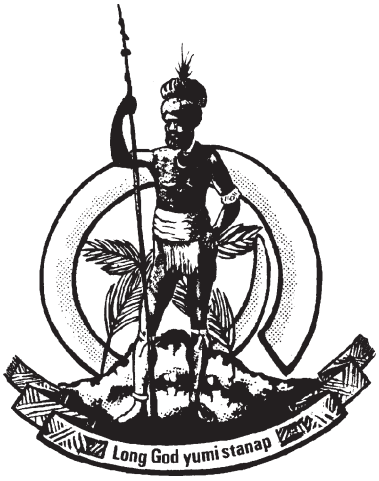
AGRICULTURE IN VANUATU

SOILS



Ministry of Education
Port Vila
Republic of Vanuatu
1997

Revised edition 1997

This book was writtn by S. J. Goodger and first published in 1987.

This revised edition has been prepared by the Ministry of Education under the auspices of the Primary and Secondary Education Project with support from the World bank (Credit 1964-VAN).

Contents

1. Introduction

What is soil?

Soil is the name we give to the layer of earth, above the solid rock, in which plants can grow.

Where does it come from?

It is made over many thousands of years, as rock on the earth's surface is broken down and mixed with other things, to make up a soil.

It can also be deposited by rivers, glaciers, and the sea

Why is it important to learn about the soil?

It is important for the following reasons:

1. We grow our food crops in the soil. From it they obtain water, and nutrients. A soil which is good for producing crops is called a **fertile** soil. We must learn how to keep our soils fertile, so that we can produce good food crops.

2. Sometimes a soil can be washed away by water, or blown away by the wind. This is called **soil erosion**, and we should learn how to prevent it.

2. Soil formation

There are two main stages in soil formation:

1. Solid rock is broken down into small **rock particles**.

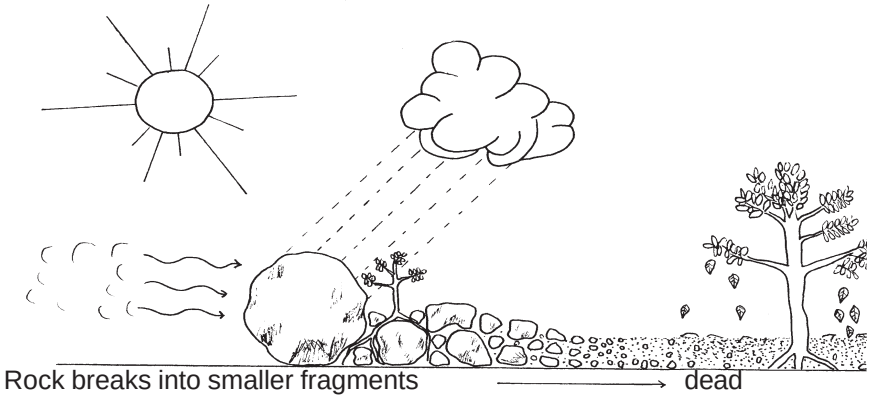
   This is called **weathering**. Things which help to cause weathering of rocks are: -

   - temperature changes (hot sun during the day followed by cool nights)
   - wind
   - rain
   - running water
   - small plants growing on the rock (see Figure 1)

Later, living things (plants and small animals) begin to inhabit the soil. These living things will die and decompose. This releases nutrients in the soil, and builds up fertility.

The processes of soil formation can take thousands of years, especially if the rock is very hard. In Vanuatu, much of the volcanic rock is very soft. This means that soils can be formed quite quickly.

Figure 1.



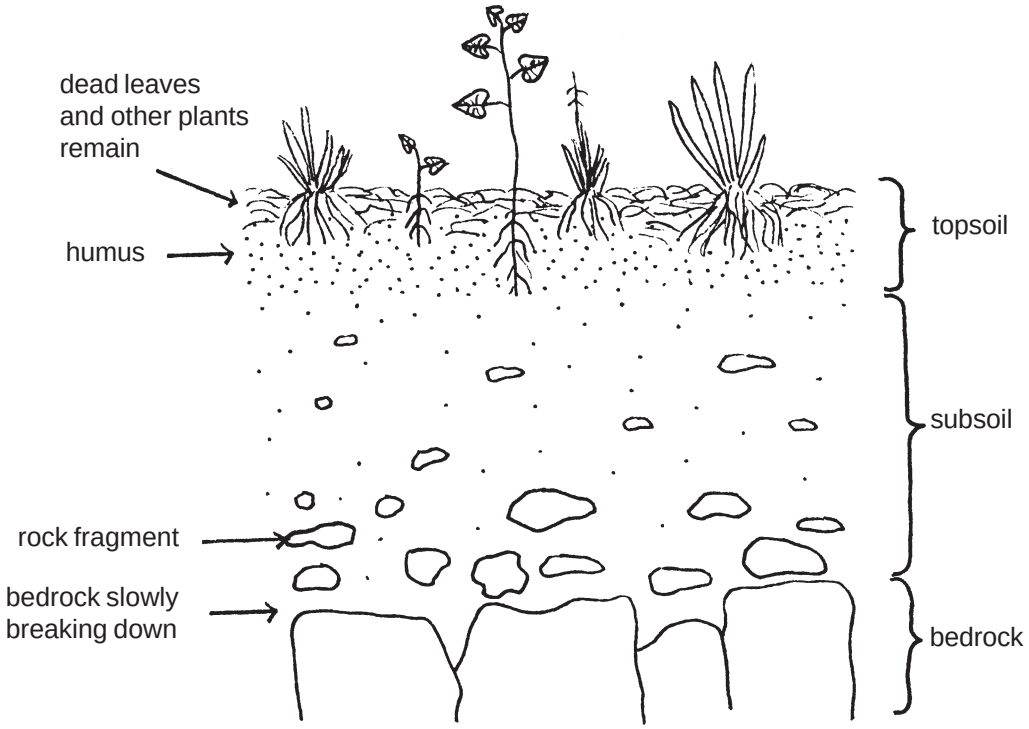
3. Soil profile

A soil profile shows us the layers that make up a soil.

We can see the profile by digging a pit down through the soil to the rock below.

Most soils consist of three main layers:-

Figure 2 **A soil profile**



Another name that is used for the soil layers is **horizons**.

Main features of the profile layers

1. **Topsoil**

This layer contains a lot of **organic matter**, and **humus**, which comes mainly from the remains of dead plants, as they rot in the soil. The **humus** makes the topsoil:-

- dark in colour
- rich in plant nutrients (see Section 7: Organic Matter)

It is therefore a **fertile** layer, good for growing crops, and should be preserved.

2. **Subsoil**

This layer is mainly a mixture of small rock particles, plus larger pieces of rock, broken off from the bedrock. It contains little organic matter which makes it:-

- lighter in colour than the topsoil
- low in plant nutrients

It is therefore an **infertile** layer, not good for growing crops, and should not be brought to the surface.

3. **Bedrock**

This layer is sometimes called the **parent** rock, because it is the rock from which the soil was originally formed.

Practical work

Profile pits can be dug to observe the features shown in Diagram 2.

It is best to dig more than one pit, in different areas, to show a variety of profiles.

NB. Digging profile pits can be very time consuming, and if necessary, should be started well in advance of the time they are needed.

4. Soil composition

A soil is made up of different parts:

1. **Rock particles** — Small pieces of rock, formed by weathering of the bedrock.
2. **Organic matter** — Dead, and decaying plants and animals.
3. **Living organisms** — Plants and animals living in the soil.
4. **Air**
5. **Water**
6. **Plant nutrients** — Chemical substances which plants need from the soil to make them grow.

Soils from different (places will contain different amounts of each of these parts.

Practical work

Students should be supplied with soil samples from different places. They should examine the samples and attempt to separate the rock particles, organic matter and living organisms.

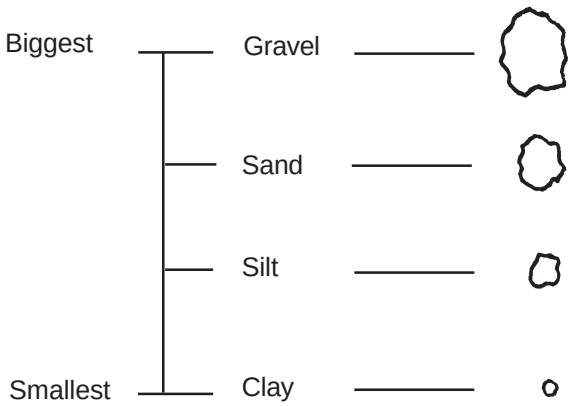
5. Rock particles

These are small pieces of rock in the soil, formed by **weathering** of the bedrock.

They are sometimes called the **inorganic**, or **mineral** part of the soil.

Soils rich in rock particles but low in organic matter, are called **inorganic** or **mineral** soils.

Rock particles are grouped according to their size:



Soils from different places will contain different amounts of each particle size. This will determine the name we give to the soil, for example:-

- soil containing a lot of sand particles is called **sandy soil**.
- soil containing a lot of silt particles is called **silty soil.**
- soil containing a lot of clay particles is called **clay soil.**
- soil containing even amounts of sand, silt, and clay is called a **loam soil.**

These names we give to soils are known as the **soil types**, or **textures**.

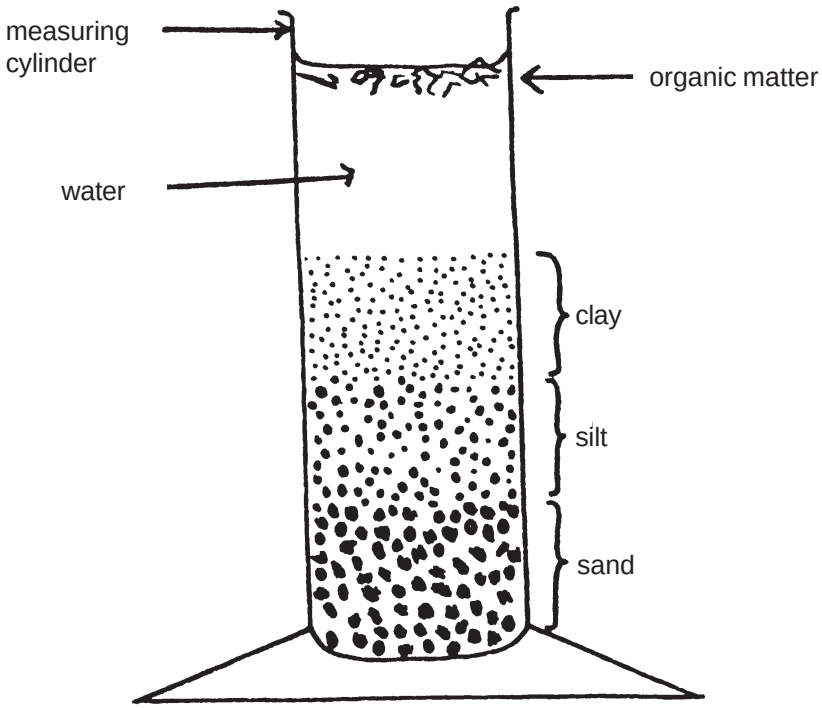
Practical work

The following simple experiment can be done to find the proportion of different rock particles in a soil:-

Procedure

1. Mix a sample of soil with an equal amount of water inside a measuring cylinder.
2. Shake the cylinder vigorously.
3. Stand the cylinder for 1-2 hours, allowing the particles to settle.
4. Observe and draw (see Diagram 3).

Figure 3 To find the proportion of particle sizes in a soil



A soil containing similar proportions to the one in Diagram 3 could be called a **loam**.

To enable observation of different soil types, local students should be encouraged to collect soil samples from their village gardens.

6. Soil texture

The proportions of sand, silt and clay. Particles in a soil tell us its **texture**, or **type**. For example, a soil containing a large proportion of clay particles has a **clay texture**, or is a **clay type**.

The texture of a soil can be found by simply feeling the soil between thumb and fingers (see Practical work).

Soils of different textures have different properties, or characteristics: -

Properties of sandy and clay soils

Sandy Soil	Clay Soil
has large particles	has small particles
has large pore spaces	has small pore spaces
contains a lot of air	contains little air
drains quickly	drains slowly
doesn't hold water	holds water
contains few plant nutrients	contains plant nutrients
loose structure, whether wet or dry	sticky when wet and hard when dry
easy to dig and cultivate	hard to dig and cultivate

It can be seen that sandy and clay soils give different kinds of problems to a farmer e.g. clay is hard to dig, sand contains few plant nutrients so it is important to know the texture of a soil, because it will affect the type of farming that can be practiced in any place.

The best type of soil for most crops is a **loam**.

A loam has properties which are between those of sandy and clay soils, for example:-

- a loam does not drain quickly or slowly, but somewhere between.
- a loam is neither very easy or very hard to dig, but somewhere between.

The same is true for the other properties of a loam.

Practical work

The following is a simple method which can be used to determine soil texture by feel:

Procedure

- Take a small amount of the soil in your hand.
- Moisten it with water.
- Use your thumb and fingers to feel it.
- Check to see if it will shine when rubbed.
- See if you can mould it into a ribbon.
- Check your results against those in the table below:-

Table to determine soil texture

Result	Texture
Feels rough Does not stick together	Sandy
Feels smooth and sticky, Can be moulded into a ribbon Shines when rubbed	Clay
Does not feel rough or smooth Can almost be moulded into a ribbon	Loam

7. Organic matter

Organic matter is the name we give to dead, and decaying plants and animals found in the soil.

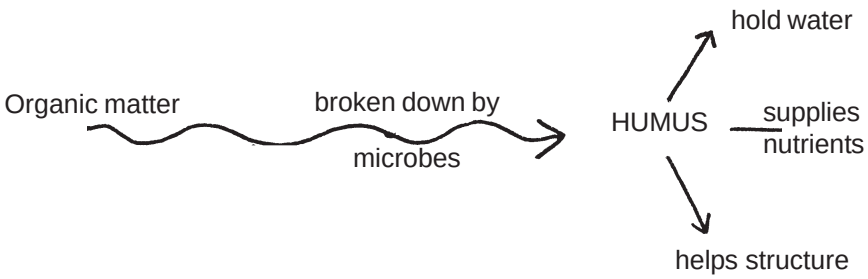
Organic matter decays because of the action of microbes (bacteria and fungi) and other organisms living in the soil. These feed on the organic matter and break it down into a substance called **humus**.

Humus makes the soil dark. It is very important in soils because it:

1. supplies nutrients to plants
2. holds water in the soil:
3. helps to make good soil structure (see Section 8)

Soils rich in humus are usually very **fertile**.

Humus is present in the topsoil because this part of the soil usually contains a lot of organic matter and soil organisms. Hence, the topsoil is always darker, and more fertile than the subsoil.



Practical work

Students can be shown leaves at various stages of decomposition to help explain organic matter decay.

During practical work in the garden students should be encouraged to observe the level of organic matter and humus in the soil, and its effect on the properties of the soil.

8. Soil structure

The soil structure is the way in which the rock particles in a soil are arranged and held together.

Soils with poor structure

1. **Sandy soils**: because their particles are loose and do not stick together which means that:-

- they can be blown away by wind, or washed away by heavy rain (**soil erosion**).
- water drains from them very quickly.

2. **Clay soils**: because their particles are very tightly stuck together which means that:-

- they are hard to cultivate.
- water will drain from them very slowly.

Soils with good structure

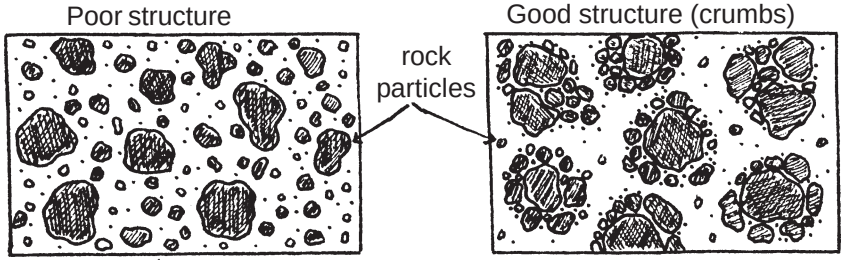
These have their particles held together in **crumbs**. **Soil crumbs** are important because they:

- stop soil particles being washed or blown away.
- allow soil to be easily cultivated.
- allow water to drain through the soil, but also hold some of it for the plants.

Humus helps to form crumbs in a soil, because it sticks the rock particles together. (It acts like a glue)

Soils rich in humus have good structure.

Figure 4 **To show soil structure**



Reasons why a soil should have good structure

- It makes it easier for water and air to move around the soil.
- It helps prevent soil erosion.
- It makes the soil easier to cultivate and prepare into a seedbed.

How to improve soil structure

If the structure of a soil is poor, such as in clay or sandy soils, we can improve it by adding:

- **Organic matter** eg. Compost, Animal Manure.
- **Burnt or crushed coral** to a clay soil.
- **Clay** to a sandy soil.
- **Sand** to a clay soil.

We can also help improve soil structure by leaving the garden to grow back into bush for a few years. This will add to the organic matter and humus content of the soil.

How soil structure may be damaged

We have seen that good soil structure is very important for a farmer. Some practices, if used by a farmer, can actually damage the structure of a soil, such as:-

- Digging a clay soil when it is wet.
- Putting heavy pressure on a clay soil (especially when it is wet).
- Using a lot of **artificial** (Chemical) fertiliser.
- Growing crops in the same place for many years without adding any organic matter to the soil.
- Bush burning which destroys organic matter and soil organisms.

Practical work

Students should be shown a sample of sand, together with a good garden soil and the differences in particle arrangement and crumb development can be observed.

During practical work in the garden students should be encouraged to use practices which encourage good soil structure.

9. Soil organisms

There are many different kinds of organisms which live in the soil, including plants and animals.

Some of these organisms we can see with our eyes (eg. earthworms), others are too small for us to see them. We call these very small organisms **microbes**.

Some organisms are good for the soil because they help to make it fertile. Others are harmful, especially those which attack and damage crop plants.

These are some of the more common soil organisms:

1. **Earthworms**: These are **good** for the soil because:

- they help change organic matter into humus
- they mix humus with the rest of the soil
- they make lots of small tunnels in the soil through which air and water can move

2. **Slugs and snails**: These can sometimes be **good** for the soil because:

- they help change organic matter into humus.

But they can also be **harmful** because:

- they feed on the leaves of crop plants.

3. **Microbes**: There are many different kinds of microbes living in the soil including **bacteria** and **fungi**.

Although we cannot see them there may be many thousands in just one handful of soil.

Most species of them are **good** for the soil because:-

- they help to change organic matter into humus
- some special bacteria can take **nitrogen** gas from the air and change it into **nitrate** which is a plant nutrient. (see Sections 11 and 15)

However some species can be **harmful** because:

- after a root crop has been damaged they may move inside and cause it to rot.

4. **Millipedes**

These can sometimes be **good** for a soil because:

- they help change organic matter into humus

But they can also be **harmful** because:

- they may feed on plant roots.

Note: Soil organisms need air to breathe. A soil containing lots of air, for example a sandy soil, will contain a lot of soil organisms.

Practical work

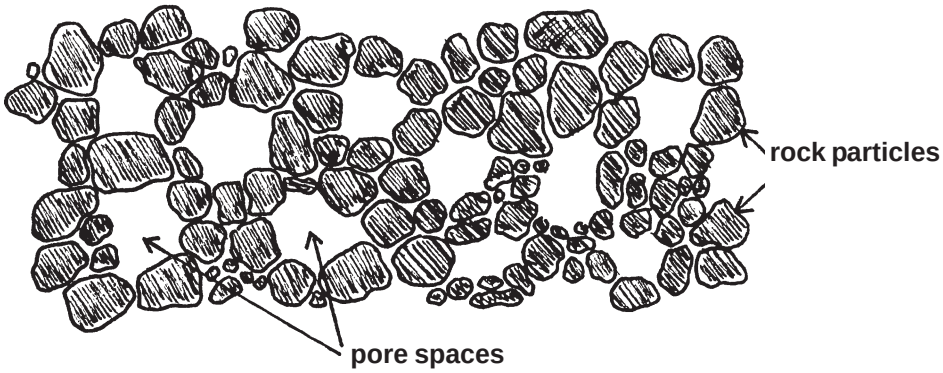
The activities of those organisms outlined in the notes, plus others, can be observed during practical work in the garden. (see ***Notes on Vegetable Growing***).

10. Soil air

Air in the soil is important to allow the soil organisms and plant roots to breathe.

Air is found in the spaces between the soil particles, these are called **pore spaces**.

Diagram 5 **Pore spaces in the soil**



Sandy soils have large pore spaces, this means that:

- they contain a lot of air
- water drains through them quickly.

Clay soils have small pore spaces, this means that:-

- they contain little air
- water drains through them slowly.

Soils rich in humus, which have good structure, will also contain plenty of pore spaces. This means that:-

- they contain a lot of air
- they drain well but they also hold onto water (see next section).

11. Water in the soil

A garden soil should always contain water to supply the needs of the growing crop plants.

Soil water contains **plant nutrients**. These are dissolved in the water and required by plants to grow well and produce good crops.

When water enters a soil it replaces air inside the **pore spaces**.

When a soil has all its pore spaces full of water it is **waterlogged**.

A waterlogged soil contains **no air** and so the soil organisms and plant roots will **die** because they cannot breathe.

Movement of soil water

There are several ways in which water can move in a soil:-

1. It can be pulled down through the soil by **gravity**. The water is pulled down to the bedrock.

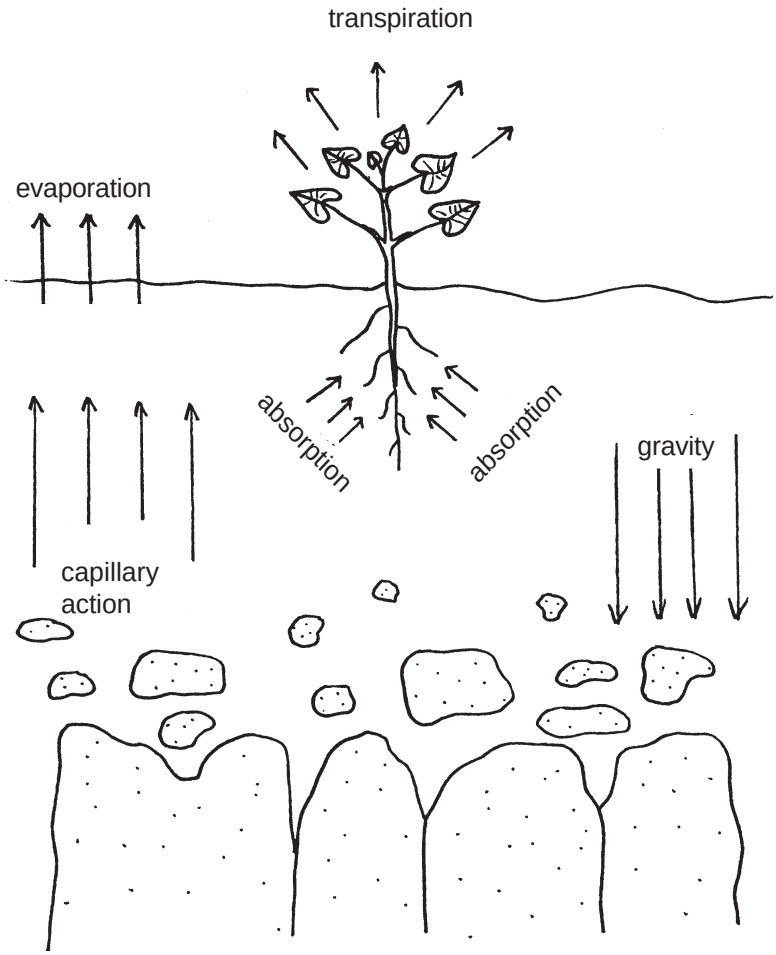
2. It can move upwards, between soil particles by **capillary action** (see practical work). This movement is important to keep plant roots supplied with water, and happens more in soils with good crumb structure.

3. At the soil surface water can be lost to the air by **evaporation**.

4. It can be **absorbed** into plant roots, and may be lost from the plants by **transpiration**.

NB Some water will not be moving but **held** by the soil between the particles. This water is very important and is absorbed by plant roots. Soil rich in humus, with good structure holds water well.

Figure 6 Water Movement in the Soil



Practical work

Students can carry out the following experiment to observe the water retention of soils.

Procedure

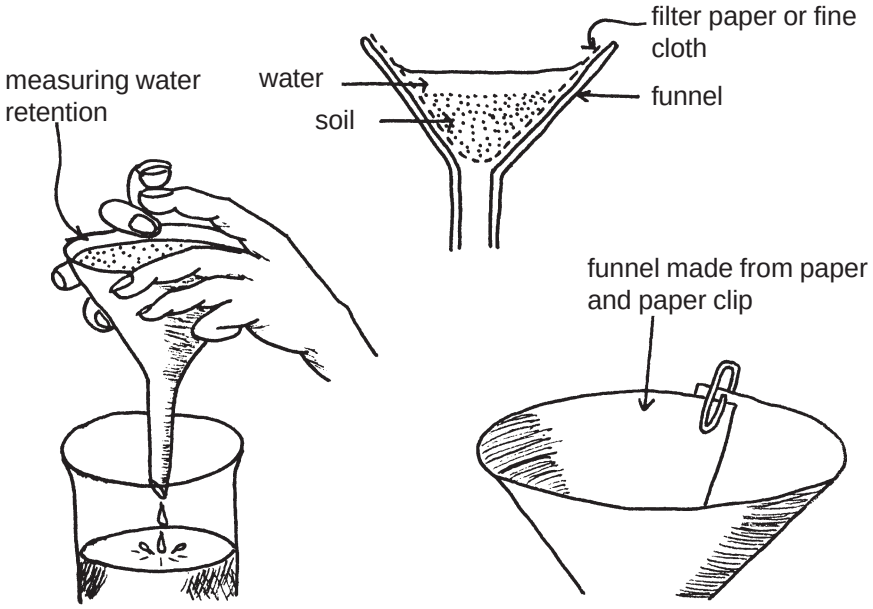
1. Place a sample of dry soil inside a funnel which should be lined with filter paper, blotting paper or fine cloth.

2. Measure out a suitable amount of water and pour it on the soil. Use another vessel to catch the water coming through the funnel and measure it.

3. Repeat for a different type of soil and compare the rate that water passes through the soils, and the amounts of water that the different soils retain.

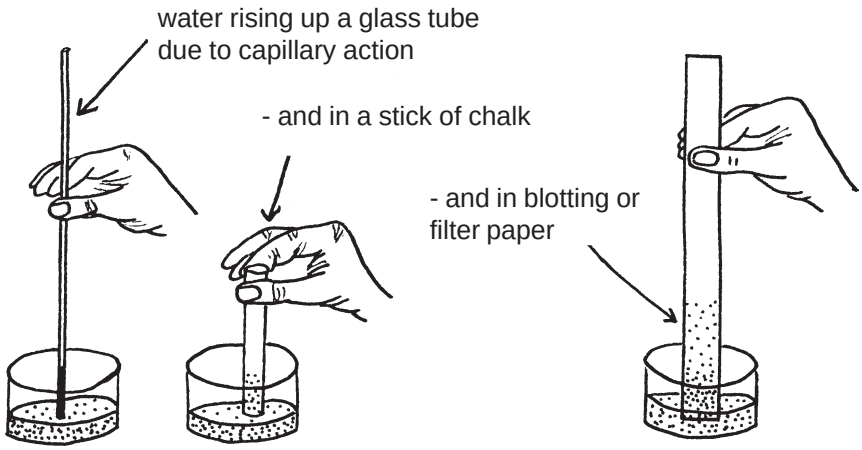
4. The experiment can be repeated using damp soils to show differences in drainage rates.

Figure 7 To observe the water retention of a soil



The capillary movement of water may be demonstrated by holding a strip of blotting paper, thin glass tube, piece of cotton wool or similar absorbent material in coloured water.

Figure 8 To demonstrate capillary movement



12. Plant nutrients

These are simple substances which plants need from the soil in order to grow strong, healthy, and produce good crops.

There are two groups of nutrients:-

1. **Trace elements**

These are important for strong, healthy growth **but** a plant only needs **small amounts** of each. Examples of trace elements are:

- **zinc**
- **boron**
- **iron**
- **copper**

Because plants only need small amounts of these trace elements, it is rare for the soil to have a shortage of them.

2. **Major nutrients**

These are also important for strong, healthy growth but a plant needs **large amounts** of each. The three most important are:-

- **nitrate** (**N**)
- **phosphate** (**P**)
- **potash** (**K**)

Sources of nutrients in the soil

There are two sources which supply nutrients in a soil:-

- a small amount is supplied from the rock part of the soil as it weathers
- most is supplied from the humus

So the topsoil will contain the most nutrients because it contains more humus than subsoil.

The nutrients from rock and humus dissolve into the soil water, and then may be taken out of the soil by the plant roots.

13. Nutrient deficiency

This is when a soil does not supply enough nutrients to the growing crop plants.

When this happens we will see signs of the plants not growing well or looking unhealthy. These signs are called **deficiency symptoms**.

The most common deficiencies occur with the major nutrients:-

Nutrient	Deficiency symptoms
Nitrate	Plants grow small with fewer, smaller leaves. Leaves become pale green or yellow
Phosphate	Plants grow small with small roots Leaves become blue-green on top and purple below Fruit quality is poor
Potash	Plants have small main shoot with many side shoots Leaves become white or dead at the edges Fruit and flower quality is poor

Reasons for nutrient deficiencies

There are three main reasons why a soil may be short of nutrients:-

- The soil type may be naturally infertile, and therefore low in plant nutrients. For example sandy soils are usually infertile.
- The nutrients may have been washed out of the soil by heavy rain. This is called **leaching**.

  Leaching is common on sandy soils because water moves through them quickly and they do not hold nutrients.
- If crops are grown in the same place for many years, the amount of nutrients in that soil will be decreased as the crops are removed.

Practical work

During practical garden work it should be possible for students to observe nutrient deficiency in plants. Simple experiments can be made up to demonstrate deficiency symptoms by growing some plants with a good nutrient supply (using artificial or organic fertiliser) and some without. Students can observe the differences.

14. Adding nutrients to the soil

If a soil becomes short of nutrients there are two ways we can put them back:

1. **by allowing the land to lie fallow**
2. **by adding fertiliser**

Lying fallow

This is when we leave a garden to grow back into bush.

If it is left as bush for several years organic matter will be added as plants die and enter the soil.

This organic matter eventually becomes humus which supplies nutrients in the soil.

This method of restoring nutrients to a soil is not expensive, but requires that a farmer has a lot of land.

Fertiliser

There are two types of fertiliser, organic and artificial

Organic fertilisers

There are made from dead plants and animals. For example:-

- **Compost**
- **Green manure**
- **Animal manure**
- **Wood ash**
- **Blood and bone fertiliser**

Most organic fertilisers can be made or obtained by the farmer without spending money.

They help to form **humus** in the soil. This means that as well as supplying the soil with nutrients, they also:-

- help to hold soil water
- help to improve soil structure

Artificial fertilisers

These consist of chemicals and are sometimes called **chemical fertilisers**.

They are made overseas in factories.

They have to be bought from shops which means that they cost the farmer money.

They are very rich in nutrients.

If we use too much of them we can **damage the soil structure**.

Practical work

The practical aspects of using fertilisers are covered in the unit on Vegetable Growing.

During their practical work in the garden, the correct methods of preparation, use and storage of fertilisers should be demonstrated to, and then practiced by students.

15. Types of organic fertilisers

The most common organic fertilisers are:

1. **Compost**

   This is made in the garden using plant remains and animal manure. (see ***Notes on Vegetable Growing***)

2. **Green manure (legumes)**

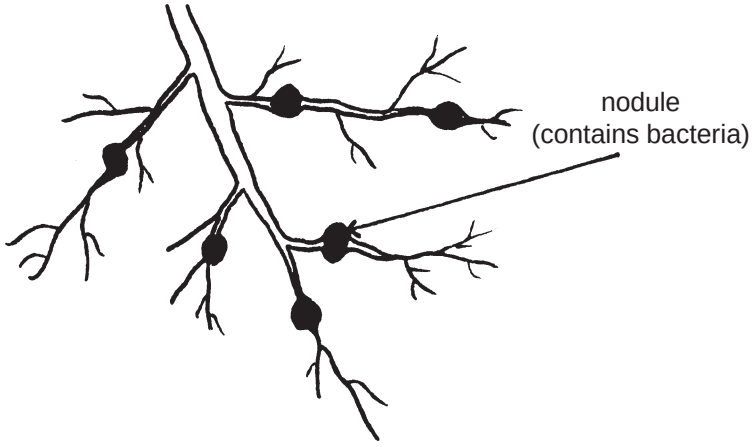
   Legumes are a group of plants which have small lumps on their roots, called **nodules**.

   Inside these nodules live tiny **bacteria**.

   These bacteria are able to take nitrogen gas from the air and turn it into **nitrate**, which is a plant nutrient.

   By growing legumes in the garden and then **digging them into the soil**, this will add nitrate, which can be used by the next crops grown in that place.

Diagram 9 **Nodules on a legume root**



Examples of legumes are:

peas

beans

puraria

glyricidea

flemigia

3. **Animal manure**

The manure of cattle, pigs or chickens can be collected and used as fertiliser. They supply Nitrate, Potash and Phosphate.

They should be applied only to the soil, and not spread onto crops, to avoid spreading disease.

4. **Blood and bone fertiliser**

This is produced as a by-product in meat factories.

It contains a mixture of dried blood and crushed bones.

It supplies a good amount of Phosphate, and a smaller amount of Nitrate.

5. **Wood ash**

This is a good source of Potash.

6. **Mulch**

This is when we place compost or dead leaves around the base of a growing plant (see ***Notes on Vegetable Growing***).

Practical work

It is recommended that students should obtain practical experience of composting and mulching during their work in the school gardens (see ***Notes on Vegetable Growing***).

Students can also carefully dig up and draw the roots and root nodules of legumes such as nail grass or kasis.

16. Types of artificial fertiliser

There are two groups of these:

1. **Simple***:* These contain **chemicals** which supply only **one nutrient** to the soil. eg.,

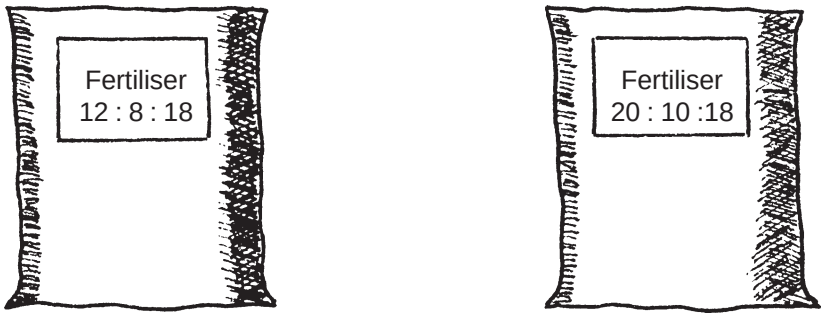
Name of chemical supplied	Nutrient
Urea Ammonium sulphate	Nitrate
Superphosphate	Phosphate
Sulphate of potash (Muriate of potash)	Potash

2. **Compound:** These will contain a mixture of those chemicals above.

   A compound fertiliser will supply **more than one** nutrient to the soil.

   The label on the bag tells us the **percentage** of nutrient inside (see Diagram 10).

Figure 10 Examples of conmpound fertilisers



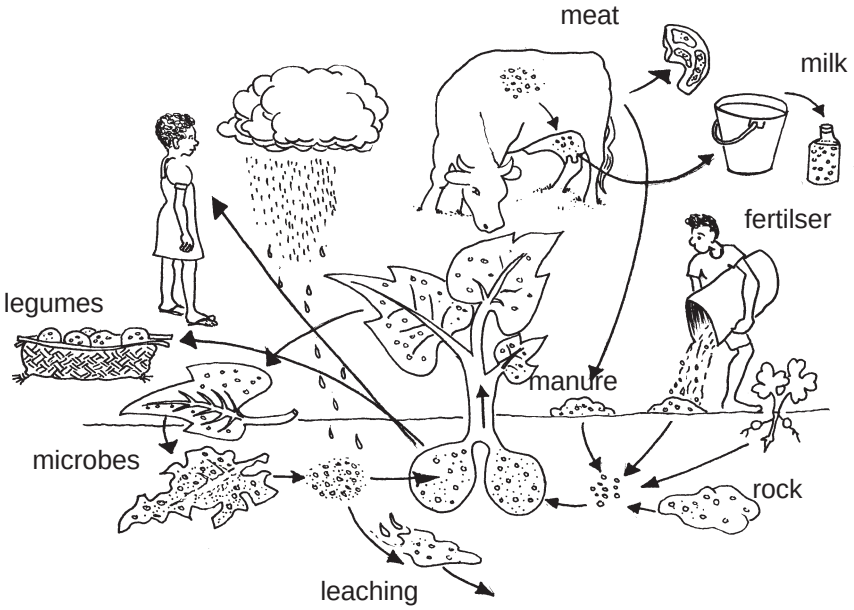
- ***Fertiliser A*** is rich in **potash** (18%) and low in **phosphate**(8%)
- **Fertiliser B** is rich in **nitrate** (20%) and low in **phosphate** and **Potash** (10%)

It is important that artificial fertilisers are stored wisely and used carefully. These aspects are covered in detail in the unit on Vegetable growing.

17. The movement (cycle) of nutrients in the soil

Nutrients are always moving from one place to another. They will be entering and leaving the soil all the time in a cycle.

Figure 11 The cycle of nutrients



How nutrients can enter the soil

- legumes growing in the soil
- farmers putting fertiliser on the soil
- animal manure falling on the soil
- microbes attacking dead plants and animals in the soil to make humus
- rock breaking down slowly in the soil

How nutrients can leave the soil

- weeds being removed and taken away
- crops being harvested and taken away
- leaching
- animals eating food plants then being taken away and killed for me

GLOSSARY

ammonium sulphate	Chemical substance used as a fertiliser to supply **nitrate** to the soil
artificial fertiliser	chemical fertiliser made in factories overseas
bacteria	type of microbe living in the soil
bedrock	solid layer of rock at the bottom of a soil
capillary action	movement of water upwards through the soil
compost	an organic fertiliser made from the remains of dead plants and animal manure
crumb	a group of rock particles stuck together by humus (found in soils with good structure)
erosion	removal of the soil by wind or running water
fallow	allowing a garden to grow back into bush
fertile	a soil rich in nutrients which produces good crops
green manure	when legumes are grown and then dug into a soil adding **nitrate** to it
horizon	a layer in the soil profile
humus	substances formed in the soil from the decay of **organic matter**.
leaching	when nutrients are washed out of the soil by heavy rain
loam	a soil containing even proportions of sand, silt, and clay
major nutrients	nutrients required by plants in **large** amounts eg. Nitrate, Phosphate and Potash

microbes	tiny microscopic organisms living in soil
mulching	covering the soil at the base of a growing crop plant
muriate of potash	chemical substance used as a fertiliser to supply **potash** to the soil
nitrate	one of the major plant nutrients
nodules	small lumps found on the roots of legumes, containing bacteria which make **nitrate** from nitrogen gas
nutrients	simple substances which plants need from soil in order to grow well and produce good crops
organic matter	remains of dead plants and animals found in the soil
phosphate	one of the major plant nutrients
pore space	spaces in soil which contain air and water
potash	one of the major plant nutrients
profile	view of layers of a soil from top to bottom (usually found by digging a pit)
rock particles	small pieces of rock in the soil formed by **weathering** of the bedrock
sulphate of potash	chemical substance used as fertiliser to supply **potash** to the soil
subsoil	the middle, infertile layer of a soil containing mostly rock particles
superphosphate	chemical substance used as fertiliser to supply **phosphate** to the soil
texture	feel of a soil based on amounts of clay, silt, and sand it contains

topsoil	upper fertile layer of a soil usually rich in organic matter and humus
trace elements	nutrients required by plants in **small** amounts eg. copper, zinc, boron, iron
urea	chemical substance used as fertiliser to supply **nitrate** to a soil
waterlogged	soil which has all its pore spaces full of water and contains no air
weathering	process by which bedrock is broken down into rock particles