calcium, magnesium and Sulphur.

Micro elements (trace elements)

These are nutrients needed by plants in small quantities though they are very important for plant growth. E.g. iron, manganese, copper, molybdenum, zinc, chlorides and cobalt.

Graph showing the effect of macro and micro nutrients supply (kg/Ha) on crop yield.



Micro-nutrient deficiency

Micro-nutrient deficiencies have rarely been a serious problem under traditional farming practices in the tropics because

- The bush fallowing system ensures recycling of nutrients from the subsoil through the organic matter accumulation.
- The unimproved, low yield crop varieties make little demand on soil nutrient resource.
- Few fertilizers provided supply the required nutrient.

Micro-nutrient antagonism

- Excess copper or Sulphur retards the utilization of molybdenum.
- Iron deficiency is more pronounced if there is an excess of zinc, manganese and copper.
- Manganese uptake is reduced by excess calcium or lime.
- Boron uptake is reduced by excess calcium or lime

- Zinc uptake is reduced by excess phosphate fertilizers.
- Copper deficiency is intensified by excess nitrogenous fertilizers.

Nutrient uptake and absorption by plants

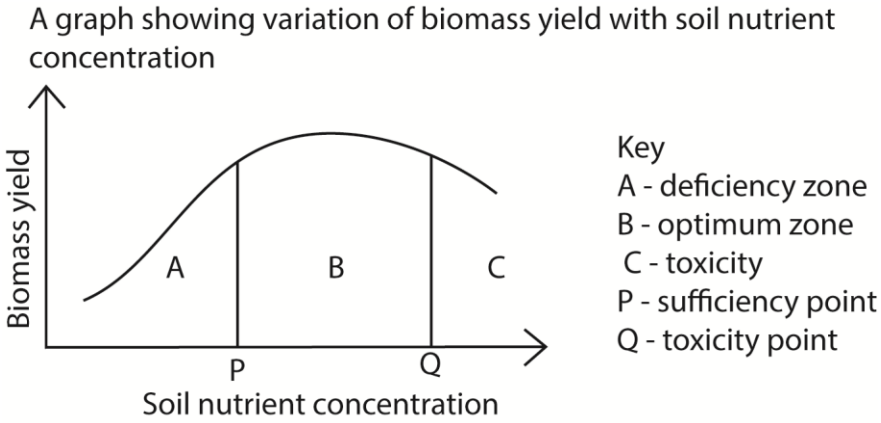
Nutrient uptake from soil is achieved by cation exchange Capacity where root hairs pump hydrogen ions into the soil through proton pumps. The hydrogen ions displace cations attached to negatively charged particles (micelles) so that the cations are available for uptake by the roots through root hairs.

Ways by which plant roots absorb the nutrients

- **Simple diffusion:** gases like oxygen and ammonia are passively absorbed along concentration gradient
- **Facilitated diffusion:** this is a rapid movement of solutes or ions along concentration gradient aided by transport proteins
- **Active transport:** is an energy requiring process that absorb nutrients against their concentration gradient

  - Root interception; nutrients collide with roots in the soil as the roots form a dense network
  - Nutrients are moved inside the plant to where they are needed and converted into biochemical compounds.

Association between nutrients uptake and pant growth



- **Region A/deficient zone:** crop production increases with soil nutrient concentration due to increase nutrient usage by the plant as soil nutrient concentration increase.
- **Region B/Optimum zone:** crop production almost remains constant as soil nutrient concentration because the plant achieves enough/adequate/optimal nutrient concentration. This zone is most suitable for feeding the pasture plants to livestock due to high pasture yield and quality.
- **Region C/toxic zone:** Biomass yield decreases because excessive nutrients lowers biomass yield due to toxicity such as soil **acidification, mineral antagonism and reverse osmosis in roots**, reducing soil fertility and capability to support plant growth.

Other factors that may affect shape the graph above or affect biomass yield of plants are.

- Soil water: soil provides water to plant which is a reagent in many biochemical reactions. However optimal amount is required because too little water may not be absorbed by plant while too much water reduces the amount of air in the soil.
- Soil air: this provides oxygen for root and microorganisms'' respiration and nitrogen for fixation by root nodules.
- Light: increase in light intensity increases biomass yield
- Prevailing carbon dioxide concentration in air: high concentration of carbon dioxide in air increases biomass yield.
- Soil microorganism; these play a role in soil aeration, recycling of nutrients, and provision of nutrients to plant when they die and decompose
- Temperature: promote plant growth by activating enzymes. At very low temperature the enzymes are inactive while at very high temperature the enzymes are denatured and the plant dies.
- Soil pH affects activity of enzymes; optimum pH necessary depending on plant type
- Soil structure: this is the proportion of sand, silt, and clay in a particular soil. Soils structure determines water retention and aeration of the soil. Plants prefer different soil structure.
- Soil pollution: this may affect the micro and macro-organisms content and quality, pH and other soil contents and interaction.

Note that under normal conditions, nutrient uptake determines plant growth in predictable way during most of crop's growth.

Macro nutrients

Nitrogen:

This is one of the most important elements needed by plants yet its deficient in most areas of East Africa.

Forms of nitrogen in the soil

Nitrates
Nitrites
Ammonium compounds

Uses of nitrogen to plants

- It's necessary for the formation of chlorophyll
- It improves the quality and quantity of leaf crops such as cabbages, dodo, etc.
- It is a constituent of plant proteins.
- It facilitates in cell division and therefore responsible for growth
- Controls the use of phosphorus and potassium in the plants
- Regulates availability of P and K.

Deficiency symptoms of Nitrogen in plants

- Leaves become yellowish i.e. suffer from chlorosis
- There is restricted root development

- Plants become stunted.
- There is even yellowing and loss of leaves
- There is pre-mature ripening of fruits.

Signs of excess nitrogen in plants

- Excessive leaf production
- Delayed maturity
- Leaf and stem logging
- Scotching of leaves
- Poor crop yields

Fate /loss of nitrogen from the soil

- Crop removal during harvesting
- Soil erosion.
- Through leaching
- Burning of crop residues
- Volatilization (denitrification; oxidation of nitrates to atmospheric nitrogen)

Sources of nitrogen

- Commercial fertilizers e.g. NPK, Urea, CAN, Sulphate of ammonia, Diammonium phosphate (DAP)
- Organic fertilizers like farm yard manure, compost manure and green manure.
- Lightening.
- Nitrogen fixation by nitrogen fixing bacteria

Phosphorous

Importance of phosphorus to the plants/crops

- Encourages the formation, development and establishment of roots.
- It is necessary in the formation of fruits and seeds.
- It is needed for cell division
- Production of fats and proteins.
- It helps in nitrogen break-down during respiration
- It is a constituent of nucleic acid (DNA, RNA)
- It is important in the synthesis of nucleoprotein
- It is a constituent of phospholipids.
- It gives resistance to certain diseases in crops.
- Its essential part of all the sugar phosphate in photosynthesis and other metabolic processes.
- Improves the quality of crops more especially vegetables.

Deficiency symptoms of phosphorus to the plants

- Purple coloration of the leaf especially at the margin.
- Low yield of grains, fruit and root crops
- Slow growth rate resulting into late maturity of the crops.
- Red necrotic areas on the leaves, petioles etc.

- Distortion of the leaf shape
- Older leaves become dark brown.
- There is a general overall stunted ness and leaf fall.

Factors affecting availability of phosphorus in the soil

- P: P is available at pH 6-7 and not available at extremes
- Iron, aluminium, and manganese ions form insoluble salts with P and prevent its availability in soil for plant use.
- Calcium precipitates phosphate ions in alkaline soil
- Decomposition of organic matter releases phosphorus into the soil
- Microorganisms breakdown organic matter to release phosphorus to the soil
- Clay soil adsorbs phosphorus and make it unavailable in the soil.

Potassium

Importance potassium to the crops/plants

- It increases resistance to certain diseases
- Activate enzymes used in metabolic processes such as photosynthesis
- It encourages root development and growth
- It is necessary for formation of starch and transport of sugar within the plant.
- It is essential for chlorophyll formation.
- It is needed in nitrogen metabolism and protein synthesis.
- It reduces lodging in plants by strengthening cellulose cell wall.
- It controls stomatal movement hence loss of water.
- It's important to folic metabolism
- It has been linked with carbohydrates metabolism.
- It regulates water in plant cells.

Deficiency symptom of potassium to the plants/crops

- Retarded root development
- Plants are easily attacked by diseases
- Leaves dry out at the edges
- Premature loss of leaves
- scotching
- Chlorosis can also be experienced
- In cereals cell at the leaf tip and margin die first.

Factors affecting the availability of potassium in the soil

- **Soil moisture:** Too much moisture interferes with exchangeable moisture.
- **Soil PH:** High soil PH favors potassium fixation
- **Temperature:** High temperature favors the level of exchangeable potassium
- **Types of colloids:** Potassium fixation is usually done in soil containing montimolironite.

Reasons to explain why crops continue to show potassium (K) deficiency symptoms even after applying the right amount of Sulphate of potash in a given field

- Perhaps there was a lot of soil moisture that reduced the exchangeable potassium elements
- Drop in soil temperature which lowered the level of exchange potassium making it unavailable to the plants
- Perhaps the field has 2:2 expanding clay soil which fixes potassium and make unavailable to the plant
- Presence of antagonistic nutrient elements in the soil preventing use of potassium by the plants

Calcium

Importance of calcium to crops/plants

- Raises soil PH which favors nitrogen fixing bacteria
- Improves root development and growth
- It improves vigor and stiffness of the stem,
- It governs the availability of certain essential minerals like phosphorus and potassium.
- It is an activator of enzymes in plants
- It is associated with cell wall structure
- In increases carbohydrates content in crops like cotton.
- It increases the number of mitochondria in wheat plants.
- It protects plants from injuries due to the effect of hydrogen ions.

Deficiency symptoms of calcium to the plants/crops

- The roots become stunted
- Death of the leaves occurs
- Formation of weak stem
- Leaves become chlorotic and chlorosis occurs along the margin of younger leaves.
- Terminal buds and tips of roots do not grow well
- There is distortion of the growing shoot tip
- Cell walls become rigid and brittle

Sources

- Crop residues
- Manure i.e. organic and inorganic
- Weathering of sol minerals
- Agricultural lime

Magnesium

Importance of magnesium to the plants

- It is a constituent of chlorophyll hence responsible for the green colour.

- It is important in the formation of oils in plants.
- It encourages the production and transportation of carbohydrates and proteins in growing plants.
- It maintains the integrity of chromatic fiber and ribosomes.
- It is necessary for full activity of two principle carbon dioxide fixing enzymes.

Signs of magnesium deficiency in crops

- Yellowing of leaves
- Development of purple, orange, and red patches in horticulture crops such as cabbages.
- It causes extensive chlorenchyma development and scanty pith formation.

Sulphur

Importance of Sulphur to plants

- It is needed in protein synthesis as it's a component of some amino acids.
- It is used in the production and activation of some enzymes.
- It increases the oil content of crops (plants)
- It is essential in the production (formation) of some vitamins like biotine.
- Sulphur together with iron form enzymes important in photosynthesis, respiration, and nitrogen metabolism.

Deficiency symptom of sulphur

- Lack of root nodules in legumes.
- Stems are thin and plants are extremely small and short.
- There is complete chlorosis
- There is rapid leaf fall
- Leaf tips and margins are rolled inwards.
- Terminal bud growth is inhibited and lateral buds develop pre-maturely.

Fertilizers and manures

A fertilizer is any organic or inorganic material of natural or synthetic origin that is added to the soil to supply one or more elements essential for the plant growth.

Types of fertilizers

- **Organic fertilizers** are materials containing carbon and other plant nutrients i.e. hydrogen or oxygen
- **Inorganic fertilizer** is a material in which carbon is not essential component of its basic chemical structure.
- **Compound fertilizer** is a fertilizer formulated with two or more major plant nutrients.
- Single/straight/simple fertilizer is a fertilizer formulated with only one major plant nutrient.
- **Complete fertilizer** is a chemical compound containing significant quantities of NPK
- **Fertilizer analysis** is the percentage composition of fertilizer determined in the laboratory and expressed as the total nitrogen, available phosphorous and water soluble potash.
- **Fertilizer grade** is the guarantee minimum analysis in percentage of the major plant material.

Organic fertilizer

These are materials derived from decayed plant and animal residues. Examples include farmyard manure, compost manure, green manure and mulches.

Advantages of organic fertilizers

- They supply organic matter that increases the cation exchange capacity of the soil.
- They supply a variety of plant nutrients.
- They act as food for microorganisms.
- They improve soil structure by binding soil particles together.
- They are cheap to purchase
- They are locally available
- They buffer pH.
- They have long residual effect
- They impart dark color to the soil which improves heat absorption.
- They require no special technique for application.
- They improve on water infiltration and moisture conservation in the soil

Disadvantages of organic fertilizers

- They release available nutrients slowly that they may not fully benefit the crop.
- They are bulky making them difficult to store and transport
- They may transmit pest and disease
- They are difficult to apply using machines
- They do not a constant composition
- Have irritating smell.
- May encourage rapid weed growth

a. Compost manure

It is made of partially decaying organic residues such as weeds, crop remaining after harvesting, domestic wastes etc. Compost manure is made by decaying these organic residues in a pit called compost heap. Composting is aerobic decomposition of organic matter by microorganisms while fermentation is anaerobic decomposition organic matter in a pit or container.

Advantages of composting

- The organic matter is made less bulky and easier to handle
- The weeds and plant pathogens are destroyed from the heat generated.
- Compositing lowers the carbon to nitrogen ratio of organic matter so that the nitrogen in the soil is not immobilized by the microbial decomposers.

Reasons for composting kitchen residue

- to make nutrients available
- to kill harmful organism in the kitchen refuse
- to avoid burning plant roots when decomposing in the garden
- to allow breakdown of any toxic substances in the kitchen refuse
-

Conditions for compositing

- Adequate moisture
- Optimum temperature
- Adequate aeration
- Correct pH

- Availability of microorganisms

Procedure for making compost manure using the pit method

Material: water, ash, urine, saw dust, lime, straw, crop residue, grass, phosphatic fertilizers

Procedure

- Dig 5 pit each 1.2m x 0.6m. The last pit should be larger than others because it receives ready manure
- Put a foundation layer of dry straw.
- A thin layer of ash is added to supply mineral salt to manure
- A layer of composting material which includes cut grass, kitchen refuse is added to provide living organisms.
- A layer of top soil or old compost is added to supply microorganism that decompose the material.
- Artificial fertilizers (phosphatic) are added to increase the nutrient level of the compost.
- Lime is added to adjust the pH of the materials
- A stich is inserted to create a hole that give avenue for addition of water and estimating the temperature of the material.
- Cover the pit with soil to protect the material from drying up
- A layer of polythene may be put to protect materials from rain that cause leaching of nutrients.
- After 3-4 weeks, the materials are transferred to another pit and turned.
- The process continues until the fifth pit.
- The materials are then transferred to the garden.

b. Farm yard manure (FYM)

It is made of animal excreta e.g. cow dung, urine, chicken droppings, mixed with beddings and remains of food provides to the animals; poultry manure is the best for vegetables because it has a high nitrogen continent which encourages vegetative growth of leaves

FYM consists of the liquid component and solid component in ratio 3:1. The liquid is mainly urine which supplies available nutrients, solids supply NPK.

The manures are mainly made indoor where animals are fed and kept under zero grazing system.

The beddings used should be a kind that absorbs urine from the dung.

Procedure of making Farm Yard Manure

- The manure is made under a shade where animals are kept.
- The excreta, beddings and food remains are trampled on the floor and mixed; the floor should be made out of concrete to avoid loss of nutrients into the soil by leaching.
- The mixture is removed periodically and heaped in a shelter to avoid loss of nutrients through exposure to sunshine and rain wash.
- The place should be well drained or raised to avoid seepage of water into the manure.
- The manure heap is covered with 5cm layer of soil to preserve it and allow it to decompose before it is added to the soil.

Major characteristics of FYM

- It is low in mineral nutrients but high in organic content.
- It has relatively high moisture content

- It is imbalanced in nutrient content.
- The residual effect of FYM is relatively shorter than that of compost.
- It is dark in colour therefore helps to absorb heat
- Its composition largely depends on the source
- It releases nutrients slowly.

Factors that influence quality of FYM

- **The type of feeds** given to the animal supplying manure: feeds rich in proteins or minerals salts give rich manure or high quality manure than feeds rich in starch.
- **Type of animal** affects the quality of FYM; for instance, non-ruminant produce rich manure than ruminants.
- **Type of litter/beddings** provided in animal house: bedding consisting mainly of grass plant material produces poor quality FYM than those rich in nitrogen such as legume.
- **Method of storage:** poor storage causes leaching leading poor quality FYM.
- **Age of the manure/degree of rotting:** this refers to the length of time the FYM has been left to rot. Well decomposed FYM is richer in plant nutrients tan freshly applied manure. Fresh FYM may scotch the plants if applied directly.
- **Age of the animals:** mature animals give better manure than young animals
- **Thickness of the beddings:** enough beddings give better FYM than small units of litter because it is able to absorb enough urine.

c. Green manure

This is manure made by ploughing vigorously growing plants or crop into the soil. The crop should be ploughed into the soil before flowering. Preference is given to legumes because they have nodules

Quality of good green manure plant

- Should have fast growth rate
- Should be highly vegetative/leafy
- Should have high nitrogen content e.g. legumes
- Should be free from pests and diseases.
- Should be drought resistant
- Should be evergreen in color
- Should not act as a competitor to the crops
- Should be able to establish on non-fertile soil
- Should decompose readily
- Should be easy to plough

Advantages of green manure

- Use of leguminous crops aids to fix nitrogen into the soil
- They act as cover crops hence control soil erosion
- They add organic matter to the soil which improves soil erosion and water infiltration.
- Provide food to soil organisms
- It is cheap and readily available

Disadvantage of green manure

- They compete with crops for nutrients
- They may act as alternative host to pests and diseases
- The plants used may be used as human food or animal feeds
- Ploughing plants into the soil is expensive
- Compete with plants for water
- Use of green manure delays the cropping program.

d. Organic mulches

These are materials used to cover the soil surface, they include

- Natural mulches: these consist of coffee husks, cereal straw, elephant grass, banana leaves etc.
- Artificial/synthetic mulches e.g. polythene materials

Advantages of organic mulches

- They reduce evaporation and maintain soil moisture in the soil
- They control soil erosion
- They control growth of weeds
- They promote soil organisms
- They protect fruits such as tomatoes, apples from mechanical damage
- Organic mulches control some pests like banana weevil
- Organic mulches decompose and add nutrients to the soil

Disadvantages of organic mulches

- Spread pests and disease
- Act as breeding grounds for pest and disease
- Are fire hazards in hot and dry weather
- They are bulky and require much labour to transport and apply.
- They may cause nutrient imbalance since bacteria that decompose the mulches use part of the nitrogen

e. Inorganic mulches

These include gravel, black plastic and landscape fabric.

Advantages of inorganic mulches

- They smoother weeds effectively
- They maintain soil temperatures longer
- They are easy to lay over a wide area and can be stored for future use
- They can be sterilized against pests and diseases
- They are attractive in appearance

Disadvantages of inorganic mulches

- They hinder aeration of the soil
- The do not improve organic matter of the soil
- They are expensive
- They prevent water infiltration into the soil
- They cause soil pollution
- They cause fire hazard

Inorganic fertilizer

These are chemical compounds artificially prepared to supply nutrients to plants for appropriate growth and development. The major elements supplied are nitrogen, phosphorus and potassium.

Reasons for applying fertilizers in the soil

- To replace the nutrients lost through harvesting crops.
- To add nutrients deficient in a soil
- To get consistent yield.

Advantages of inorganic fertilizer

- They are less bulky thus easy to transport and store.
- They are easy to apply.
- Contain known nutrients required by the plant

- They are soluble and release nutrients easily to the plants
- They are easily applied by machines
- They can be applied at any stage of plant growth.
- Contain nutrients at known concentration

Disadvantages of inorganic fertilizers

- They are expensive to buy
- They pollute the environment when misused
- Change soil pH
- They are easily leached
- Influence survival of microorganisms
- Do not improve soil structure
- Pollute water bodies
- Have low residual effect
- Excessive application of some inorganic fertilizers e.g. nitrogenous fertilizers cause lodging of crops.

Characteristics of a good fertilizer

- Should have high nutrient content
- Should supply required nutrients to the soil
- Should be easy to apply
- Should be cheap
- Should be easy to store
- Should add long lasting effect to the soil
- Should not affect soil pH

Classification of inorganic fertilizer

(a) According to chemical/nutrient composition

- **Direct fertilizers:** are made of readily available plant nutrients e.g. potassium nitrate, magnesium Sulphate, ammonium Sulphate etc.
- **Straight/single fertilizers** are fertilizers that contain one of the major plant nutrients e.g. SSP (single super phosphate), DSP (double super phosphate), TSP (triple super phosphate)
- **Mixed/compound fertilizers** are inorganic fertilizers that contain and supply two or more organic plant nutrients e.g. NPK, DAP, ammonium phosphate.

(b) According to fertilizer material/nutrient content

(i) **Nitrogenous fertilizers:** these are fertilizers which supply nitrogen when applied to the soil. Examples are

- Urea ($CO(NH_2)_2$ or NH_2CONH_2)

- It contains 45 – 46% nitrogen
- It is a white granular substance
- It is highly soluble in water

- It is acidic
- It hydrolyzes in water to produce ammonium carbonate which converted to nitrates by nitrifying bacteria.

- Calcium ammonium nitrate contains 25- 28% nitrogen
- Ammonium Sulphate [(HN4)2SO4] contains 21% nitrogen
- Ammonium phosphate contains 11% nitrogen

Why nitrogen fertilizers are usually top dressed
- They are highly soluble and easily washed down the root zone
- They are required by plants at a later stage of development and not at germination
- They are applied at establishment to avoid misuse by weeds because at this stage plants can fully utilize it
- They are very soluble and volatile if applied on dry soil

- **Slow release nitrogen fertilizers** are fertilizers that that gradually release nitrogen to the soil at a slow rate e.g. sulphur coated with urea.
  Advantages of slow releasing fertilizers
  - They reduce nitrogen loss due to leaching
  - There is reduction in immobilization
  - There is reduction in denitrification
  - There is better season distribution of vegetative growth
  - They have improved storage and handling properties
  - There is a reduction of seed and seedling damage from highly localized concentrated salts.

(ii) **Phosphatic fertilizers** supply phosphorus e.g. DSP and TSP.
Genera characteristics of posphatic fertilizers

- They are sparingly soluble in water
- They are added to the soil before or during planting
- They have a lower scotching effect on plants
- Have high residual effect
- They are soluble in acidic conditions

(iii) **Potassic fertilizers** which supply potassium e.g. potassium nitrate, potassium chloride etc.

Advantages of compound fertilizers
- They contain and supply many plant nutrients
- Application of compound fertilizers save time and labour compared to several application of single fertilizers
- They occur in different rations and analysis. This enables easy choosing of a given material on a given soil
- The mixture is usually well mixed, dry, fine that can be applied by hand and fertilizer drill.
- They do not deteriorate on storage

Disadvantages of compound fertilizers
- They are expensive to buy
- Require skill selection of the fertilizer for a given soil

Methods of fertilizer application

- **Broadcasting** where the fertilizer is spread or scattered uniformly over the field after the land has been ploughed and then mixed into the soil.
- **Plough sole application** where a fertilizer is placed in a continuous band at the bottom of the plough furrow. Each band is covered as the succeeding furrows are turned over.
- **Foliar application** is where the fertilizer is directly sprayed on the crop e.g. urea and micro nutrients of copper, iron, magnesium and zinc.
- **Drilling** where a fertilizer is applied with a drill at the same time the seeds are sown
- **Top dressing** where a fertilizer is applied on the soil surface at a distance from the crop after the crops have emerged/or germinated from the soil.
- **Fertigation** where the fertilizers are applied with irrigation water during irrigation. It is used for water soluble fertilizers.
- Side dressing where a fertilizer is applied besides the plant between plant rows. It best for perennial crops and fertilizers are placed 2-4cm deep.
- **Band placement;** the fertilizers are placed in bands on one or both sides of the row.
- Ring placement; the fertilizers are placed around each and every crops within reach of crop roots.
- **Pumping into the soil;** liquid fertilizers are pumped into the soil using pressure to the required depth.
- **Perforation;** many holes that extent into the soil are dug around a tree under the shade and fertilizers are placed into the holes

Factors that affect the choice of method of application of fertilizers

- **Crop type** i.e. different crops have varying nutrient requirements and root structure which may dictate the most effective application method
- **Soil conditions** such as soil structure, pH, moisture level and organic content can influence availability and uptake
- **Nutrient requirements:** The specific nutrient needed by the crop at different growth stage can influence whether fertilizer are applied to the soil or directly to the plant leaves (foliar feeding).
- **Timing:** the growing stage of the crop is crucial, for example, young plant might benefit more from band placement, while mature plants might need broadcasting.
- **Environmental conditions;** weather conditions such rainfa, temperature and wind can impact the effectiveness of fertilizer application
- **Availability of equipment for application of fertilizers**
- **Cost benefit consideration**

Factors affecting the response of crops to the fertilizer

- **Age/stage of the crop:** different nutrients in the fertilizers are required at different stage of the crop
- **Soil texture:** this affects nutrient retention and cation exchange capacity of the soil. Coarse soils have low adsorption of nutrients and encourage leaching
- **Type of the soil** for instance clay soil fix nutrients making them unavailable to the plants.
- **Soil pH:** extreme pH reduced availability of some nutrients to the plants because it affects solubility and ionization of fertilizers.

- **Method of placement of fertilizer:** fertilizers placed within reach of the plant roots are readily absorbed
- **Amount of water in the soil:** water dissolves and helps absorption of fertilizers. While too much moisture can lead to leaching.
- **Plant density:** proper plant spacing reduces competition for the fertilizer and help their optimal used by plants
- **Amount of fertilizer applied:** optimal amounts of fertilizers are recommended; too little may not illicit proper response while too much is poisonous
- **Rooting habit of a crop:** plants with roots near the surface easily take up fertilizer and show fast response.
- **Amount of bioactivity in the soil:** some organism help in the transformation of nutrients into absorbable form e.g. mycorrhiza.
- **Health status of the crops:** healthy crops respond optimally to the fertilizers
- **Level of weed infestation:** weeds compete with plants for nutrients thus limiting utilization of fertilizers by the plants.
- **Solubility of the fertilizer:** soluble fertilizers are easily utilized by the plant and lead to fast response
- **Good crop management practices** such as thinning, pruning produce good results from application of fertilizers
- **Weather conditions:** wet and warm weather conditions increase solubility and absorption of fertilizers.
- **Soil permeability;** if the movement of soluble fertilizers is impended by hard pans, the crops will have a low response to the fertilizer than if movement is free.
- **Soil structure;** poor structure may interfere with root growth which may fail to benefits from a fertilizers
- **Soil temperature;** if the temperature is high, volatilization of a fertilizer may occur reducing the amount of fertilizers available to the plant and hence low plant response.

Irrigation

It is artificial supply of water to crops or soil when rain is inadequate.

Importance of irrigation

- Provides soil water to the plants
- Modifies soil temperature
- Controls wind soil erosion
- Increases cultivable land
- Safe guards against food shortage
- Make soil soft for tilling
- Can be used to some pest in crops e.g. aphids which are most serious in dry seasons.
- It may control weeds in some crop field e.g. in rice field
- It ensures timelessness in agriculture

Disadvantage/ problems cause by irrigation

- It to spreading of water borne diseases such as bilharzia
- May lead to accumulation of salts in soil when salty water is used
- May lead to soil erosion
- Reduce the amount of air in the soil
- Causes leaching of nutrients
- May cause waterlogging and death of microorganism

- It is expensive

Methods of irrigation

a) Surface method

This is application of water over the surface of land. They include

(i) **Furrow irrigation:** this is where water is supplied to ridged land from the main source through supply channels which allow water to flow into the field along the ridges. Excess water is collected at the bottom of the field

Advantage of furrow irrigation

- Cultivation and irrigation can both go on the same time
- Less evaporation of water takes place
- It is heap where land is leveled
- It does not require special skill
- It reduces leaching since less water is used
- It is easy to control water supply than in flooding system
- Labour costs are relatively low.

Disadvantages of furrow irrigation

- Salts tend to accumulate in the furrow.
- Sometimes the ends of the furrow do not receive enough water.
- Furrows interfere with movement of machinery
- High cost of unblocking furrows
- Requires leveling land

(ii) **Uncontrolled flood:** in this method water is applied by flooding flat areas. It is only applicable in areas with abundant water supply.

Advantage of uncontrolled flood irrigation

- It is cheap
- Requires no special skills to apply
- Supplied enough water to the crops.

Disadvantages of uncontrolled flood irrigation

- It may cause soil erosion
- May cause waterlogging
- It require a lot of water
- Causes a lot leaching
- Land cannot be worked immediately

(iii) **Boarder irrigation:** this where water from the supply canal is applied to the top end of the strips of land which are divided by low earth bunds.

Advantages of boarder irrigation

- Different crop can be grown in different bunds since they can be watered differently.
- It requires less labour
- Requires no special skill
- It is cheap
- It gives good water distribution if bunds are correctly made

Disadvantages of boarder irrigation

- It may require leveling of land that may make it expensive
- It is unsuitable for sand soil

(iv) Basin irrigation: this is a method where water is allowed to flow from irrigation canals into basins (water trough). The basin may vary in size and may be for trees or group of trees.

Water is retained in the basin until infiltration take place. Lateral canals convey water from one basin to another.

Advantages of basin irrigation

- Uses little water
- Reduces soil erosion
- It conserves irrigation water and rainfall water
- It helps to flash out excess salts from soil

Disadvantages of basin irrigation

- Requires leveling of land
- A lot of land is required for canals and basins
- Requires high labour when basins are big
- It may not be suitable for crops that require free drainage of soil

b) Subsurface irrigation

This is the method of irrigation where underground ditches or perforated pipelines are used to supply water to the plants. The water is applied to the root zone directly such that the plants can have access to it immediately.

Advantage of subsurface irrigation

- Little water is lost through evaporation
- Does not promote soil erosion
- Water is readily accessible by plant roots since it is applied to the root zone
- Saves land for crop cultivation

Disadvantages of subsurface irrigation

- It is expensive to buy pipes
- Requires skill in application
- Difficult to locate fault and maintain the system

c) Aerial irrigation

This is the method of irrigation where the water flows through the pipes above the ground and is delivered to the plants

(i) **Overhead/sprinkler irrigation** is a system of aerial irrigation where water is pumped under pressure and allowed out of the pipes through small nozzles and falls the ground as rain.

Factors that affect the efficiency of sprinkler irrigation

- **Quality of water:** good quality water is required to prevent blockade of pipes
- **Type of soil** affects the rate of water infiltration
- **Pump pressure** affects the rate of water delivery
- **Weather conditions** such as strong wind may change the direction of water leading to ineffective irrigation of some parts of the field
- **Temperature** affects the rate of evaporation

(ii) Drip/trickle irrigation: in this system water is applied to the rows of crops through pipes with nozzles that deliver water around the plant roots

Advantages of aerial irrigation methods (drip and sprinkler methods)

- They efficiently supply water to the plants
- Can work well on rugged surfaces
- Fertilizers may be applied during irrigation
- Flow rate is controlled minimizing waterlogging
- Does not promote growth of vectors such as mosquitoes
- It is preferable in green houses
- Easy to operate.

Disadvantages of aerial irrigation

- It is expensive to install
- Required power to run the pump
- Expensive to maintain
- Requires clean water
- Promote pests and diseases.

Factors that determine the method of irrigation to use

- Topography of the area: surface methods are best for slanting land
- Type of soil: surface methods are not suitable for sand soil.
- Availability of water: uncontrolled flood irrigation requires a lot of water while aerial methods require clean water.
- Type of crops e.g. uncontrolled flood method is best for rice cultivation
- Distance from water source: aerial methods require nearby water to minimize cost.
- Availability of funds for initial cost e.g. buying pipes in aerial irrigation.
- Availability of labour
- Technology and skills

Soil Erosion

is the washing away of top soil

Types of soil erosion

- **Sheet erosion:** the surface of the soil is removed evenly over the whole surface of a slope
- **Rill erosion:** top soil is removed to an extent that small channels in which the run-off is concentrated appear
- **Gully erosion:** top soil is removed to an extent that deep valleys are formed by water run-off.

Agents of soil erosion

- Wind
- Water
- Animals

Man's activities that cause soil erosion include

- Overgrazing
- Clearing land for agriculture
- Deforestation
- Road construction

Methods to reduce soils erosion are

- Afforestation
- Planting grass cover
- Mulching
- Strip cropping
- Terracing
- Contour cropping

Soil sampling

Soil sampling refers to the act of taking or obtaining small quantities (samples) of soil from different parts of the field and taking them to the laboratory for analysis.

Aims of sampling

- To test for pH
- To determine organic matter content
- To determine soil mineral composition
- To determine drainage and water retention of the soil
- To determine soil aeration
- To find out the presence of microorganisms in the soil
- To determine the best crop for the soil

Methods of soil sampling

(a) Transverse method: the soil samples are taken from selected sited along the diagonals from the corner of the field
(b) Zigzag/random method: soil samples are randomly picked.

Procedures for obtaining a soil sample

- Determine the size of land area where sampling is to be carried out and determine the number of samples to be picked.
- Obtain clean sampling materials required e.g. polythene bags, soil auger and shovel.
- Decide on the sampling method to be used
- Identify and clear the vegetation from the sampling sites (about 20)
- Pick small sample at a depth 2cm – 15cm from each sampling site in a big polythene bag into which these samples are mixed thoroughly.
- Then a representative sample is picked from the mixture; labeled with date, plot or field number location and signature of the responsible person
- The representative sample is carried to the laboratory for testing

Revision questions

1. The main disadvantage of broad casting fertilizers during seed bed preparation is that
   A. There is wastage of fertilizers where seeds will not land
   B. The spread of fertilizers is not uniform throughout the field
   C. Some of the fertilizers is leached before crop emerge
   D. Weeds are also stimulated to grow with the crops at the same time
2. The reactions below represents a process of weathering
   $2Fe_2O_3$ (s) → 4FeO(s) + O_2(g)
   Which of the following processes in rock weathering is represented by the equation?
   A. Reduction
   B. Hydrolysis
   C. Oxidation
   D. hydration
3. What happens during rock weathering by the process of hydrolysis?
   A. Metallic cations in the rock are replaced by hydrogen ions
   B. Hydroxyl ions in the rock are replaced by metallic cations
   C. Metallic cations in the rocks are replaced by hydroxyl ions
   D. Hydrogen ions in the rock are replaced by metallic ions
4. Interveinal chlorosis of leaves in a crop is a symptoms of
   A. Magnesium deficiency
   B. Calcium deficiency
   C. Phosphorus deficiency
   D. Sulphur deficiency
5. Biological activities in the soil may cause acidity through
   A. Microbes secreting acids into the soil
   B. Anaerobic decomposition of organic matter
   C. Plant roots secreting acids into the soil
   D. Their interaction with fertilizers
6. Which one of the following may lead to increase in the population of earthworms in the soil?
   A. Drainage
   B. Application of artificial fertilizers
   C. Cultivation to loosen the soil
   D. Application of organic manure
7. Organic matter buffers soil pH because of its
   A. High cation exchange capacity
   B. Adsorption capacity
   C. Neutral nature
   D. Amphoteric nature

8. Which of the following factors least affects the efficiency of sub-surface drainage
    A. Soil structure
    B. Soil porosity
    C. Volume of water
    D. Type of land use
9. The purple coloration of leaf margins in cereals is a deficiency symptoms of
    A. Phosphorus
    B. Magnesium
    C. Nitrogen
    D. calcium
10. Which of the following characteristics of water contribute least to weathering? It
    A. Expand on freezing
    B. Dissolves most natural materials
    C. Has a high specific heat capacity
    D. Seeps into narrow cracks and crevices
11. Which of the following characteristics makes clay and humus an essential component of arable land?
    A. Dispersion effect
    B. Cation exchange capacity
    C. Ability to swell and shrink
    D. Ability to obey the cohesion-tension theory
12. Leterisation in the tropics is likely to occur if the parent rock is
    A. Sandstone
    B. Oxisol
    C. Red tropical soils
    D. ferralsols
13. Which of the following is the biggest disadvantage of classifying soils as silt, clay and sand? It
    A. give no information about mineral origin
    B. relies too much on management practices
    C. over emphasize the effect of climate
    D. does not discuss forming process
14. Why is classifying soils as silt, clay and sand not appropriate method? It
    A. does not discuss forming process
    B. over emphasizes the effect of climate
    C. gives no information about mineral origins of the soil
    D. relies too much on management practices
15. Which of the following process occur when rocks disintegrates by hydration during soil formation?
    A. Metallic cations in rocks take up water molecules
    B. Metallic cations in rocks are replaced by hydrogen ions
    C. Metallic cations in rocks are turned into hydroxides

D. Metallic cations in rocks form strong bonds with hydrogen ions.

16. Which one of the following best explains why plants of the same species may respond differently in deficiency of the same nutrient?
    A. Uneven distribution of the same nutrient
    B. Genetic variation of the plant
    C. Uneven distribution of water in the soil
    D. Different photosynthetic mechanism of the plant
17. Which of the following does not adversely affect the pH of the soil?
    A. Absorption of bases by plants
    B. Production of carbon dioxide by the roots
    C. Leaching
    D. Water logging
18. Clays soils retain more water than sandy soils because clays have
    A. Tiny particles and long macro pores
    B. Large particles and tiny micro pores
    C. Tiny particles and tiny micro pores
    D. Tiny particles and large micro pores
19. Moderate moisture in the soil is important because it;
    A. Dissolves organic matter
    B. Source of water to living organism
    C. Regulates soil temperature
    D. Neutralizes acidity of the soil
20. The purple coloration of leaf margins in gramminae is a deficiency symptoms of
    A. Magnesium
    B. Calcium
    C. Phosphorus
    D. potassium
21. the term soil reaction refers to
    A. mineralization of elements in organic matter
    B. antagonism between soil nutrients
    C. hydrogen potential of the soil
    D. fixation of nitrogen in the soil
22. sub-soiling is carried out in order to
    A. mix the soil
    B. encourage soil drainage
    C. discourage soil erosion
    D. expel soil organism

23. When a super phosphate fertilizer is applied to a clay soil, crop may not show a positive response because
    A. Phosphate uptake by crops is suppressed y other minerals in clay
    B. The acidity of clay soils reduce the solubility of phosphates
    C. Phosphates get fixed into insoluble minerals, once in clay
    D. Clay soils are usually water logged and dissolve the phosphates which are less leached
24. Which of the following is the reason why regular turning of material during composting is recommended
    A. Allow even distribution of nutrients
    B. Prevents loss of nutrients through seepage
    C. Allow uniform decomposition of the compost materials
    D. Allow adequate wetting for proper decomposition
25. Which one of the following may lead to increase in the population of earthworms in the soil?
    A. Drainage
    B. Application of artificial fertilizers
    C. Cultivation to loosen the soil
    D. Application of organic manure
26. A nutrient is essential for plant growth and development if
    A. It is required by the plant at the critical stage of growth
    B. Its presence in the plant does not cause a growth abnormality
    C. Its deficiency results into a growth deformity
    D. It is easily absorbed by the plant
27. Which one of the following is an advantage of using farm yard manure over inorganic fertilizers? Farm yard manure
    A. Contains more nutrients
    B. Adds organic matter which improves on soil structure
    C. Does not alter soil pH
    D. Supplies all the micro-nutrients required by the plant
28. Phosphatic fertilizers are normally applied at planting time because they
    A. Do not scorch the seedling
    B. Promote growth
    C. Are required for seed germination
    D. Promote root growth
29. Inorganic fertilizers are not usually applied on a sandy-silty because they
    A. Rarely retain minerals
    B. Hardly support crop growth
    C. Contains sufficient minerals

D. Are acidic

30. What do you understand by 'heavy soils'
    A. Soil that is difficult to cultivate
    B. Very dark colored soils
    C. Soils very rich in mineral components
    D. Soils with plenty of organic matter
31. In which of the following will terracing be most applicable?
    A. Contour farming
    B. Crop rotation
    C. Mixed farming
    D. Strip farming
32. In chemical weathering:
    A. The weak carbonic acid dissolves the rocks slowly
    B. Chemical elements in the rocks react and disintegrate
    C. Chemical reactions are speeded up to break down rocks slowly
    D. The rocks break down slowly soon after physical weathering
33. In which ionic form is nitrogen not available to plants?
    A. NH_4^+
    B. NO_2^-
    C. NO_3-
    D. NH_4^-
34. The nutrient which causes short joints and unthrifty growth in plants is
    A. Calcium
    B. Nitrogen
    C. Phosphorus
    D. potassium
35. Which one of the following is not a disadvantage of sub-surface drainage?
    A. They are expensive and require skilled labor
    B. They are liable to be obstructed by roots
    C. They leave the field free of obstruction
    D. With heavy rainfall, nutrients may leach
36. Which one of the following does not affect the amount of nitrogen released during 'nitrogen flush?'
    A. Soil temperature
    B. Organic matter content
    C. Length of dry period
    D. Number of cultivators
37. Mulching is known to reduce caking in
    A. Loam soils
    B. Clay soil

C. Sandy soil
D. Sandy loam soils

38. The severe nitrogen deficiency in the soil which follows that addition of fresh plant residues with high carbon : nitrogen ratio is due to
    A. Less nitrogen content in the plant residue
    B. Ammonia compounds being fixed
    C. Less decomposition arising from the damage
    D. Lack of competition between microorganisms and plants
39. The amount of fertilizer applied in a given field depends mainly on;
    A. The type of fertilizer
    B. Result of soil analysis
    C. The type of crop grown
    D. Soil structure and texture
40. For which of the following reasons is excess water never present in plants
    A. Water loss is always greater than gain
    B. When the cells become turgid no more water is absorbed
    C. The greater the water content in the leaf space the greater the rate of transpiration
    D. The root hairs are too short lived
41. Deflocculating is not a desirable process in soil because it
    A. Leads to the destruction of soil structure
    B. Disperse soil nutrients from the root zone
    C. Leads to fixation of plant nutrients in the soil
    D. Leads to leaching of plant nutrients.
42. Plants grown in clay soils are likely to show phosphate deficiency symptoms because
    A. Phosphates is unavailable to the plants in poorly aerated soils
    B. Plant roots are poorly developed in poorly aerated soils
    C. Fixation of phosphorus occurs in clay soils
    D. Phosphorus will get lost through leaching
43. The major reason for adding sand to clay soil for crop production is to
    A. Decrease acidity
    B. Improve drainage
    C. Improve water retention capacity
    D. Decrease alkalinity
44. Supply excess nitrogen to the plant may cause
    A. browning of leaves and premature drop off
    B. chlorosis
    C. delayed maturity
    D. production of pigments other than chlorophyll

45. Good drainage and ploughing of soil reduces the process of

A. Nitrification
B. Decomposition
C. Denitrification
D. Nitrogen fixation

46. The conversion of nitrates into proteins in the soil by microbe can be termed as
    A. Mineralization
    B. Immobilization
    C. Denitrification
    D. fixation

47. Root nodules formation is a result of infection of the root cortex by a group of bacteria called
    A. Azotobacter
    B. Nitrobactor
    C. Rhizobia
    D. Nitrosomonas

Answers to objective questions

1D	6D	11B	16B	21B	21B	26A	31A	36D	41A	46B
2A	7D	12A	17B	17B	22B	27A	32B	37B	42C	47C
3A	8D	13A	18C	18C	23B	28D	33D	38B	43B	
4A	9A	14C	19C	19C	24C	29A	34D	39B	44C	
5D	10C	15A	20C	20C	25D	30A	35C	40C	45C	

48. Give three reason why kitchen refuses should be composted before application
    - to make nutrients available
    - to kill harmful organism in the kitchen refuse
    - to avoid burning plant roots when decomposing in the garden
    - to allow breakdown of any toxic substances in the kitchen refuse

49. (a) what is cationic exchange
    This is interchange between a positively charge ion in the soil solution with the adsorbed positively charged ions on the soil colloids such as clay or humus.
    (b) Outline three factors which affect the rate of cation exchange in the soil
    - Concentration of cations in the soil solution. Concentrated cations in soil solution replace the less concentrated ones
    - The speed of movement of hydrated ions: movement of hydrated ions is slow compared to those not hydrated
    - The amount of charge: ions with more charges are more in replacing those with less number of charges.
    - The type of colloid: humus has a higher cation exchange capacity than clay.

- The nature of charge on the exchange complex: monovalent charged elements have higher cation exchange than divalent charged elements.
- **soil type, the soil pH and the soil organic matter content**.

50. (a) Describe the methods of applying solid fertilizers to the soil
    - Broadcasting: the fertilizer is scattered uniformly over the field either by using hand or machine broadcaster
    - Band placement: fertilizers are placed in bands on one or both sides of the crop row, about 5cm below the seed and 4cm away from the seed or plant
    - Top-dressing: involves application of fertilizers to the soil after the crop is fully established.
    - Side dressing: the fertilizer is placed alongside the band besides the crop row after planting and establishment of the crops
    - Frill/dibble placement: a hole is made in the soil where the fertilizer is placed and then covered with the soil.
    - Application by plough: the fertilizer is placed in continuous bands at the bottom of the plough furrow. Each band is covered as the succeeding furrows are turned over.
    - Application through irrigation system: fertilizers are mixed with water for irrigation
    - Spraying on leaves of the crop especially urea
    - Contact placement: the fertilizer is mixed with planting seed so that the seed and fertilizer are simultaneously placed in the soil.
    - Ring placement: the fertilizer is placed in a circular manner around the plant.
    - Basal placement: the fertilizer is placed directly into the planting hole, covered with soil before the seed.

    (b) Discuss the factors affecting the response of crops to the fertilizer

    - Age/stage of the crop: different nutrients in the fertilizers are required at different stage of the crop
    - Soil texture: this affects nutrient retention and cation exchange capacity of the soil. Coarse soils have low adsorption of nutrients and encourage leaching
    - Type of the soil for instance clay soil fix nutrients making them unavailable to the plants.
    - Soil pH: extreme pH reduced availability of some nutrients to the plants because it affects solubility and ionization of fertilizers.
    - Method of placement of fertilizer: fertilizers placed within reach of the plant roots are readily absorbed
    - Amount of water in the soil: water dissolves and helps absorption of fertilizers.
    - Plant density: proper plant spacing reduces competition for the fertilizer and help their optimal used by plants
    - Amount of fertilizer applied: optimal amounts of fertilizers are recommended; too little may not illicit proper response while too much is poisonous

- Rooting habit of a crop: plants with roots near the surface easily take up fertilizer and show fast response.
- Amount of bioactivity in the soil: some organism help in the transformation of nutrients into absorbable form e.g. mycorrhiza.
- Health status of the crops: healthy crops respond optimally to the fertilizers
- Level of weed infestation: weeds compete with plants for nutrients thus limiting utilization of fertilizers by the plants.
- Solubility of the fertilizer: soluble fertilizers are easily utilized by the plant and lead to fast response
- Good crop management practices such as thinning, pruning produce good results from application of fertilizers
- Weather conditions: wet and warm weather conditions increase solubility and absorption of fertilizers.

51. (a) State the major forms of nitrogen in the soil

Nitrates (NO_3^-)

Nitrites (NO_2^-)

Ammonium compound (NH_4^+)

(b) Outline uses of nitrogen to crops

- Increases the sizes of grains
- Encourages growth of vegetables
- Formation of plant proteins
- Promotes formation of chlorophyll
- Regulates the availability of potassium and phosphorus to the plants
- Required in fruit formation e.g. pineapple, cucumber, water melon

(c) State the factors that affect leaching in the soil

- Soil structure; weak structure encourages leaching
- Soil texture; coarse texture encourages leaching
- Rainfall intensity; high rainfall water encourages leaching
- Vegetation cover minimizes leaching
- Soluble nutrients are easily leached
- Tillage removes vegetation cover and encourages leaching
- Cation exchange capacity of the soil; high exchange capacity increases leaching
- Level of humus in the soil; high content of humus reduces the rate of leaching

52. Give reasons to explain why crops continue to show potassium (K) deficiency symptoms even after applying the right amount of Sulphate of potash in a given field

- Perhaps there was a lot of soil moisture that reduced the exchangeable potassium elements
- Drop in soil temperature which lowered the level of exchange potassium making it unavailable to the plants

- Perhaps the field has 2:2 expanding clay soil which fixes potassium and make unavailable to the plant
- Presence of antagonistic nutrient elements in the soil preventing use of potassium by the plants

53. (a) Explain the factors that affect the rate of decomposition of organic matter in the soil
    - Age of the plant- young plant materials decompose faster than old ones
    - Amount of water in the material: wet materials decompose faster than dry ones
    - Carbon: nitrogen ration – legumes decompose faster than cereals because they have high percentage of nitrogen.
    - Presence of putrefying organisms; for instance sterilizing soil with heat delays decomposition
    - Soil temperature: rate of decomposition increases with soil temperature
    - Soil aeration: adequate oxygen in the soil encourages growth of microorganism and promotes decomposition.
    - Soil pH between 6 and 8 promotes growth of microorganisms and thus promotes decomposition
    - Pollution kills microorganisms and delays the rate of decomposition
    - Climatic factors such as rainfall that provides water necessary for rotting

(b) Define the following terms as used on nutrient deficiency

i. Chlorosis: this is general yellowing of the leaf tissue. It is very common deficiency symptoms since many nutrients affect the photosynthesis process directly or indirectly.
ii. Coloration abnormalities: some deficiency lower the amount of photosynthesis and chlorophyll which is produced by the plant
iii. Firing: yellowing followed by rapid death of lower leaves moving up the crop.
iv. Interval chlorosis: yellowing in between leaf veins, but with the veins themselves remaining green in grasses, this is called stripping.
v. Necrosis: severe deficiencies result in death of the entire plant or part of it.
vi. Stunting: many deficiencies result in decreased growth. This result in shorter height of the affected plant
vii. Die-back of shoots in plants: refers to death of death tips or meristems
viii. Mobility of nutrients in plants: mobile nutrients can be translocated from old tissue (bottom of the plant) to new tissues (top of the plant). Deficiency symptoms occur on the lower older leaves; nutrients that are mobile include nitrogen, phosphorus, potassium, magnesium etc.
ix. Immobile nutrients: these are nutrients which are not easily translocated in plants e.g. iron, calcium, copper, manganese, molybdenum etc. Deficiency symptoms occur in new leaves.
x. Volatilization refers to sublimation of ammonium compounds to form nitrogen that escapes to the atmosphere. The process is favored by high temperature, high soil reaction, leaving fertilizers on the soil surface and soil with low cation exchange capacity or when urea is applied on grass or soil surface.

54. (a) suggest conditions that encourage soil aggregation

- Soil organic matter binds the soil particles together
- Soil water: moist soils are more plastic than dry ones
- Liming: calcium has a capacity to flocculate soil colloid
- Living organisms produce substance such as mucus that binds soil particles together
- Compaction lead to formation of platy structures
- Soil texture: soils with large particles are not plastic enough so their particles easily detach.

(b) Explain the importance of soil structure in crop production.

- It controls the passage of water through the soil i.e. granular structure enables are more rapid downward flow of water than planty structure
- It controls aeration of soil
- It controls soil temperature
- It regulate water holding capacity
- Controls soil pH by controlling air passage
- It controls workability of the soil; single, loose grained soil is easier to work than sticky heavy soils.
- It control root soil penetration
- Control soil erosion; loose soil is easily eroded.
- Controls the ability of soil to hold nutrients

(c) Outline the effects of soil erosion in farming

- Leads to loss of nutrients
- Wash away/dislodges crops and planting materials
- Creates gullies that make movement of machineries and livestock difficult and also reduce available land for farming.
- Creates sand deposition to cover fertile soil.
- Cause silting of water bodies and drainage tunnels
- Gullies reduce the size of the farm
- It may bury crops
- It promotes spreading of water borne disease
- Spreads pests by dispersing crop debris.
- Spreads weeds
- Lead to landslides and destruction of life
-

55. (a) Give the reasons for the increase in soil nitrate level soon after the first rains after a dry season
    - Accumulation of organic matter from plant tissues in the soil during dry season. These decompose and release nitrates.
    - Rapid multiplication of decomposers
    - Rapid increase of nitrifying bacteria that oxidize ammonium compounds into nitrates

- Rapid increase of the population of nitrogen fixing bacteria
- Nitrogen fixation by lightening

(b) Explain the factors affecting nitrification in the soil

- Level of ammonia: nitrification takes place when there is a source of ammonia.
- Aeration: nitrification process requires air.
- Temperature: high temperature favors nitrification and nitrogen fixation
- pH: nitrification and nitrogen fixation require favorable pH
- chemical kill nitrifying and nitrogen fixing bacteria and reduce the level of nitrification
- moisture content of the soil: nitrification is slowed by very high and very lower soil moisture

56. (a) Give four ways in which soil organism contribute to soil fertility
    - Decompose plant and animal remaining into humus
    - They are used for nitrogen fixation
    - Help in soil aeration e.g. earthworm
    - Mix up soil particles
    - Produce mucus causing aggregation of soil particle e.g. earthworms
    - Improve soil drainage
    - Improve soil aeration

(b) State four harmful effects of soil organism to crop

- Some organism destroy plant tissue e.g. millipedes
- Some organisms such as fungi cause disease
- Termites burrow deep and bring to the surface poor unfertile soil which reduces soil fertility.
- Soil organism e.g. nematode suck plant sap and block the transport tissues thereby hampering growth.

57. (a) Distinguish between bulk density and particle density in soil.
    Bulk density is the weight per unit volume of a dry sample of soil in its natural structure intact while particle density is the mass per unit volume of soil solids.

    (b) Explain factors that influence bulk density
    - Organic matter content: organic matter is very light and spongy and so increase in organic matter content lowers bulk density of the soil.
    - Soil particle size: clay soil with tiny particles have higher bulky density than sand with large particles
    - Porosity of the soil: porous soil has lower bulky density than non-porous soil
    - Soil depth: bulk density tends to increase the deeper one goes into the soil profile due to lower organic matter and high density of the underlying rocks.
    - Level of cultivation: intensive cultivation increases bulk density because it causes rapid break down of organic matter and cause compaction of the soil

- Systems of soil management: addition of manure in large amounts to soil lowers its bulk density.
- Cropping systems: continuous cropping reduces the amount of organic matter in the soil and increases the bulk density.
- Amount of air in the soil: the higher the air in the soil, the higher the bulk density
- Soil structure: the more compacted the soil structure, the higher the bulk density
- Mechanization: use of heavy machines such as tractors during cultivation compact the soil increasing its bulk density.

(c) Suggest activities that can lead to destruction of soil structure

- Pollution of the soil such as application of fertilizers and insecticides.
- Ploughing soil at high moisture content results into mingling of the soil especially those that contain high clay content
- Excessive leaching especially calcium and iron oxides that bind soil particles
- Continuous cultivation of the soil break up soil aggregates
- Bush burning destroy the organic matter and expose the soil to agents of erosion
- Soil erosion erodes the aggregates destroying their shape
- Use of heavy machinery compact the soil and destroy soil structure.
- Water logging prevents organic matter from decomposing encouraging crumbling of soil structure

58. (a) Explain ways through which soil becomes acidic
    - Application of organic manure: decomposition of organic manure produces acidic substances
    - Application of Sulphur and nitrogen containing inorganic fertilizers
    - Leaching of bases such as calcium, magnesium and potassium leaving aluminium ions.
    - Water logging cause anaerobic respiration that produce carbon dioxide and lowers pH
    - Acidic rain
    - Acidic parent rock from which soil is formed
    - Uptake of bases by the plant roots and replaced by hydrogen ions from the plants.
    - Release of acidic industrial and domestic wastes.
    - Water logging causes acidic hydrolysis of salts such aluminium salts.

(b) What is the importance of lime to the soil?

- Improve soil structure by binding soil particles
- Neutralizes acidic soils
- Supplies calcium to the soil
- Binds soil particle to make aggregates that improves soils aeration and drainage.
- Prevents some plant diseases such as fungal diseases
- Makes availability of plant nutrients such phosphorus and nitrogen

- Make clay soil less sticky and easy to till
- Promotes soil organism's activity and nitrogen fixation in root nodule
- Promotes decomposition of organic matter.
- Reduces toxicity of aluminium

(c) Explain factors to be considered before applying lime to the soil

- pH of the soil; the amount of lime required depends on the acidity of the soil
- size of particles of limestone or carbonates: this affects the solubility
- type of crops grown; different crops require different pH
- the amount of manganese and aluminium present
- The texture of the soil: fine textured soils have high cation adsorption capacity and less leached than coarse textured soil so more lime is applied.
- The amount of organic matter in the soil. Soil with much organic matter requires more lime because it has high cation adsorption capacity.
- Depth of the soil: deeper soil experiences high rate of leaching and thus requires larger amounts of lime.
- Frequency of application of lime; infrequent application of lime requires high amount per application.
- Fineness of limestone or carbonate used

59. (a) Distinguish between soil texture and soil structure (02marks)
Soil structure refers to the fineness or coarseness of the mineral particles of the soil while refers to the general arrangement of soil particles within a soil mass to form aggregates.
(b) Explain how soil structure can be destroyed.
    - Continuous cultivation of the soil breaks soil aggregates
    - Ploughing soil with high moistures breaks soil aggregate
    - Soil erosion washes away top soil
    - Poor sol drainage limits soil organisms that would otherwise enhance soil structure
    - Excessive leaching of calcium and iron that bind the soil aggregate
    - Pollution that kill microorganism that would otherwise enhance soil structure
    - Use of heavy machines that deform/compact soil
    - Poor harvesting practices that do not add organic matter to the soil

    (c) Explain how soil structure can be maintained.

    - Minimum tillage
    - Growing cover crops to reduce soil erosion
    - Mulching to reduce soil erosion, maintain soil moisture and add organic manure to the soil.
    - Bush fallowing with grasses so that fibrous roots bind soil particles
    - Proper drainage to remove excess water that cause dispersion

- Liming to bind soil particles
- Controlled irrigation to provide soil moisture
- Controlled grazing to prevent soil compaction and erosion
-

60. (a) What are the causes of low soil productivity/fertility?
    - Soil erosion leads to loss of crop nutrients
    - Leaching leads to inaccessibility of soil nutrients
    - Poor drainage may lead to water logging and hence poor soil aeration and unfavorable soil temperature.
    - Poor tillage destroys soil structure leading to leaching
    - Unfavorable pH
    - Soil capping i.e. development of impervious layer on the soil surface
    - Development of hard pans or impervious layers below the soil surface
    - Lack of required soil nutrients
    - Presence of pests and disease causing organisms in the soil
    - Presence of weeds which compete which compete with plants for nutrients
    - Lack of adequate soil moisture.
    - Mono-cropping cause soil exhaustion and buildup disease causing organisms
    - Burning of vegetation destroys soil living organisms
    - Excessive irrigation cause leaching
    - Excessive drainage lead to loss nutrients
    - Salinity of the soil

(b) Explain how soil productivity can be improved

- Through application of manure and fertilizers
- Practicing crop rotation to promote usage of different nutrients
- Irrigation to provide water in the soil.
- Drainage of excess water
- Modifying soil pH
- Prevention of soil erosion
- Control pests and diseases
- Proper cropping like preventing overcrowding
- Applying effective method of water conservation

61. (a) Explain the benefits of draining agricultural land
    - Improves soil aeration
    - Prevents buildup of toxic substance from decomposition of organic matter.
    - Cause favorable soil temperature that promote germination and plant growth
    - Frees soil of excess water
    - Make the soil lighter and easy to till

- Helps control pests and diseases
- Discourage leaching
- Facilitate growth of plants that do not require water logged contions
- Reduces soil erosion
- Prevents rotting of roots.
- Prevents accumulation of toxins

(b) What problems may result from draining agricultural land?

- May lower water table
- May lead to death of water loving organisms such as frogs
- Lead to loss of dissolved nutrients
- May dry up soil
- May cause unfavorably high temperature
- Salinization of the soil surface
- Upset ecosystem

(c) Outline the disadvantages of using surface drainage channels in draining land.

- Waste land since channels are constructed on the soil surface
- Ditches interfere with agricultural operations and livestock movement
- The open channels are prone to silting
- Expensive to maintain
- Require leveling before water can flow into the drains.

62. (a) Explain what should be considered when designing a crop rotation
    - Nutrient requirement of the crops
    - Rooting system of crops: deep and shallow rooted crops should alternate.
    - Botanical families to which the crops belong: crops should be rotated from one family to another.
    - Cover crops: the rotation should include cover crops to control soil erosion
    - Pest and disease control: crops affected by the same pests and diseases should not be grown in succession.
    - Rest phase should be included in the rotation
    - Growth habits of the crops: crawling crops should be alternated with erect crops.
    - Water requirement of the crops: crops that required a lot of water should be grown during wet seasons and those that require less water in dry seasons.
    - Ease of weeding: crops which are easy to weed should alternate with crops difficult to weed.
    - Inclusion of legumes such as beans, peas, groundnuts in the cycle to add nitrogen

    (b) Explain the role of crop rotation in maintaining soil fertility

- Rotating crops of different rooting system enables plants to absorb nutrients at different soil layers
- Different crops prefer different nutrients which prevent soil exhaustion.
- Some plants like legumes fix nitrogen to the soil
- Crops rotation improves soil structure such as those with fibrous roots.
- Crop rotation controls pests and diseases by breaking their life cycles
- Crop rotation controls some weeds such as striga
- Resting helps regain fertility
- Nutrient recycling i.e. deep rooter against shallow rooter
- Conserve soil moisture when cover crops are planted
- Control soil erosion by maintain soil structure or planting cover crops,

63. Explain how each of the following affects crop growth

(a) Soil pH on crop production

- Affects availability of plant nutrients e.g. low pH makes phosphorus and molybdenum unavailable while high pH makes manganese and potassium less available.
- At low pH, iron and aluminium become excessively available and become toxic to the plants.
- Very low pH inhibits nitrogen fixation
- pH determines the types of crops that can grow in an area e.g. tea and pineapples prefer low pH.
- Control prevalence of disease causing organisms, e.g. fungal disease are common in acidic soils.
- It influences the type of fertilizer to be applied e.g. sulphates of ammonia should not be applied to acidic soil.

(b) Soil temperature on crop production

- warm temperature encourages decomposition of organic matter to release plant nutrients
- low temperature discourages germination
- high temperature encourage drying of the soil
- increase in temperature increase cell wall permeability
- low temperature lowers the rate of photosynthesis and respiration
- very high temperature cause wilting and death of the plant
- affects solubility of nutrients
- affects absorption of water and nutrients i.e. warm temperature encourages absorption
- alternate hot and cold temperature promotes weathering
- Influence nutrient loss from the soil for instance volatile ammonium compounds are lost on hot weather.

(c) Soil organisms on crop production

- fix nitrogen to the soil
- decompose organic matter to release nutrients
- some cause diseases to the crops
- denitrifying bacteria reduce nitrogen from the soil

- compete for oxygen in the soil with roots
- some organisms produce toxic substances that cause disease to the crops

64. Explain the factors to consider when deciding on which crop to grow.
    - Soil type; different crops prefer different soils
    - Rainfall
    - Temperature
    - Prevent weed
    - Labor requirement
    - Food value
    - Taste preference
    - Soil fertility
    - Cost of production
    - Available size of land
    - Government policy – the government may dictate crops to be grown
    - Altitude
    - Land ownership may determine whether to grow annual or perennial crop
    - Price of the crop
    - Purpose of the crops either for animals or human or drug
    - Gestation period
    - Culture for instance Baganda prefer growing bananas

65. (a) Discuss factors that affect soil porosity
    - Soil texture: very fine soil texture such as clay soil lead less porous soil
    - Level organic matter in the soil: high organic matter content increase soil porosity by promoting soil aggregate
    - Frequent tillage promotes soil porosity by breaking up soil particles
    - Soil organisms like earth worms burrow and levels tunnels in the soil improving soil porosity.
    - Soil depth: soil porosity tends to decrease and the soil depth increase.

    (b) Means by which plant root take up nutrients

    - Simple diffusion
    - Facilitated diffusion
    - Active transport
    - Root interception

66. (a) Outline six properties of humus
    - Dark brown
    - Odorless
    - Colloidal

- Insoluble in water
- soluble in dilute alkali giving a dark colored solution
- contains modified plant residues and synthesized microbial compounds
- has high cation exchange capacity
- has high water absorbing capacity about 5-7 that of clay
- has high relative molecular mass
- light amorphous material with very low bulk density(0.2 -0.5mg/g)

(b) Give five uses of humus in the soil

- it is a source of N, P, S and most micro-nutrients
- it increases cation exchange capacity (CEC) of the soil because organic matter is negatively charged.
- Source of food for soil organisms
- It increases water holding capacity especially of sand soil
- It improves soil structure by binding soil particles together
- Ti reduces the impact of compaction and capping in soil
- It buffers pH change
- It promotes root penetration into the soil because it keeps soil soft

(c) Describe any appropriate test that can be used to find humus content of the soil

Procedure

- Dry the soil sample (w g) in an oven at 105^0C to a constant weight x g
- Heat the soil until red hot to a constant mass y.
- Percentage of humus =$\frac{x-y}{w} x100\%$

67. Suggest the factors which influence soil erosion
    - The amount/density of rainfall: in areas which receive heavy rainfall, the rain drops hit the ground with much force causing splashing of the soil and the soil is carried in running water
    - Steep relief encourages soil erosion
    - Type of soil: loose soil particles are easily carried away by the agents of soil erosion.
    - Vegetation cover minimize soil erosion
68. (a) List five factors that affect symbiotic nitrogen fixation in the soil (05marks)

    - Presence of nitrogen fixing bacteria (**of** the genus **Rhizobium)**
    - Presence of root legume roots in whose root nodule bacteria live
    - Presence favorable temperature
    - Presence of oxygen in the soil for respiration of bacteria
    - Presence of nitrogen in the soil to be fixed
    - Presence of zinc in the soil: zinc is necessary for nitrogen fixation acting as a secondary signal for nitrogen fixation
    - Presence of antimicrobial agents in the soil

(b) Give five uses of nitrogen in plants (05marks)

- used in synthesis of chlorophyll
- used in production structure i.e. constituent of proteins
- used in synthesis of enzymes
- used in synthesis of hormones
- used in synthesis of poisonous substance that protect the plants from predators.
- Controls the use of phosphorus and potassium in the plants
- It improves the quality and quantity of leaf crops such as cabbages, dodo, etc.
- It helps in cell division and therefore responsible for growth
- Controls the use of phosphorus and potassium in the plants

69. (a) State three factors that influence the temperature of the soil. (03marks)
    - Amount of soil radiation: high solar radiation increase soil temperature
    - Soil colour: dark soil color absorbs heat and increases soil temperature
    - Crop cover: plant cover lowers soil temperature
    - Organic matter increases soil moisture retention and give a darker color to the soil increasing heat retention in the soil
    - Soil moisture: retains heat in the soil
    - Compositing release heat increasing soil temperature
    -

    (b) Explain the effect of temperature on soil productivity. (04marks)
    - High soil temperature promotes activities of soil organisms such as nitrogen fixation
    - High soil temperature promotes active uptake mineral soil
    - High soil temperature promote decomposition and release of nutrients from organic matter
    - High soil temperature increases water uptake
    - **low** temperature discourages germination
    - high temperature encourage drying of the soil
    - **alternate** hot and cold temperature promotes weathering of soil

    (c) Explain three ways by which a farmer can modify soil temperature. (02marks)
    - Mulching lowers soil temperature
    - Drainage increase soil temperature
    - Planting of cover crops

Thank U

Dr. Bbosa Science