CHAPTER THREE

Soil Science

Key Words	By the end of this chapter, you should be able to:
• Soil • Rocks • Weathering • Nutrients • Soil fertility • Soil pH • Fertilizer • Soil texture • soil structure • soil sampling	• show skills in analysing and identifying the different components of soil. • appreciate the different types of weathering processes and factors influencing soil formation. • illustrate skills in distinguishing between the different soil particles, soil textures, soil structure, soil profile horizons and types of soils as used for agricultural purposes. • recognise the importance of plant nutrients and soil pH. • demonstrate soil improvement practices and understand their effects on plant growth.

Competency: You should be able to comprehend how soil is formed from rocks through the process of weathering.

Introduction

In this chapter, you will learn about soil. Soil is the upper layer of the earth in which plants grow. It is black or dark brown and typically consists of a mixture of organic remains, clay, rock particles and humus in various proportions.

What is Soil?

Soil is the material which nourishes and supports growing plants. It consists of rock particles, water, organic matter and air. Soil gives human beings the ability to produce food through agriculture. It is where humans and other animals are held to carry out several activities that support life.

Components of Soil

The four major components of soil are minerals, organic matter, air and water. Mineral and organic matter are the solid particles in soil, while water and air fill up the spaces between the particles. Soil also has living organisms; some are very tinny to be seen with our naked eyes, while others such as like moles, millipedes and centipedes are big.

Pie chart showing the percentage composition of soil

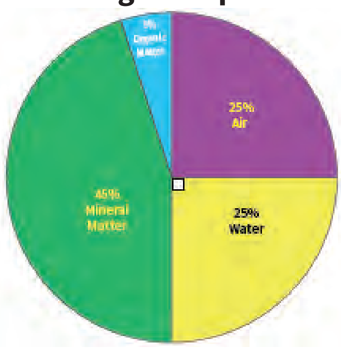


Figure3. 1: Composition of soil

3.1 a) Activity: Examining the composition of soil

i) In your group, get three different samples of soil from various places in your community (garden, near a kraal, from a swamp, from a forest/tree plantation, school compound, lake shore/river bank/dam/pond).
ii) Place a given amount of the soil in a jar/measuring cylinder with a lid.
iii) Add some water so that the jar/measuring cylinder is three quarter full.
iv) Put the lid firmly and shake the jar/measuring cylinder.
v) Leave the jar/measuring cylinder and its contents to settle for two days.
vi) Repeat steps ii - v for all your soil samples collected.
vii) Make your observation on how the particles settle.
viii) Describe what you see in the jar/measuring cylinder.

3.1 b) Activity: Investigating the main components of soil

In small groups, carry out the following experiment:

i) Get two dry sample of soil from two areas (on top of a hill (A) and in the valley (B)) in or around the school. Label the soil samples A and B.
ii) Get three dry 250ml conical flasks or 100ml measuring cylinders and label any two A and B respectively.
iii) Stick a strip of graph paper on the side of the conical flask/measuring cylinder.
iv) Put 70ml of dry soil sample A into the respective conical flask/measuring cylinder.
v) Put 70ml of dry soil sample B into the respective conical flask/measuring cylinder.
vi) Measure 100ml of water and pour it into each conical flask/measuring cylinder containing the soil samples A and B.

vii) Cover with your hand or lid and shake thoroughly for 2 minutes. Repeat this for the other conical flask/measuring cylinder.
viii) Allow the conical flask/measuring cylinder to stand for 10 minutes.
ix) Examine the results of your experiment after settling.
x) Estimate the percentage of each type of soil particle using the formula

$$\text{Percentage of soil component} = \frac{\text{Height of the component}}{\text{total height of all solid matter+ height of organic}}$$

Note: During the experiments, at first you will be able to see bubbles come up in the cylinder as you pour the water. This means that soil contains air. The things that float on top of water in the cylinder are pieces of dead plants, dead insects, rotten roots or leaves and small soil particles. The bigger soil particles will sink to the bottom by size. The colour of the water in the cylinder will start as brown then clear after 7 days. Humus makes the soil look dark brown.

Soil Formation

Soil is formed from a mixture of mineral particles, air, water, decaying plant and animal materials. The mineral particles come from rocks. The rocks are the solid material forming the earth crust. Thus the crust of the earth is made of solid rock. But deep inside the earth is very hot. When the rock inside gets very hot, it melts to form a liquid. The molten rock is called magma. Magma is a mixture of different minerals. When magma cools, it forms new rocks. Thus the rocks are classified by the way they are formed. These rocks differ in their chemical composition and the way they were formed. They are classified as: igneous, sedimentary and metamorphic rocks.

Activity 3. 2: Investigating the properties of rocks

i) In your group, look at three different rocks (metamorphic, igneous and sedimentary) given to you by your teacher.

ii) Write down a list of questions you will need to ask about these rocks (texture, colour, roughness, crystal size, porous, hard by scratching)
iii) Use a hand lens to examine each of the rocks.
iv) Describe what you see.
v) State four properties of each of these rocks.

Weathering

Rocks do not stay the same forever. They get changed slowly and with time. **Weathering** is the breaking or splitting down of rocks. It is the process by which rocks break down to form soil particles.

Types of weathering

The process of wreathing is either physical or chemical. Sometimes, both the physical and chemical process of weathers involve a biological component.

a) Physical weathering

This involves the splitting of rocks into small particles without any change in chemical composition. The following are the agents of physical weathering:

i) Force of running water

When water is fast flowing in a river or stream, it carries along with it many small rocks, stones and other particles. As these materials move, they knock each other and keep breaking. The small particles that break off form part of soil.

ii) Glaciations

Sometimes rocks are split by the movement of huge blocks of ice. The rocks end up knocking each other and splitting into smaller particles.

iii) Freezing of water

This is a when rain water collects in cracks of rocks. When it becomes very cold, this water freezes and expands. This forces the cracks to widen, making the rocks to break. This is due the anomalous behaviour of water.

iv) Wind

When strong wind blows rock particles, they knock each other and split further into small particles.

v) Temperature

When temperatures are high, the rocks expand and when it becomes cold, they contract. The expansion and contraction of rocks causes rocks to crack and split. These changes in temperature weaken the structure of rocks leading them to split into small particles.

b) Chemical weathering

This involves a change in the chemical composition of the original rock. The following are the processes involved in chemical weathering:

i) Solution

When water dissolves any soluble minerals found in rocks, this weakens the structure and changes the form of the resulting rock. Thus the rock will easily crumble.

ii) Hydrolysis

When weak acids react with minerals found in rocks, they form new substances that dissolve out and this weakens the structure of rocks. Examples of weak acids are sulphur dioxide and nitric acid.

iii) Oxidation

When oxygen from air reacts with minerals like iron-and aluminium-containing rocks, new compounds are formed. These weaken the structure of rocks.

iv) Carbonation

When carbon dioxide reacts with metals found in rocks to form carbonates, it weakens the structure of rocks.

c) Biological weathering

i) When heavy animals move over rocks, they set up vibrations that weaken the structure of rocks.

ii) The activities of human beings such as stone quarrying, building construction, dynamiting and mineral extraction lead to rocks being broken into small particles.
iii) When plants and animals die, they decompose/decay into organic matter and humus. These are components of soil and contain plant nutrients.
iv) The activities of burrowing animals such as moles and squirrels mix rock particles with organic matter.
v) The activities of animals with sharp hooves on rock surfaces will cause crumbling of rocks.
vi) The roots of plants or mosses create humid conditions which speed up chemical weathering. Likewise, when plants grow and expand in cracks of rocks, it leads to the splitting of rocks further.

Factors influencing soil formation

The following factors determine the formation of soil:

Parent material

This the material from which soil develops. These materials include rocks, stones, in some places peat, and specific minerals. Peat is the decaying plant matter found in a very wet place.

Climate

The action of wind, temperature and rainfall of an area affects the weathering process and the movement of rock particles. Strong winds can move large quantities of particles from one area to another. Also, heavy rainfall around streams and rivers causes them to fill up and carry particles to far away distances.

Activity 3.3: Finding out how microorganisms help in decomposing of plant remains

i) Gather fresh plant material and cow dung.
ii) Dig a trench or hole.
iii) Put the fresh plant material in the hole and cover it with the cow dung.
iv) After 7 days, check to find out what is happening to the materials.
v) Find out whether there are any living organisms feeding on the materials.
vi) Describe what happened to the material.

Living organisms

Microorganisms act on dead plant and animal remains which leads to decomposition of materials. Decomposition or decay is the process by which plant and animal materials are broken down to form part of soil. The part of soil formed from these materials is known as organic matter or humus. These bacteria and other living organisms in the soil break all organic materials into smaller particles as they feed.

Topography

Topography is the nature of the land surface. The slope of the land clearly affects the distribution of soil. Land that slopes will have faster water runoff and dry out more quickly than flat land. Water running down the hills picks up soil particles and carries them off, leaving the hill tops with little amount of soil. Most of the soil particles carried by erosion settle in the low lying areas and valleys. There areas therefore have huge amounts of soil and nutrients.

Time

The weathering process is only the beginning of the long journey to form soil. Soil is known to take many years to mature. It involves distribution of particles, movement of the rock particles, the addition of organic matter and the continuing action of soil organisms, rainfall, winds and plant roots gradually form the soil we see. So the age of a soil or how long it has been forming determines the nature of the soil in an area.

Soil Profile

Soil profile is defined as a vertical section of the soil from the ground surface downwards to where the soil meets the underlying rock. The soil profile can be as little as 10 cm thick in immature soils and as deep as several metres in tropical areas where the climate is conducive to rapid alteration of the underlying rock to form soil. In temperate areas, the soil profile is often about a metre deep and is somewhat shallower than this in arid areas.

Soil profile is the vertical cross-section through the soil showing different horizontal layers soil. The horizontal layers are called horizons. Each horizon differs in colour, depth, texture and structure.

Activity 3.4: Determining soil profile

i) In groups or as a class, you are going to observe the different layers of a soil profile.
ii) Select an area in the compound.
iii) Dig it up to about 2 metres deep
iv) How many layers are seen?
v) Observe the layers or colour of soil as you dig deeper.
vi) Draw the layers you see.
vii) Study and mention the characteristics of the layers.
viii) Compare your drawing with the sketch below. What differences do you see?
ix) Alternatively, go and visit a dug pit latrine site. Ensure that you take precautions to avoid accidents like slipping into the pit as you observe the different layers of soil.

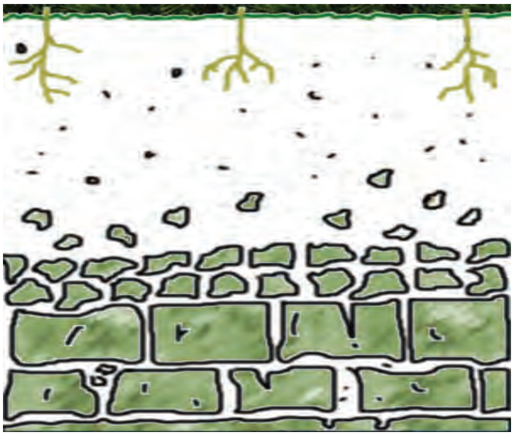


Figure 3.2: Sketch of the locations of soil horizons

How does a soil profile determine the type of crop to be planted in garden?

There are four identified layers/horizons in a soil profile. The most useful part of soil for growing crops is found at the top, that is Horizon A. As you study this, what comes to your mind when you hear the word horizon? Ask your neighbour before searching for it in the library or internet.

Horizon A

This is also called the top soil. It is covered by a layer of rotting organic matter. Its soils are friable and have a good crumb structure. Air and water can move freely which enables many soil organisms and plant roots to live. Most of the plant nutrients occur in this layer.

Horizon B

This layer, also known as sub-soil, has its soil particles closely packed together and there is less movement of air and water. It is red-brown in colour. This is an indication of the accumulation of iron. The layer often has large quantities of silica and calcium.

Horizon C

This layer is made up of rocks slowly disintegrating or weathering. It has coarse rocks, stones and with no or few plant roots. It is also called the stony or weathering region.

Horizon D

This is the soil rock at the bottom of the soil profile. It is also called the bed rock. It may collect underground water forming ponds on top of this rock. It is likely to undergo weathering and in very dry areas some plant roots may penetrate all the other layers to search for water here.

Activity 3.5: Investigating the things that makes up soil

Work in pairs
You will need a measuring cylinder, dry soil, different layers from dug pit, water, and a stop clock

i) Get a transparent 250 ml measuring cylinder.
ii) Get dry soil from your compound or gardens.
iii) Pour 100 ml of dry soil into the measuring cylinder.
iv) Add 100 ml of water to the cylinder with dry soil.
v) Record what you see when you have poured all water.
vi) Cover the mouth of the cylinder and shake. Allow the water mix up with the soil.
vii) Allow the contents of the cylinder to settle for 15 minutes. What do you see?
viii) Are there materials that sink or float?
ix) What is the colour of the water?
x) Draw the final result and label the components in the cylinder of the activity after 7 days.

Importance of the soil profile

A soil with a thick top soil is more fertile and will produce good crops. An area with a thin top soil layer will not have much fertility and will not produce large crops. Therefore, farmers need to use practices that keep the top soil from being lost.

A soil profile will determine which crops or vegetation to grow normally in an area. Crops with deep roots will need deep soil with a sizeable thickness of top soil. This is because deep soils have more nutrients and water to support plant life or thick and vigorous healthy looking vegetation.

Young soils or heavily eroded areas have thin layers of each of the first three horizons and is less fertile. This renders such places to naturally support few plants or little pale vegetation.

Soil Sampling

Soil sampling is the practice of collecting samples of soil from a given area for detailed study in the soil laboratory. Soil samples are used to determine whether soils are acidic or alkaline and have enough and balanced plant nutrient levels. This information is then used to make and suggest recommendations on fertiliser, lime or phosphate applications for optimal plant production.

Procedure of soil sampling

1. Remove the top surface (1 to 3 cm) of the area to be sampled. This part usually contains and a relatively high content of plant and animal residues (debris) in different stages of decomposition. These do not form part of soil and will most likely introduce error.
2. Take what is known as top soil, which is the soil that is up to 30 cm deep from the top surface. A tool widely used for soil sampling is an auger (see pictures), which works in an analogous manner to a cork screw. It is inserted into the soil by applying a downward force while rotating it, and fills as it goes deeper into the soil. Once filled

at the correct depth, the auger is then removed and the top soil placed into a clean, dry container marked "top soil". If no auger is available, a simple spade will do just as well.

3. Then take a sub-soil, which is a further 30cm deeper into the soil. In other words, a depth of up to 60cm of soil is taken from the same sampling spot. The sub-soil is then placed into another container marked "sub-soil".
4. Finally, ensure that both the top and sub soils are representative of the whole area that is being sampled by repeating the three steps above several times at other randomly chosen spots (the more replicate samples collected the higher the likelihood that the area will be well represented). The top soils should then be well mixed together to form a composite top soil. The same must be done for the sub-soils. The two composite samples must never be mixed together to form a unit sample, but, from each composite, a laboratory sample weighing about 1.5 kg must be obtained. The two laboratory samples (labelled "top soil" and "sub-soil" in their respective clean, dry containers) are then sent in for analyses.

Figure 3.3: Soil auger for soil sampling

There are two main methods of soil sampling: Transverse and Zigzag. Check for the meaning of the two methods in the library or using internet. After soil sampling, then you can study more about soil to determine the physical and chemical properties in the coming section.

Physical Properties of Soil

Farmers need to know the physical properties of soil. These include size, colour and shape. The characteristics of soil depend on the parent material, amount of organic matter available and weathering process that were in action. Thus the type of soil particles determines the physical nature and characteristics of the soil in a given area.

Activity 3.6: Mechanical analysis of soil particles

You will need a sieve mesh set, dry soil samples, tray and dishes
Either Part 1: Using a sieve mesh

i) Get a set of sieves with different hole sizes.
ii) Get a dry amount of garden soil from your area.
iii) Place the sieve with the smallest hole diameter in the sieve holder.
iv) Place a collecting tray below the sieve holder.
v) Place 200 gms of dried soil in the sieve.
vi) Collect the soil particles that fall through the first sieve to obtain the first fraction.
vii) Repeat the process above with a new sieve of a bigger diameter until all sieves are done.

The soil that is collected one by one in order of increasing diameter size will be helping you to separate the soil particles into fractions of the similar size. The percentage of the whole soil sample (200 gm) that each fraction will be representing will be calculated by weight/mass or volume.

Or Part 2: Using a measuring cylinder
You will need a measuring cylinder, dried soil samples, water, beakers, hand gloves, a stop clock, a weighing scale, a sheet for recording your findings and safe place to keep the experimental set up for 7 days

i) Get three 250 ml measuring cylinders which are clean and dry.
ii) Measure about 50 gm of dried soil.

iii) Place the measured dried soil in the measuring cylinder.
iv) Using another cylinder, get 100 ml of water.
v) Pour the measured volume of water into the cylinder with soil.
vi) With one hand in gloves put over the mouth of the cylinder, shake it vigorously for 3-5 minutes.
vii) Allow the cylinder to stand for 20 minutes, 60 minutes, 120 minutes, 240 minutes and 7 days.
viii) Record what you see each of the times above
ix) Draw what you see in the measuring cylinder after shaking up with the dry soil and allowing it to stand for 120 minutes and for 7 days.
x) Do you notice any difference?
xi) What does it tell you about soil?

Note: Mechanical analysis is a process of separating soil particles according to their size. In the case of a measuring cylinder, the particles will settle in order of their size, the heaviest first. Thus big stones or coarse particles will be found at the bottom of the cylinder. Organic matter or plant and animal remains will float on top. The volume of each fraction can be read off the scale of the cylinder. Sometimes it is called soil sedimentation.

Soil Texture

Soil texture is the size distribution of different particles that make up soil. It is the proportion of clay, silt and sand in a given sample. Soil texture determines the size of the spaces between the particles, which are occupied by the air or water you find in the soil. This will influence the living organisms that can be found and the movement of water through the soil particles.

For instance, the large particles of sand do not fit closely together. Thus they have large air spaces between them and water easily passes through them. This means that sand soils cannot hold water for a long time.

Clay particles are very small and which allows them to stick together very closely. These particles have no or little air spaces between them and water does not easily pass through. Consequently, clay soil particles hold water for long and are known to be poorly drained.

Soil Structure

Soil structure is the way soil particles are arranged together to form an aggregate or lump. It is the way the soil particles stick together and hold our plants.

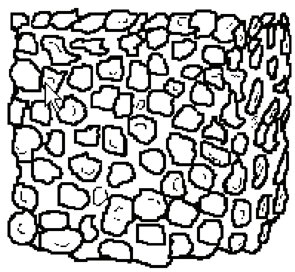
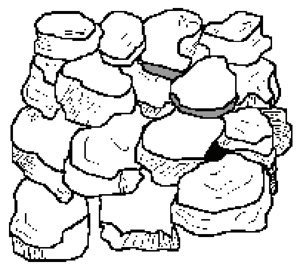
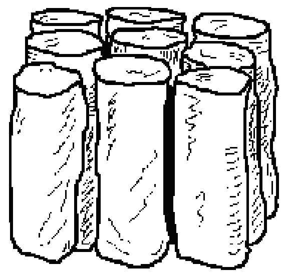
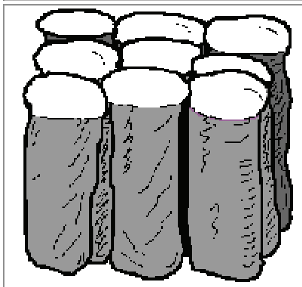
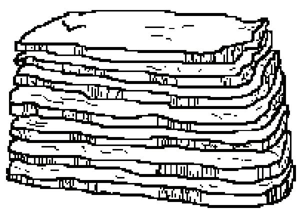
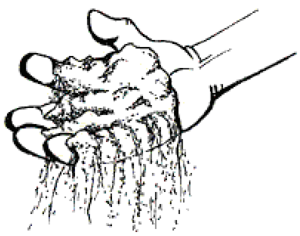
		
Granular: Resembles cookie crumbs and is usually less than 0.5 cm in diameter. Commonly found in surface horizons where roots have been growing.	**Blocky**: Irregular blocks that are usually 1.5 - 5.0 cm in diameter.	**Prismatic**: Vertical columns of soil that might be a number of cm long. Usually found in lower horizons.
		
Columnar: Vertical columns of soil that have a salt "cap" at the top. Found in soils of arid climates.	**Platy**: Thin, flat plates of soil that lie horizontally. Usually found in compacted soil.	**Single Grained**: Soil is broken into individual particles that do not stick together. Always accompanies a loose consistence. Commonly found in sandy soils.

Figure 3.4: Examples of soil structures

In summary, there are five types of soil structure namely:

i) Crumb or granular structure has porous granules with high amounts of organic matter, subject to wide and rapid changes

ii) Platy/plate-like structure is arranged as horizontal plates and found in virgin lands.

iii) Blocky structure has irregularly six-faced cubes or rectangles found in the sub soil.
iv) Prismatic are pillar like aggregates with a prism shape found in the sub-soil.
v) Columnar structure has round pillar-like aggregates found in the sub-soil.

Importance of soil texture and structure

For plants to grow successfully, they require air and water. Soil texture and soil structure play a role in determining how much space is available for air and water to occupy. The best soil for crop production is loam soil which has a balanced amount of sand, silt and clay particles. Loam soils have a good soil texture and soil structure with the following advantages for plant growth:

i) Loam soil is porous. It has enough space between the particles to allow water pass through easily and at the same time holding sufficient amounts for plant use. Clay soil has only very small particles and gets waterlogged during rainy seasons as the space between its particles get filled with water. Clay soils are not porous. There is no air because the particles get closely packed together. Sandy soils are very porous, which allows water and nutrients to be washed away easily. Sandy soils also dry out quickly on exposure to drought or heat.
ii) A good soil texture and structure allows good circulation of air in and around the soil particles. This is essential in plant growth and existence soil organism. Plants and soil organisms are well supplied with oxygen to carry out their life processes.
iii) It allows plant roots to grow and extend to greater heights in the soil profile without much obstruction or barriers.
iv) It helps in controlling soil temperature as warm air will carry away heat from the soil particles.
v) The soils are easy to cultivate or plough using a tractor as they easily break up.

Activity 3.7a: Experiment to show the relative porosity of soils

You will need 6 measuring cylinders (50 or 100 ml), 4 funnels, beakers or conical flasks, pestle, mortar, filter papers/cotton wool, water, retort stand, weighing balance, a graph paper and a stop clock.

i) In pairs, get dry samples of clay, silt, sand and loam soils and grind them into powder.

ii) Set up four measuring cylinders with a funnel and a filter paper as shown below.

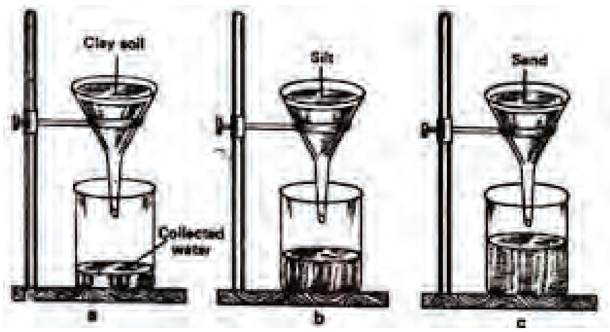


Figure 3.5: Relative porosity experimental setup

iii) Weigh 50 gm of dry soil particles from each sample.

iv) Put the 4 soil samples in the four funnels of equal size. The end of each funnel is blocked with cotton wool or a filter paper.

v) Measure 50 mls of water; for each in its own beaker/conical flask.

vi) Start the stop clock as you pour the volume of water on the funnel filled with the first sample. Record the time the first drop of water comes out and the volume collected after 10 seconds, 20 seconds, 30 seconds, 60 seconds, 90 seconds, 120 seconds, 180 seconds, 240 seconds and 360 seconds. Repeat the above task for the remaining funnels.

vii) Plot a graph of the volume collected against time.

viii) Display the graph in a learning station or classroom notice board/wall.

ix) Describe what you learn from this experiment.

Activity 3.7b: Investigating the water-holding capacity of different soils

You will need dry samples of clay soil and sandy soil, two funnels, three measuring cylinders of 100 mls each, a beaker of 250 mls to hold water, stop clock and filter paper or cotton wool.

i) Set up two measuring cylinders with a funnel and filter paper or cotton wool inside the funnel.
ii) Place 25 gm of dry soil into the funnel. Label the first one A (with sandy soil) and B (with clay soil).
iii) Pour 100 ml of water over each sample as you start the stop clock.
iv) Record the time when the first drop appears.
v) Record the volume of water collected every after 5 minutes until all water has drained through. Calculate how much water has been retained by the soil.
vi) Work out how much water would be retained by 100 gm of soil. This is the water holding capacity of that soil.
vii) Draw the experimental setup on a large sheet of paper. Display your work in one corner of the class.

Types of Soil

Figure3.6: The different soil particle sizes

At the start of this chapter, you learnt that soil is made up of mineral matter, organic matter, living organisms, water and air. You also learnt about the different soil particles sizes and how the particles arrange themselves into soil aggregates or lumps. This means that the soil one finds in one area cannot be exactly the same.

There are three basic types of soil: sandy, silt and clay. But most soils are composed of a combination of three types. How they mix will determine the texture of the soil, or, in other words, how the soil looks and feels.

You can identify the different soil types using colour. For instance, soils containing much iron will appear red/ brown or yellow. While fertile loam soils are dark in colour because of the amount of humus content they carry. There are other ways you can use to determine the soil type. These are examination of the soil profile, chemical analysis, mechanical analysis/soil sedimentation and estimation of humus content.

Table 3.1: Soil types

Soil type	Properties	Challenges
Loam soil	Well drained; friable; fertile; has a good proportion of sand, clay and silt; easy to work; forms crumb structure	
Silty soil	Has fine particles larger than clay, fairly draining	
Clay soil	Has very tiny particles of soil; is compacted; has little air space and holds water for long time thus poorly drained; becomes hard like a stone in dry season	Can be water logged, difficult to cultivate, requires lime to flocculate
Sandy soil	Has big and coarse particles, is well drained and cannot hold water	Has less ability to hold water for crops

Plant Nutrients

These are the chemical elements that are necessary for plant growth. These chemical elements are divided into two major categories: the macro nutrients and micro elements.

Macro nutrients are the chemical elements that are needed in large quantities by plants and are necessary for plant growth. Table below lists the major nutrients needed by plants.

Table 3.2: Examples of macro nutrients and their deficiency symptoms

Element	Uses	Symptoms of deficiency
Carbon (C)		No growth
Hydrogen (H)		No growth
Oxygen (O)		No growth
Nitrogen (N)	Chlorophyll formation, vegetative growth, protein formation	Stunted growth (short but aged), yellowing of leaves
Phosphorous (P)	Root formation and development, quick maturity	Poor root system, no tubers, leaves are grey or purple
Potassium (K)	Formation of proteins and carbohydrates	Browning of leaf edges
Calcium (Ca)		Young leaves die-back at the tips and margins
Magnesium (Mg)		Leaves curl upwards
Sulphur (S)		Delay in flowering and fruiting

Micro nutrients are the chemical elements or substances required in small or trace amounts for the normal growth and development of plants. There are about seven nutrients essential to plant growth and health that are only needed in very small quantities. Though these are present in only small quantities, they are all necessary as seen below:

i) Boron is involved in carbohydrate transport in plants
ii) Chlorine plays a role in photosynthesis.
iii) Copper is a component of some enzymes.
iv) Iron is essential for chlorophyll synthesis.
v) Manganese activates some important enzymes involved in chlorophyll formation.

vi) Molybdenum is essential to plant health. Molybdenum is used by plants to reduce nitrates into usable forms.
vii) Zinc participates in chlorophyll formation, and also activates many enzymes.

Table 3.3: Example of micro nutrients and their deficiency symptoms

Element	Symptoms of deficiency
Iron (Fe)	Yellowing of leaves
Manganese (Mn)	Leaves have spots
Zinc (Zn)	Leaves are mottled or thickened; low starch and seed formation
Copper (Cu)	Leaves are pale green, low nitrogen fixation
Boron (B)	Growing points of shoot and root die off, poor cell division
Chlorine (Cl)	
Cobalt (Co)	
Molybdenum (Mo)	Leaf curling

Soil Acidity or Alkalinity and Soil pH

Soil pH is a way of expressing the acidity and alkalinity of soil. This measure of the acidity or alkalinity of soil solution or soil water employs the use of a pH scale. This scale measures the number of ions in a solution. Hydrogen exists in the soil or solutions as an electrically charged particle called hydrogen ions (H^+). The positive sign shows that the ion is positively charged. Therefore, soil pH is the measure of the concentration of hydrogen ions in the soil.

When there are many hydrogen ions in the soil, then it is acidic. If the soil is too acidic, some nutrients such as phosphorus will not be available. This is very common in poorly drained soils. Therefore, only a few crops like tea may be supported. On the other hand, soils that are too alkaline will not have iron and potassium available to plants. Soil alkalinity or salinity is a condition that results from the accumulation of soluble salts in soil. The most extensive occurrences of alkaline soils are in arid regions, and in low-lying areas where evaporation concentrates the salts received from more elevated locations in surface water, ground water, or irrigation water. Since low-lying areas are most easily cultivated and irrigated, they have the greatest agricultural value. The degree of alkalinity of a soil is conveniently expressed in terms of pH values.

The pH scale is divided into 14 divisions or pH units numbered from 1 to 14. Soils with a pH of 7 are neutral. Soils with pH values below 7 are acid or "sour" and soils with pH values above 7 are alkaline or "sweet". A pH of 9 is ten times more alkaline than a pH of 8 and a pH of 10 is ten times more alkaline than a pH of 9. Thus, a soil with a pH of 10 is 100 times more alkaline than a soil with a pH of 8.

The pH value of most soils falls in the range between 4 and 8. Most crop plants grow and produce best on slightly acid or neutral soils. There are exceptions, however, such as some berries which do best on strongly acid soils. Saline conditions are caused by high concentrations of the following ions: sodium, calcium, magnesium, chloride and carbonates. Alkali conditions are caused primarily by a high concentration of sodium carbonate. This reduces uptake of calcium, breakdown of the soil structure and makes soil particles to hold plant nutrients strongly.

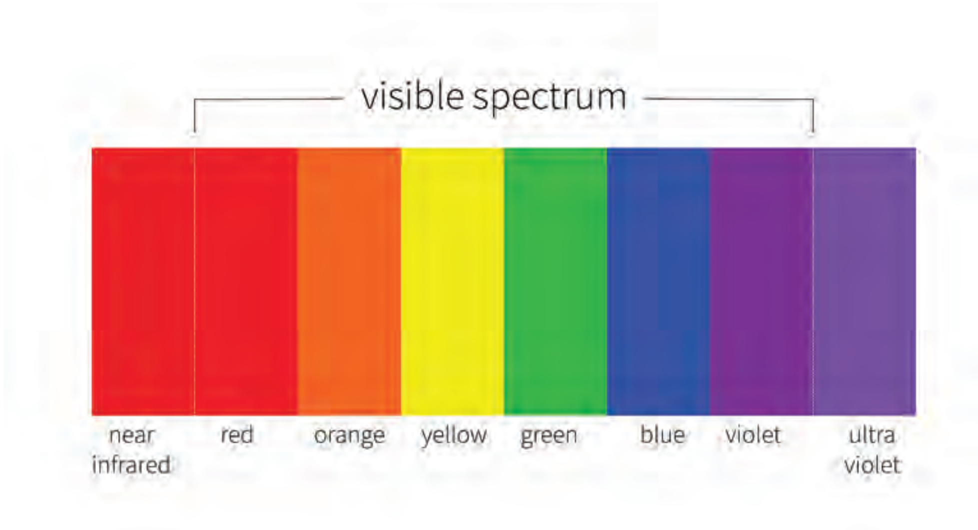
Activity 3.8: Determining soil pH

You will need dry samples of soil from different locations (crop garden, anthill, freshly burnt bush area, along the road), universal indicator, litmus paper, Munsel chart, soil test kit, water, test tubes, measuring cylinder (25 mls or 50 mls), pipette or dropper

i) In pairs or individually, collect the dry soil sample and label it.
ii) Put about 5 mls of the dry soil particles into a test tube.
iii) Add about 10 mls of water to each test tube containing the soil samples.
iv) Shake the mixture while covering completely the mouth of the test tube for 5 minutes and allow it to stand for 5 minutes or 10 minutes.
v) Add 3 drops of universal indicator to the solution in the test tube; above the settled soil particles.

vi) Observe the colour and compare it with the standard range of colours, matched to the pH values.

vii) What do you say about each soil sample?



pH	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Colour	RED		ORANGE		YELLOW		GREEN			BLUE		PURPLE-VIOLET		
strength	Strong	ACIDS			Weak		Neu-tral	Weak		ALKALIS			Strong	

Figure 3.7: Munsel Colour Chart

Fertilizers

Fertilizers are any substance used to provide plant nutrients. This is because crops need nutrients to grow and bear fruits. Good crop yield will require adequate supply of nutrients. Fertilizers may occur in a dry or liquid form. The dry fertilizers are usually packed in bags or containers as pellets or granules, while liquid fertilizers are normally materials that have been dissolved in water at certain concentration. There are two major forms of fertilizers namely organic (manure) and inorganic (fertilizers).

Organic fertilizers

These are plant and animal residues which the farmer can use to maintain soil fertility. There are four forms of organic fertilizers: compost manure, farm yard manure, green manure and mulch.

1. Compost manure

This consists of crop residues, weeds, kitchen or household wastes and animal remains that have been rotted and decomposed as material to supply plant nutrients. This type of manure is normally got from decaying household waste like food peelings, slashed grass, leaves of trees, kitchen waste, plant or animal remains, ash from cooking stove and rubbish from the compound. All these are put in compost pits or piles to rot. After 14 days, the heap is turned over. After another 14 days, the heap is turned over again for 2 more rounds before it is ready for use.

Picture of compost pit

Picture of stack of compost

Figure 3.8: Procedure for making compost manure

Activity 3.9: Making compost manure

a) Traditional method

You will need hoes, shovel, spade, rake, wheel burrow, panga, tape measure and ruler.

i) Choose a site near your crop garden for making compost.
ii) Get the materials, tools and equipment.
iii) Clear away the vegetation.
iv) Measure a 1 m x1 m area.
v) Dig two or more holes of 1 m x 1 m and 1 metre apart. Each hole/pit should 1 m deep.
vi) Begin by putting your household wastes, dry grass, weeds, banana peelings and wastes into the first hole.
vii) Remove big braches, plastic materials, and glass or metallic objects.
viii) When the materials are 25 cm high, add some soil or dung/ farm yard manure.
ix) Put another layer of material to 50 cm high then add some ash and dung/ farm yard manure.
x) Sprinkle some water because wet things rot faster.
xi) Allow this material to rot for 2 weeks and transfer it to the second pit. This will make the material on top to be placed at the bottom and have even rotting.
xii) Erect a shade over your pit to prevent rain and excess heat.
xiii) After 8 weeks, the material should be ready.
xiv) Start preparing compost in March for use in May.
xv) Suggest your own method of making compost manure.

b) Innovative way of making compost manure

i) Get the materials like cow dung/ poultry droppings, green plant materials, dry plant material and water.
ii) Clear the ground where you are going to make your compost from.
iii) Chop the green plant materials and dry plant materials in the ration 2:3.
iv) First put three buckets of dry plant material spread in a diameter of 1 metre then sprinkle a bucket of water.
v) This is followed by two buckets of green plant material and one bucket of cow dung.
vi) Repeat the above two steps 6 times to complete making a heap and cover it.
vii) Temperature will increase to 55^0 - 70^0C.

viii) You need to turn over the materials 8 times and every time squeeze the material to do a moisture test. If there is low moisture, add green plant material and if there is high moisture content, then add dry plant material.

2. Farm yard manure

This is the straw, food remains and animal beddings mixed with urine and faeces allowed to rot and decompose to be used as fertilizers. It is a mixture of rotten beddings and animal wastes. It normally made by people who keep animals and put dry grass on the floor or ground where animals are kept. The grass materials absorb the urine and faeces. After sometime, these animal beddings are collected with the food remains and are put in a heap to be allowed to rot and decompose.

The composition and quality of farm yard manure) varies or depends on:

i) the type of animal kept: poultry, pigs, goats, sheep usually produce farm yard manure which is high in nutrients than horses and cattle.
ii) the age of the animal
iii) the diet of the animal
iv) the type of bedding used
v) the time given for rotting and decomposition

3. Green manure

This is manure made by cutting or ploughing growing crops into the soil just before flowering to provide soil nutrients. Any fast growing green crops are used in making green manure. The most effective green manure crops are legumes. This family of plants has nodules on their roots in which the *Rhizobia* bacterium lives. These bacteria have the ability to fix nitrogen of the air into the soil. They use nitrogen gas for their own chemical processes but as a result convert it into nitrates. Legumes such as cowpeas, beans, soya, peas, and groundnuts or Lablab, Sesbania, Mucuna and Caliandria are mostly used.

4. Plant mulch

This is the dry plant material or dry grass applied to the surface of the soil which is then allowed to rot and decompose to provide nutrients.

Biological Tea as an innovative way to supply plant nutrients

This is where plant material is prepared into a solution so that you can extract nutrients from it. The extracted liquid is applied to growing crops. There are two kinds of plant material used to make biological tea namely compost and animal manure.

Preparing biological tea

i) Get a drum, bag/sack, wood ash, sticks and vegetative/plant material.
ii) Put the wood ash and plant material into the bag. The bag should be half full.
iii) Put the stick through the bag near the mouth or tie it with ropes.
iv) Place the drum under a shade to protect it from sunshine and rain.
v) Hang the bag in the drum filled with water to three quarter volume.
vi) Allow the bag to hang in the drum for 3 or 4 weeks.
vii) Remove the bag from the drum.
viii) The remaining liquid is liquid plant tea.

The process of making manure tea is the same as above only that you use animal manure instead of plant material.

Figure 3.9: Picture of a drum with a bag hanged in with cross bar

Inorganic fertilizer

These are chemical or rock material specifically prepared and manufactured for agricultural use. Their compositions are known and are used in small quantities to provide plant nutrients. Inorganic fertilizer refers to manmade or chemical fertilizers or soil amendments. Soil rarely contains all the nutrients needed to support optimal plant growth. That means that organic or inorganic fertilizers must be added to improve soil quality. Inorganic fertilizers are quick-release formulas that make the necessary nutrients almost instantly available to the plants. Inorganic fertilizers enrich the soil with specific nutrients which may be lacking. There are two ways of categorizing the inorganic fertilizers as shown below:

i) Straight fertilizers

These contain only one nutrient element. For example, nitrogen (N), phosphate (P) or potassium (K) and sulphate (S). These can include urea (46-0-0), ammonium nitrate (34-0-0), calcium ammonium nitrate - (CAN), single super phosphate - (SSP), etc. Rock phosphate is an inorganic fertilizer type that provides phosphorus to the soil. Sodium nitrates are also referred to as ciliates or Chilean nitrate. These fertilizers contain amounts of nitrogen of up to 16 percent. They make nitrogen, the most important component in plant growth, immediately available to plants. Sodium nitrates are considered a valuable source of nitrogen and are commonly added to the soil as a top and side dressing, especially when fertilising younger plants and garden vegetables. Sodium nitrate fertilizers are especially useful in acidic soils.

ii) Compound fertilizers

These contain at least two or more fertilizing agents or nutrient elements. For example, DAP, NPK - 25:5:5. Sulphate of potash is the inorganic fertilizer which supplies the third-most needed nutrient, potassium, to the soil. Those who sell fertilizers must be able to tell you the amount of each nutrient in the fertilizer. For example, single superphosphate contains 20 percent P_2O_5 and about 11.9 percent S. Then buy the right fertilizer to give you the nutrients needed. Calculate the amount of fertilizer to give the amount of nutrient.

While NPK - 10:10:20 means that this fertilizer contains 10 kg of nitrogen (N), 10 kg of phosphorous (P) and 20 kg of potassium per 100 kg bag or for every 100 kg. Therefore, a bag of 50 kg will have 5 of nitrogen, 5 of phosphate and 10 of potassium. While with 2:1:1 (24) this number in brackets indicates that 24 percent of the material in the bag is the fertilizer elements and 76 percent is the carrier material. So you can compute the amount of in 50 kg bag as 24%. This will be only 12 kg of the fertilizer elements. Hence $^2/_4$ x 12 = 6 kg is nitrogen, ¼ x 12 = 3 kg of phosphate and ¼ x 12 = 3 kg of potassium.

Methods of applying fertilizers

Fertilizers must be placed where the plants can get it in the soil. Proper placement means that the fertilizer is close enough for roots to get it but not so close to damage the plant roots or leaves. Fertilizers should therefore be applied during the following times:

- **i) Pre planting/before planting** (broadcasting - scattered on the soil surface)
- **ii) At planting** (drill-put in the planting hole, band-put in rows along the holes)
- **iii) Post planting** (applied when the plant is growing through top or side dressing – placed 15 cm from the root area of the plant; ring placement – fertilizer is applied in a ring around the plant; spraying on the soil surface or leaves of the growing plants (in case of copper or zinc deficiency).

The methods of applying fertilizers include:

a) **Broadcasting:** This is where the fertilizer material is scattered or spread all over the garden or soil surface. This can be done before or during planting.

b) **Ring method:** This is where the fertilizer material is applied in circle of radius 60-90 cm around the plant.

c) **Drill method**: This is where the fertilizer material is applied in the planting hole before the planting material has been put.

d) **Spraying:** This is where the fertilizer material is made into a solution and applied in form of sprays on the plant or garden.

e) **Top dressing**: This is where the fertilizer material is applied over the ground where the crop is growing. Here it is expected that rainfall or dew will dissolve the fertilizer material and it will get soaked into the soil.

f) **Side dressing**: This is where the fertilizer material is applied along the sides of the rows of growing crops. This is about 15-30 cm away from the root zone.

Factors to consider when applying fertilizers

i) **The nutrients which are deficient or missing in the soil and the degree of deficiency.** It is important to find out which nutrients are missing in the soil before applying any fertilizer. This will help you determine the kind of nutrients requires and thus the fertilizer to be used.

ii) **Methods of application:** Phosphorous is most effective when drilled with or near the seeds since it takes time to dissolve. Placing a band of phosphate fertilizer near developing roots of annual crops is the most effective way.
Phosphates should not be broadcast in pastures or forages as it will delay response owing to its slow movement into the root zones. Nitrogen fertilizers can be broadcasted as they quickly dissolve in water and move readily in moist soil. They can, however, be leached to deeper layers where they will not be available to crops. So placement with or very near the seed is not necessary. Therefore, apply nitrogen fertilizers by broadcast, side band, top dressing or row.

iii) **The estimated response of the crop to a given level of fertilizer application.** Different crops respond differently to the same amount of fertilizer. The most accurate way to determine crop response is by a soil test. **Note** that the presence of weeds in the garden and late planting will lower the crop response to fertilizers and the yield potential of the crop. The weeds will compete for the fertilizer that is applied. Crops with high yield potential generally respond better to higher nitrogen fertilizer application.

The assessment of economic returns from the use of fertilizer. In some instances, the cost of the fertilizer cannot be recovered from the profit gained by the sale of the crop products. So it does not make sense to apply the fertilizers. For example, crops grown in an area which has been under fallow will often require little or no additional nitrogen. On the other hand, non-legume crops can give profitable returns if you apply 250 kg of nitrogen fertilizers per acre. This is because there are three main sources of nitrogen to non-legume crops namely: that stored in the soil particles; that released from soil organic matter or crop residues and manure; through application of nitrogen fertilizers.

Type of fertilizer. Plants need a large amount of the major nutrients and very small amount of trace elements. Therefore, chemical analysis of the soil will tell you whether there is too much or too little nutrients. This information will help to tell you the type of fertilizer to apply. Very often the soil cannot provide enough nutrients as plants are harvested and carried away with plenty of nutrients. When this happens, then nutrients must be provided by buying and applying the right type of fertilizers. Buy the right fertilizer to give the nutrient needed or lacking in the soil.

iv) **Amount of fertilizer**. Those who sell or use fertilizers must be able to tell you the amount of each nutrient found in a given fertilizer. For example, single super phosphate (SSP) contains 20 % P_2O_5. while triple super phosphate contains 43% P_2O_5. So you will need twice as much single super phosphate (SSP) as you can get from a given amount of triple super phosphate to give the same quantity of P_2O_5. Further you will need 65 gm of SSP per plant.

Figure 3.10: Bag of Fertilizers with its analysis

Safety, health and environmental protection measures when handling fertilizers

There are many set out guidelines on the safe handling of fertilizers on the farm. Among them include the following:

i) Ensure personal safety when handling fertilizer products.

ii) Ensure good housekeeping practices for indoor and outdoor storage.

iii) The need for security when storing fertilizers as follows:

- Do not store fertilizers where there is public access.
- Do not leave fertilizers or unused fertilizer in the field/garden overnight.
- Do not store fertilizers near or visible to the children and public roads or highways.
- Do not buy ammonium nitrate fertilizer without the proper certificate. It is an offence.
- Purchase fertilizer from approved suppliers and outlets.
- Retain and file in your records all fertilizer delivery notes or purchase receipts.
- Store all your agrochemicals including fertilizers under key and lock building.

- Make regular checks on stocks.
- Report any stock discrepancy or loss of fertilizer material to the police.

iv) Knowledge of how to minimize environmental impact during storage and use.

v) The importance of following instructions, reading of product labels and manufacturers safety information.

vi) The proper care required along the whole fertilizer value chain right from product development, purchase and handling of raw materials, the process of manufacturing, packaging, storage and transportation right up to the end delivery, application, use and disposal of unwanted materials on the farm.

vii) Wear protective gear including gloves, gumboots, mouth and nose.

viii) Wash thoroughly your body after handling fertilizer.

ix) Clean the applicators and other equipment.

Activity3.10: Identifying inorganic fertilizers

Individually or in pairs, you should identify inorganic fertilizers

You are provided with sample of fertilizers A, B and C. Study them carefully when wearing protective gears and answer the questions that follow.

1. List down three observable characteristics of fertilizers.

Fertilizer A	Fertilizer B	Fertilizer C

2. What are the four characteristics of a good fertilizer?
3. Enumerate five advantages and disadvantages of artificial fertilizers.

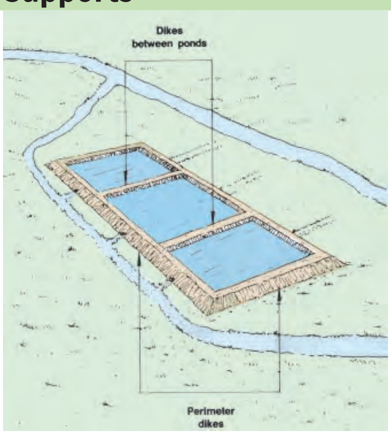
4. Extended work in groups: “Carry out integrated soil fertility management and demonstrate how it caters for environmental protection”.

Activity of Integration

Context

The Ministry of Agriculture, Animal Industry and Fisheries developed the Kumi Wetlands Fish Farming Project which was seeking to promote the conservation and sustainable utilization of wetlands and wetland resources in Kumi District. The Ministry encouraged improvement of nutritional intake and widening the income base of the rural communities. The major activities include developing training on soil for fish pond construction and management. But the soils used to construct ponds in wetlands are not firm and they allow water to seep across the pond banks and through the bottom. Therefore, the lime applied is continuously lost through seepage and more lime is continuously required to keep the acid levels low.

Supports



Task

Make a presentation to members of one community in Kumi about how they should go about pond construction in the wetland available to them so that they can start reaping from fish farming.