Community Development Strand
Agriculture

Unit 1: Agriculture Resource Science

Module 1.1 Soil

Student Support Material

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Unit outline

Unit	#	Modules
Unit 1	**1.1**	**Soil (Core)**
	1.2	Crops (Core)
Agriculture Resource Science	1.3	Livestock (Core)
	1.4	Sustainable Agricultural Systems (Core)

Icons

🕮	Read	or	research
✍	Write	or	summarise
☞	Activity	or	discussion

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Module 1.1 Soil

Rationale

The purpose of this module is to provide you with an understanding of the importance of and maintenance of healthy soil. All agricultural practices require and depend upon healthy soil for crop and livestock productivity. The main aim of this module is to provide you with a deeper knowledge and skills of soil use and care, how healthy soil benefits plants and people, the properties of soil and reasons for its behaviour. Garden plots will be used to provide you with a deeper context on which to practice the skills and knowledge presented in this module. Throughout the module we will draw a connection between human health and the need for healthy soil.

Objectives

By the end of this module you will be able to:

- Describe different types of soil and how soil is formed
- Identify and describe the various weathering agents in soil formation
- Describe the difference properties of soil
- Describe different ways of maintaining soil fertility
- Identify soil nutrient deficiency symptoms in plants and be able to apply appropriate remedies
- Build at least one type of compost system and describe the benefits of composting to good soil health.
- Describe the use of fertilizer and compost and how it improves the soil condition for plant growth
- Prepare teaching and learning resources for a teaching portfolio suitable for teaching grades 6-8

Topics

1. Formation of soil
2. Types of soil
3. Soil fertility
4. Care and maintenance

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Topic 1: Formation of Soil

Objectives

By the end of this topic, you will be able to:

- describe concisely what soil is
- identify and describe the different weathering agents and how they are involved and contributed to soil establishment

Resources

- Student Support Material book
- Student garden plots
- College garden project

Scope

This topic looks at the initial stage of soil formation – the weathering of rocks, brought about by physical, chemical and biological agents. It examines the different weathering agents that contribute to soil formation. The 'portfolio activities' and the importance of working in college gardens will be discussed.

Introduction

The soil is the home of innumerable forms of plant and animal life. Life in the soil is amazingly diverse, ranging from microscopic single celled organisms to large burrowing animals. As in the case of organisms above the ground, there are well- defined food chains and intense competition for survival of organisms inside the soil. *(See Figure 2 and Figure 16 for examples of micro-organisms and food chains)*

Soils are formed from rock products which have been broken down. They may form soil at that same spot or they may be carried away by rivers and deposited as soil elsewhere. However different the parent rock material may originally have been, if the climate and weathering conditions were similar the break down products would be about the same. In physical weathering – the rocks are broken down into smaller particles by sun, ice, rivers, rain and wind. In the tropics, the heat of the sun causes expansion of the rocks followed by cracks and peeling off of the surface layers. In temperate climates, water gets into cracks in rocks and freezes into ice. This causes expansion of the rocks followed by further cracks and break down of the rocks. Rocks carried by rivers wear away as they move with the water and break down into smaller particles.

What is weathering and how do weathering processes aid the formation of soil?

Figure 1 The Sepik River carries millions of cubic metres of soil and organic matter per minute to the sea.

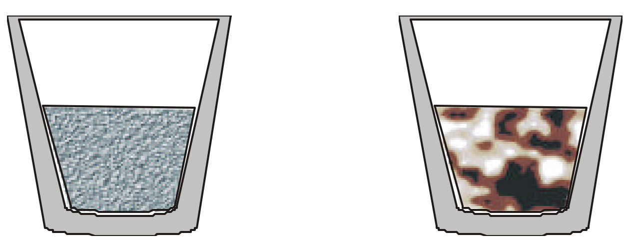
Rivers play a big part in carrying away soil. They deposit in the lower part of their courses sediments obtained from erosion. If the speed of a river is increased, its transporting capacity also increases. When a river enters more gently sloping valleys, it flows more slowly and deposits along the sides of its bed the material it can no longer carry. If the land over which a river flows is raised the river will flow more quickly and will begin to cut the land down to a new base level. As it cuts into its own alluvial flood plains, it produces terraces on which particular types of soil are formed.

Rivers also bring and deposit the finer grained silt and clay along the coasts close to the river mouths. When land rises because of earth movements, we get large flat areas of soil. These are called alluvial soils.

☞ 1.1 Activity 1

The purpose of this activity is to highlight the differing qualities of sand and clay as growing media for seeds.

Sow some small corn seeds in little glass jars containing moist sand in one and moist clay in another. The seeds soon germinate in the sand but not in the clay. It is known that seeds will not germinate unless they have air and water that is warm enough. There was water present in both jars and both jars were also warm.



Jar with moist sand *Jar with moist clay*

Why did the seeds not sprout in the jar containing moist clay?

Parent rock types

There are three main types of rocks.

1. **Igneous rocks** – are made from hot, molten materials from deep inside the earth, like lava that comes out of volcanoes.
2. **Sedimentary rocks –** are made up of layers of particles that were laid down under water and then barded together.
3. **Metamorphic rocks –** were sedimentary rocks but they were melted by heat and pressure due to movements of the earth's crust. When they cooled, their form was changed. Eg. limestone became marble.

What are the factors of soil formation?

There are five groups of factors responsible for the kind, rate and extent of soil formation.

These are:

1. Climate
2. Organisms
3. Parent material
4. Topography
5. Time

Soil from one place is different from another because of the differences in the influence of these factors. *(See Figure 6 Potential Agricultural land use)*

This module will give you general principles and background knowledge of how the different weathering agents and factors work towards the formation of soil. For more information, refer to the relevant science module or library resource.

Different weathering agents

1. **Moving water –** the streams and rivers, water moves stones about, rubbing them together. Small particles break off and they may eventually become part of the mineral or inorganic particles of the soil.
2. **Heat and cold –** make rocks expand and contract. If they have weak places, they will crack and break up.
3. **Wind –** in desert areas sometimes wears rocks by blowing sand against them.
4. **Carbon dioxide –** in the air forms weak carbonic acid. This can dissolve limestone and chalk rocks. The activities of plants and animals contribute to the formation of soil by adding organic materials.

5. **Plants (biological)** – that live on rocks, like mosses and lichens, slowly cause the rock surface to crumble. They also trap dust from the air and build up a layer of soil, which includes their own organic materials.
6. **Animals** – living in the soil, like earth worms, termites and ants help to increase the amount of organic matter in the soil. *(See Figure 2 Micro-organisms)*

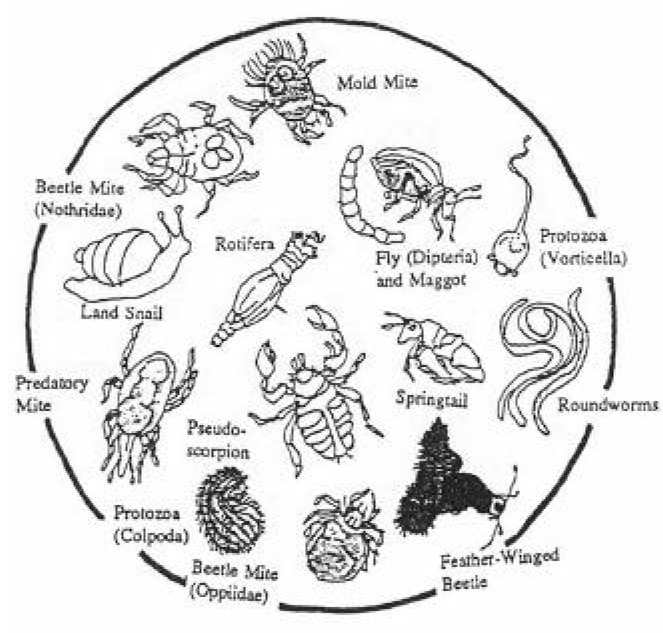


Figure 2: Some of the micro-organisms that live in healthy soil.

☞ 1.1 Activity 2 Looking for micro-organisms

Dig a sample of soil from your garden

Put the soil on a small piece of fly wire and suspend it above a piece of white paper.

Keep the white paper in the dark way from sunlight.

What do you think will happen?

What might happen is that the living creatures in the soil will escape the light and fall on the white paper.

Look at the photo entitled 'Sterilising soil'.

Explain why this is done.

Sterilising soil

Agriculture portfolio

The agriculture portfolio is a resource which you will be developing through the course of this module. All portfolio activities should be completed and kept in a specific teaching folder. As a new teacher, you will be expected to be a leader in your community. Part of being a leader is being able to support traditional practices with new techniques. Through agriculture studies, you will be expected to learn and put into practice new and different agriculture techniques. When you eventually go into the field, we would expect you to be able to develop a model school garden in which you share these new agricultural techniques with your community.

The purpose of the 'portfolio' is to help you to:

- develop practical teaching resources which can be used with children.
- be able to establish a model school garden with new and innovative agricultural ideas, which can support traditional ways.

☞ 1.1 Portfolio Activity (1)

We expect you to be able to establish a model school garden with new and innovative agricultural ideas, which can support traditional ways.

The main use of this portfolio should be the collection of teaching and learning materials which can assist you in establishing a model garden.

Task 1 : *This task asks you to produce a simple wall chart (A3) which explains the formation of soils.*

The chart must:

- *Show soil as being alive*
- *Have illustrations*
- *Include at least five facts*
- *Include at least three open-ended questions and two closed questions.*
- *Have a border and bold heading*
- *Include at least three complimentary colours.*

Task 2*: Make an accurate sketch of the ideal soil profile with a set of question and activities suitable for Grades 6-8.*

Topic 2: Types of soil

Objectives

By the end of this topic, you will be able to:

- identify and describe different types of soil
- discover the pH of a soil based on what is growing on it
- decide what crops grow best in a particular type of soil

Resources

- Student Support Material
- Student garden plots

Figure 3: Sandy loam and clay.

Scope

This topic examines the types of soil commonly found around Papua New Guinea and *introduces* you to practical ways of determining and recognizing soil types.

Types of soil

The type of soil in an area is determined by the parent rocks of a particular area. However, the early civilizations of Papua New Guinea had knowledge of their soils long before the scientific study of soils emerged in the western world.

For example: the Baruya people belonging to the highlands had twenty names for soils and at least ten names for rocks and related materials. The soils were classified according to their use as pigments or for agriculture. Pigments play a very important role in the society and may be used for colouring string, war paints or ceremonial purposes.

The agricultural soils are subdivided by the people into four major groups, which refer to dark coloured soils, reddish coloured soils, alluvial soils and salt grass soils. The distinction between these soils were based mainly on textural and colour differences of certain soil horizons. The people were able to classify their soil according to their relative suitability for sweet potato, this being the staple food in the highland areas.

☞ 1.1 Activity 3

- *Describe the role of clay pigment in your society.*
- *How do the Baruya people classify the various type of soils found in their area?*
- *Work with peers from your culture group. Build up a list of traditional classifications and uses of soils and clay pigments.*
- *Use the following table with the three headings to classify the uses your people have for clays and soils.*

Figure 4 Andep people, Middle Sepik demonstrating the use of clay pigment for a traditional singsing.

Society/culture	Soil classification	Use of soils and clays

The composition of soil

The soil consists of mineral particles mixed with some organic matter. The organic matter is made up of plant remains in various stages of decay. The mineral and organic matter are mixed together especially in the topsoil. Below the topsoil is the subsoil. The subsoil is largely composed of mineral matter. In addition to the mineral and organic matter which are called the soil solids, there are spaces in between the solid particles. These spaces taken up by water and air and make up the non- solid part of the soil.

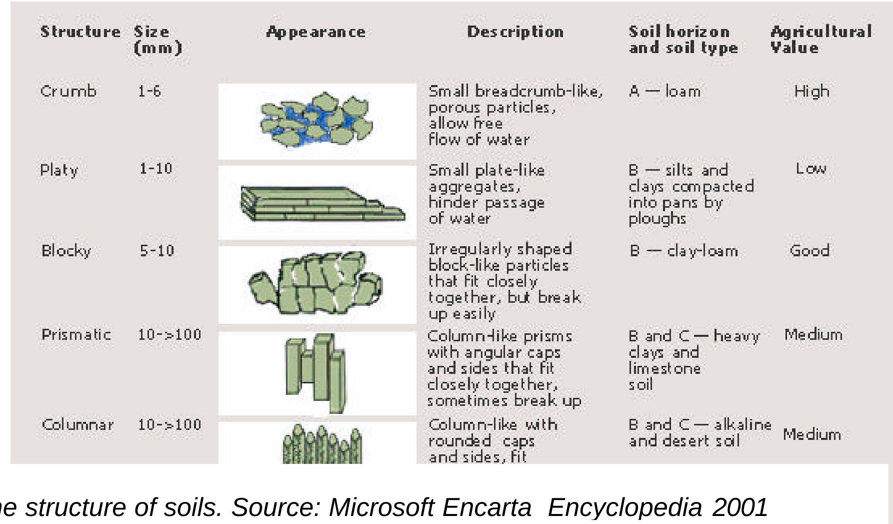
Types of soil

- Sandy loam – sand (58%), clay (18%) and silt (24%)
- Loam – sand (40%), clay (20%), and silt (40%)
- Clay loam – sand (33%), clay (33%), and silt (33%)

- Clay – sand (30%), clay (45%), and silt (25%)

Mineral particles

- Clay –smaller than .002 mm
- Silt – between .002 mm to .02 mm
- Sand – between .02 mm to 2 mm
- Gravel – larger than 2 mm



Structure	Size (mm)	Appearance	Description	Soil horizon and soil type	Agricultural Value
Crumb	1-6		Small breadcrumb-like, porous particles, allow free flow of water	A — loam	High
Platy	1-10		Small plate-like aggregates, hinder passage of water	B — silts and clays compacted into pans by ploughs	Low
Blocky	5-10		Irregularly shaped block-like particles that fit closely together, but break up easily	B — clay-loam	Good
Prismatic	10->100		Column-like prisms with angular caps and sides that fit closely together, sometimes break up	B and C — heavy clays and limestone soil	Medium
Columnar	10->100		Column-like with rounded caps and sides, fit	B and C — alkaline and desert soil	Medium

Figure 5 The structure of soils. Source: Microsoft Encarta Encyclopedia 2001

Soil types of Papua New Guinea – an exercise in lateral thinking

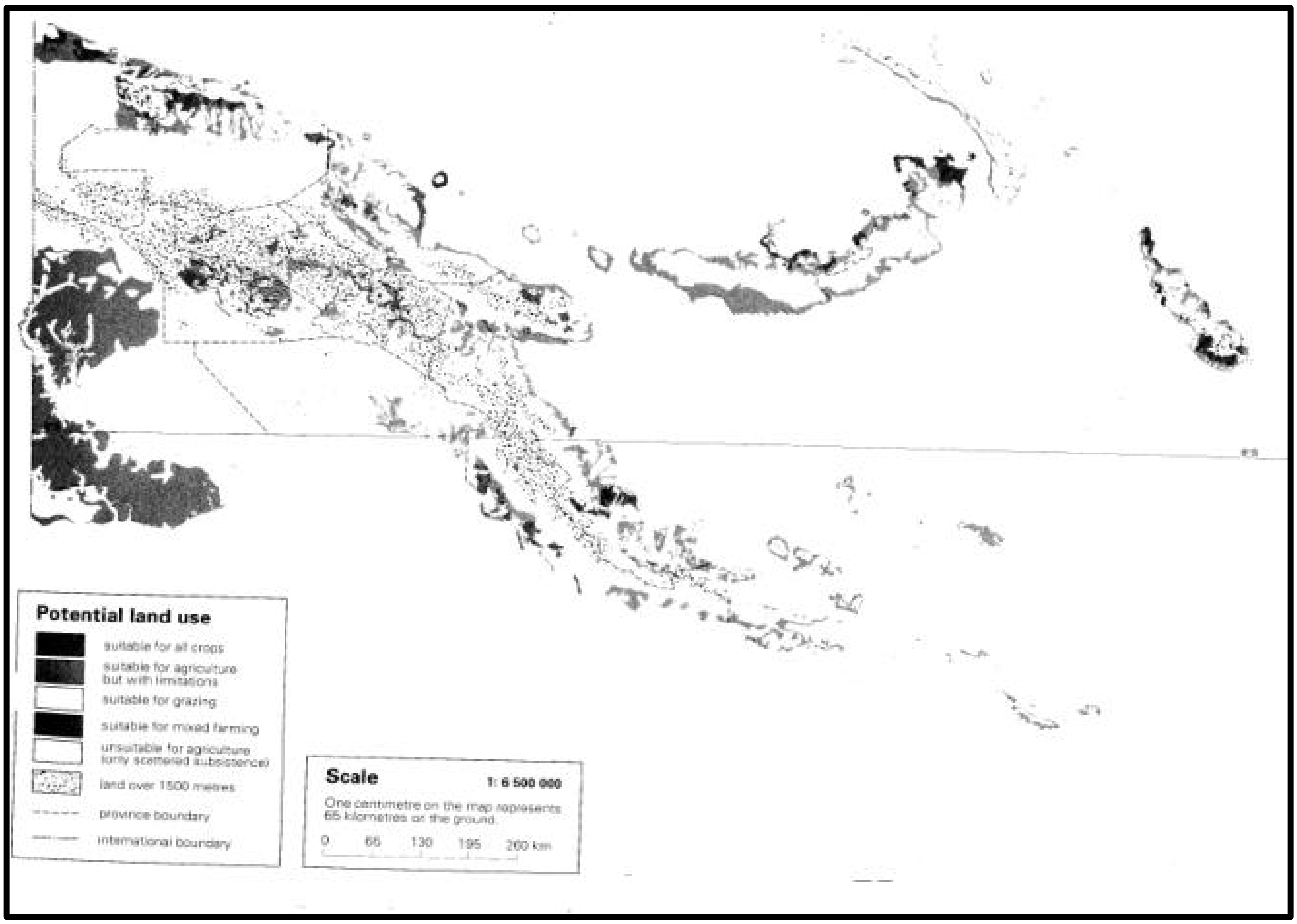


Figure 6: Potential agricultural land use.

☞ 1.1 Activity 4

The map at Figure 6 shows potential agricultural land use for different areas of Papua New Guinea. Look at it carefully. The objective of this activity is to find out as much as possible about the type of land and soil in five areas identified. Take factors such as elevation above sea level, coastal factors, vegetation, and population pressures into account when describing the land.

Use these questions to help if necessary:

Land use: *What is growing there now? How is the land used?*

Soil type: *What type of soil is likely to be there knowing the type of vegetation, geography and climate of the area?*

Soil structure

Structure means the arrangement of different layers in the soil formation. The layers of clay, silt, sand and gravel.

Soil profile

The side view of the soil after it has been dug. Taking a closer look at the different soil properties such as different colour of horizons, living organisms and the parent materials. Look at Figure 7 which shows an ideal soil profile.

- *Explain in your own words, how would you improve waterlogged soil.*
- *What is lacking in a desert soil?*
- Describe the composition of a soil profile and what has caused this to happen.

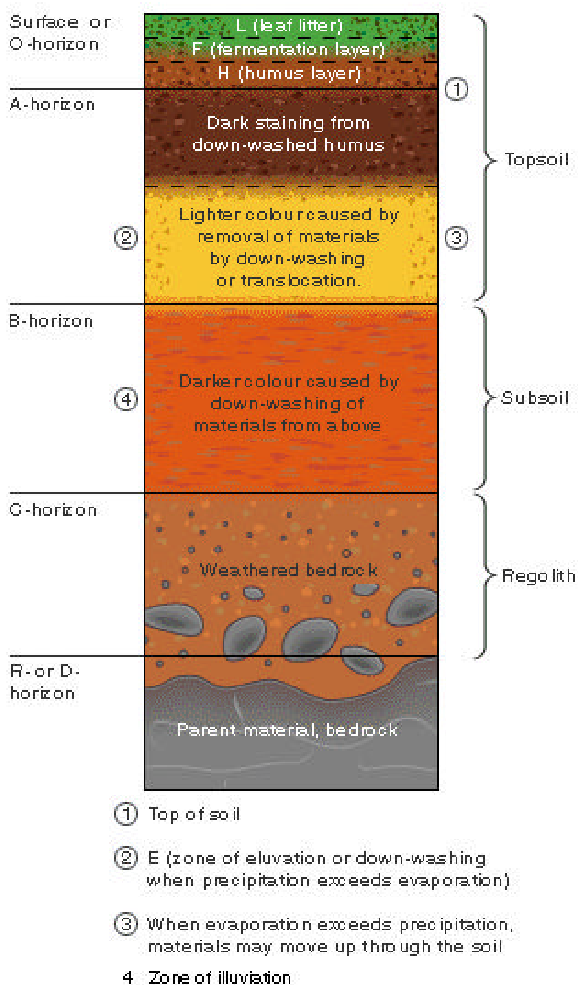
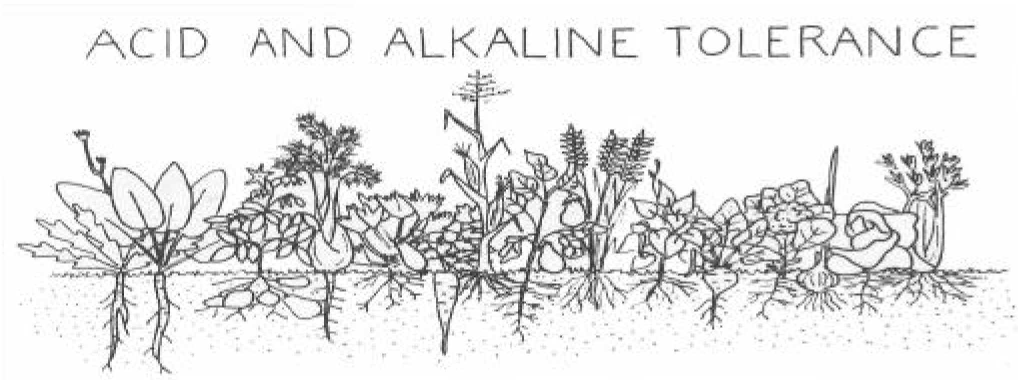


Figure 7 An ideal soil profile. Source: Microsoft Encarta Encyclopedia 2001

Acid and alkaline tolerance

Soils may be classified by a number of different characteristics, one such classification is 'acidity and alkalinity'. It is helpful is a gardener knows how to read the pH levels of the soil because as can be seen in Figure 8 plants prefer acid and alkaline conditions.

Acid and alkaline tolerance



Quite Acid pH 4.0 –6.0	Slightly Acid pH 6.0 – 7.0	Neutral to Alkaline pH 7.0 – 7.5
Blackberry	Apple	
Blueberry	Apricot	Alfalfa
Coffee	Beans	Asparagus
Fennel	Cherry	Beet
Conifer	Eggplant	Broccoli
Flax	Grains	Brussels sprouts
Marigold	Grape	Cabbage
Moss	Mustard	Carrot
Oak	Parsley	Cauliflower
Pecan	Pea	Celery
Potato	Pear	Cucumber
Peanut	Pumpkin	Leeks
Radish	Soybean	Lettuce
Raspberry	Squash	Onion
Rhubarb	Strawberry	Silver beet
Shallot	Tomato	Spinach
Kaukau	Turnip	zucchini
Tea		
Watermelon		

Figure 8 Acid and alkaline tolerance

☞ 1.1 Activity 5

- *What is the advantage of knowing this information? How can it help the gardener?*
- *If soil is acidic, how can we tell –what are the signs?*
- *In order to grow cabbages in acidic soil, what does the gardener have to do?*
- *What is the value of ash to soil conditioning?*
- *In traditional society/gardening what were these soil types known as*
- *How did/do gardeners modify soils to make them more or less acidic?*

Discovering your soil type first hand

Gardeners are in so many ways like environmental facilitators. They need to know what conditions and plants to encourage and which plants, creatures and conditions to minimise. The chart ' Discovering your soil type first hand' is a useful guide to help you determine the characteristics of different soils in the garden.

Read it carefully and complete 1.1 Portfolio Activity (2)

Discovering your soil type first hand

IF IT LOOKS…	AND FEELS…	AND IS…	IT'S	AND NEEDS…
hard baked, crusty and perhaps even deeply cracked when it dries out. scarce in pore spaces holding air and water	harsh and rock hard when it dries out sticky, greasy or rubbery when wet	hard to work very slow to absorb water and to dry out. likely to form large congealed lumps if worked when wet	**CLAY.** If other kinds of particles are present in quantity, such soil can be classified as stony clay, sandy clay or silty clay.	substantial additions of organic materials to open channels for aeration and drainage. Some good choices: compost, manure, leaf mold, coffee husks, peat moss, coarse sand, sawdust and woodchips.
loose and friable quite porous full of large, irregularly shaped mineral particles more of less devoid of larger pieces or granules	grainy and gritty crumbly and won't hold it's shape when squeezed	easy to work fast drying low in nutrients because soluble plant foods are lost through leeching.	**SANDY.** Depending on the size and texture of the particles, such material may be classified as course, medium, fine or loamy sand.	continual additions of large amounts of organic matter to hold water and nutrients within the range of plant roots. plentiful application of peat moss, compost, leaf mold or sawdust in topsoil layer. green manures to build structure
very dark brown full of organic matter in varying stages of decay granular and porous	like moist peat moss when squeezed.	easy to work slow to decompose low in minerals	**MUCK or PEAT** Peat is not fully decomposed. Muck is the same soil in a more advanced state of decay. It tends to get waterlogged and lacking in lime but rich in nutrients such as nitrogen.	layers of gravel, drainage tiles or open drains to improve drainage. lime added as needed
Full of crumbs of various sizes Quite porous	Spongy, compacting readily into a ball when squeezed, but falling apart readily when prodded. Or flour-like when dry and only a little plastic when moist	Easy to work Very productive Well-drained yet able to retain moist as it is needed. Well aerated Retentive of nutrient	**LOAM.** A mixture of sand, silt and clay., this close to ideal soil combines the best qualities of light and heavy growing media.	Regular additions of organic matter to maintain its already excellent fertility and structure.

☞ 1.1 Portfolio Activity (2)

Make two, 30-minute lessons on soil type for Grades 6-8. Part of one lesson must involve the students discovering soil types themselves outside the classroom.

Topic 3: Soil Fertility

Objectives

By the end of this topic, you will be able to:

- use suitable methods for caring and maintaining soil fertility.
- describe the elements required for healthy soil
- explain the value of earthworms to soil health
- demonstrate alternatives to 'burning' for creating soil fertility
- describe the advantages and disadvantages of burning and the advantages and disadvantages for the alternatives to burning.

Resources

- Student Support Material
- Student garden plots

Scope

This topic introduces you to soil fertility, what it means and how it can be maintained. Composting is briefly mentioned and is covered more fully in the following section.

What is soil fertility?

We have learnt that crops require nutrient elements essential to their growth and most of these elements are derived from the soil. If the soil cannot supply these nutrient elements in adequate quantities and in correct proportions, the crop production will decline.

The inherent capacity of a soil to supply nutrients to plants in adequate amounts and in suitable proportions is referred to as soil fertility. This is different from soil productivity which is related to the ability of a soil to yield crops. Productivity is the broader term since fertility is only one of a number of factors that determine the magnitude of crop yields. Some of the other factors of soil productivity are soil density, soil structure, soil depth, and soil water retention capacity.

When many rainforests are first cleared of their native vegetation and cultivation for crops, they are quite productive for a few years if moisture is adequate. With a continued cropping however, yield decreases because the fertility of the soil is depleted. In order to restore the fertility of the soil, farmers allow a cultivated piece of land to stay fallow (leaving under natural vegetation without cultivating any crops) for about 5 to 10 years before bringing it back for cultivation. This method of cultivation is often practiced in subsistence farming.

With the increase in population and consequent pressure for land, farmers in many countries are now forced to reduce to fallow period to less than 5 years or so and this results in a

decline in crop yield. This short fallow period is not sufficient to restore fully, the fertility of the soil.

Figure 9: House with no garden.

Figure 10: Bush garden.

Discuss and debate these questions -use the photographs as references.

- *List the 'pros' and 'cons' of making a 'slash and burn' garden seen in Figure 9.*
- *Why do you think there are no gardens (beans, kumu, kaukau,..) growing around the house in Figure 9. How could this be changed using your model school garden as an example?*
- *The forest maintains a thin layer of top-soil but survives by continuously recycling the forest organic matter.* (See Figure 19) *What do you think we can learn from this system for our own gardens?*

Cropping systems and the maintenance of fertility

The best signs of soil fertility are the colour of plant leaves. Dark green leaves are generally healthy. Yellow, brown or red leaves are generally a sign of food shortage (malnutrition) in the plant.

Crop rotation

In many countries, where annual crops are grown, the crops are rotated. In order to maintain the fertility of a soil it is often good to rest the land by introducing a pasture phase in the rotation. It is well known that too much cultivation destroys the soil structure. It also destroys the humus and is very good for improving the soil structure.

Different crops take different kinds of food from the soil. Because of this we must change the place where we plant our crops after each harvest.

For example:

Crops which take lots of nutrients from the soil	Crops which take some nutrients from the soil	Crops which give nutrients to the soil.
corn lettuce cabbage capsicum tomato cucumber	kaukau cassava taro yam potato carrot	wing bean soya bean mung bean rice bean snake bean dwarf bean black velvet bean peanuts

It would be a good idea to plan a crop rotation so that a legume (or another creeping plant like basella) is planted just before the long school holidays, at the end of the year. This will stop weeds from spoiling the garden site, and when school begins the following year, the garden can be prepared by chopping up and digging these beans back into the soil

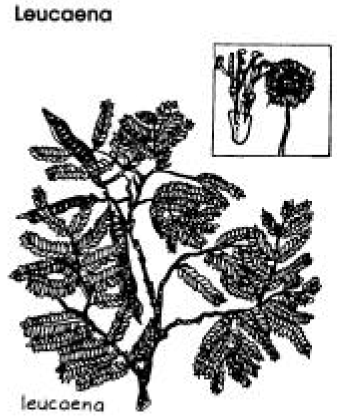


Figure 11 Leucaena or 'landro

Use of legumes

Legume plants, such as peanuts and soya bean, get nitrogen from the air. They do this by allowing a special type of bacteria to live in their roots. On the roots of legumes are tiny swellings which are called root nodules. The bacteria live in these nodules. The legume supplies food to the bacteria and the bacteria convert the nitrogen into a plant food. In this way, nitrogen in the soil can be broken down again by different bacteria so that other plants may take up this nitrogen for their own use.

Legumes are often grown in rotation with other crops.

Sometimes they are used for food, for example peanuts and various beans, such as the soya beans. Sometimes they are grown and mainly meant to be ploughed under to enrich the soil with their nitrogen – rich humus.

If the same crop is grown year after year on the same soil, diseases and pests will become a problem. By rotating crops we can help to avoid these problems because many diseases and insect pests are quite specific. That is they attack a particular type of plant.

Figure12 Cassarina trees add nitrogen to a Highland garden

Most of the cover crops and plants are legumes which supply valuable nitrogen when they die. They therefore, improve the soil in a long run.

Alley cropping

In Morobe Province, women have begun planting trees on steep garden slopes. These are mainly fruit trees but there are also firewood trees. In between rows of leucaena (landro) they usually plant kaukau. These people were very surprised at the good harvest of kaukau when grown underneath the leucaena.

College gardens should have examples of 'alley cropping'. Leucaena is the obvious tree because it is so common and versatile. Green manure crops should also be grown

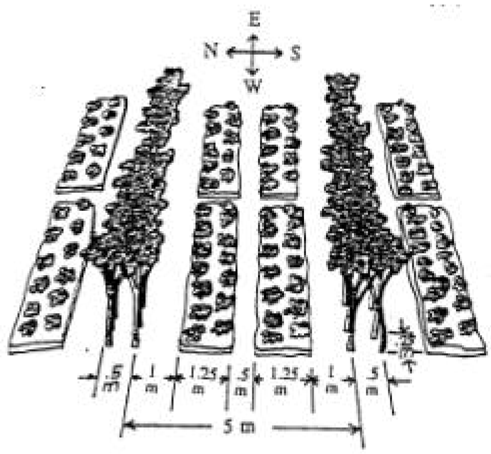


Figure 13 Alley cropping with leucaena

Factors affecting soil fertility

The soil supplies plant food, water and air. Root systems develop in soils and the fertility of the soil is therefore linked with their growth. Soil management by people must help to change some of these factors which affect fertility.

1. Soil texture influences all aspects of root development. A heavy compact soil may offer a physical barrier to root growth and thus reduce the plant's growth. Texture also influences the moisture status of soil.
2. Avery important factor is the depth of the soil profile. Deep permeable (water can pass) soils enlarge the volume through which the roots can spread. If the roots are shallow, many plants would be seriously affected during dry weather.
3. The presence or absence of a water table and its position also affects the fertility. Poor drainage causes the roots to be affected by high carbon dioxide and low oxygen levels.
4. Whether a soil can supply adequate plant food or not will depend on whether the soil has reserves supplies. It also depends on whether these reserves can be quickly converted into a form which the plant can readily take up into the roots.

☞ 1.1 Activity 6 Soil Fertility – Discussion questions

1. *Consider types of annual crops best for crop rotation. Why?*
2. *Draw and describe the nutrient cycle – the process by which the rain forest recycles the organic matter of the forest. Beside this illustration draw an example of a slash and burn garden. Finally, add an alternative which tries to improve the traditional system and imitate the natural systems.*

Slash and burn garden	*Rain forest nutrient cycle*	*Alternative to slash and burn.*

Soil health

Soil health is very important to an overall healthy garden, and compost is a critical component of achieving soil health. Gardens existing in healthy soil will require less energy, money, and time to maintain. Nature's own system of checks and balances will help to control pests and diseases. This section describes healthy soil and explains how the addition of compost, aeration, and water can build the health of the soil.

Elements required for healthy soil

Healthy soil smells sweet, is loose, friable, well-drained, rich in organic matter. It feels moist because it is able to hold moisture. Soil will be aggregated into particles with lots of air around them. Air and water move freely through the soil because air space exists around aggregated soil particles. Healthy soil will have about 24% air, 25% water, 45% minerals, 3 - 5% humus, and up to 1% living organisms.

Air

Aeration is critical for micro-organisms, macro-organisms, and vegetation to provide natural ecological balance in soil. These living plants and animals need oxygen to survive, as well as other gases found in air.

Water

Water is also essential to the survival of micro-organisms, macro-organisms, and vegetation. While too much water is a problem, these living plants and animals must have enough water to live. Healthy soil provides water retention ability as well as good drainage, so the proper amount of water is held in the soil. A 5% increase in organic material quadruples the soil's ability to store water.

Minerals

Healthy soil will have a pH between 6.2 and 6.5. This is well within the 5.5 to 7.5 pH range in which essential nutrients are available to plants. Outside this range, they become bound and cannot be absorbed by plants and micro-organisms. Calcium, magnesium, potassium, sodium, and other trace elements can be found in their proper relative proportions if the soil is healthy.

Humus

Humus contains lignin, protein, and complex sugars. Micro-organisms transform humus into enzymes, acids, and minerals which are the slow-release foods for vegetation. Humus is constantly being consumed by the micro-organisms and so must constantly be replaced. In the forest, this process is natural as each season adds a fresh layer of leaves to animal wastes, carcasses, and other organic wastes on the forest floor. In our less natural lawns and gardens, adding compost and other organic material is required to maintain the constant supply of decomposed matter.

Living organisms

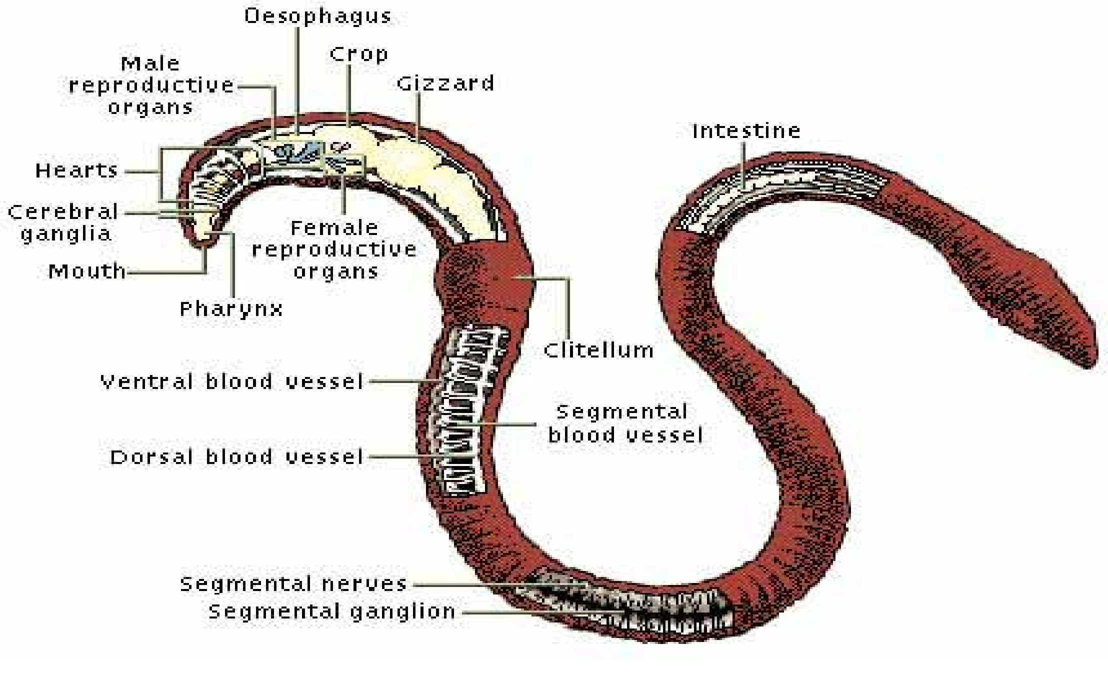
Healthy soil serves as a home to insects, earthworms, and microscopic plants and animals. Their presence indicates that soil contains materials which are being decomposed, releasing nutrients into the soil. The balanced ecology extends to the micro and macro-organisms so that pests and diseases may be kept in check through nature's system of checks and balances.

We can explain how most of these results are obtained using the earthworm as an example.

Earthworms -- Nature's sign of healthy soil

A good indicator of soil's health is the presence of earthworms. Earthworms migrate to and inhabit healthy soil, then help to maintain that health. To increase your earthworm population, feed them organic foods and composted manures, avoid over tilling, mulch

Figure 14: Common earthworm.



all bare soil and avoid high nitrogen fertilizers and chemical pesticides. Earthworms will repopulate naturally if they aren't poisoned.

Earthworms tunnel through the earth, excreting polysaccharides. Polysaccharides are sugars that act like glue to line the pencil-size tunnels, preserving them for years. As they move through the earth both horizontally and vertically, earthworms drag bits of organic material around, helping to mix organic matter into the soil. As they eat the organic material, they turn it into rich nutrients by leaving castings everywhere they go. There are also compartments within the worm's body in which micro-organisms multiply and are then released into the soil.

This simple activity of the earthworm provides numerous benefits:

- Web of tunnels aerates the soil so that plants and organisms can breathe. They break up soil hardpans and compacted soil.
- Web of tunnels allows moisture to move to and through the soil, so that plants and organisms receive the water they need, but have good drainage too.
- Having a tunnel built for them rather than pushing through compacted soil means that roots can grow up to 7 inches a day through the tunnels. Plants can root more deeply. Castings provide nutrition right at the root.
- Converting humus to castings provides nutritional value to plants and organisms. As plants decay, they form phenols and formaldehyde which can inhibit growth in plants. Earthworms reduce these substances and generate auxins and cytokinins instead, which stimulate plant growth. Castings contain as much as 10 times the soluble, plant-available nutrients as the original soil.
- Increased water absorption means that there is less run-off to (1) wash away topsoil and (2) prevent rain from reaching plant roots.
- Polysaccharides left by the earthworms help the aggregation of the soil. Sandy soil has large particles with large air pores, causing these soils to drain rapidly without adequate water retention. In sandy soil, compost helps to form larger aggregates from unconnected particles so that water and nutrients are retained. Clay soils have small particles which have small air pores. They drain poorly, retaining so much water that the soil cannot hold adequate air for vegetation. In clay or silt, compost breaks up the compacted particles to form aggregates so that water and air can move through the soil. Root systems can also forge their way through the soil more easily.

☞ 1.1 Portfolio Activity (3)

(Possible activities for the students to choose from)

- *Make a fact sheet about earthworms.*
- *Make a crossword or word-find using words connected with the importance of earthworms to soil fertility.*
- *Write a lesson which gets the children to study worms and build a worm farm. (Research about worm farms)*

The dangers of scorched-earth gardening (burning)

Burning new garden sites kills the most important plant foods (particularly nutrients like nitrogen, sulphur and phosphorus) and organic matter (micro-organisms and bacteria which change rotting leaves and trees to good soil). When the rains fall it washes away many of the important plant foods. This is called leaching.

Figure 15: Scorched earth gardening.

Most gardeners in Papua New Guinea strongly believe in burning the ground and all the organic matter growing on it before planting.

Traditionally this cleared land is used for 2-3 years. It was then left fallow for 15-25 years so the bush would grow back and the soil fertility restored.

Increasing populations and land shortages have changed this traditional system.

> *Describe in your own words the significance of these changes.*

Land close to villages loses its fertility if it is over used and continually burnt. In many areas of Papua New Guinea, more and more new ground is being cleared far away from the villages.

Figure 16 An example of fallow land, Western Highlands.

☞ 1.1 Activity 7

What are the consequences of gardens being located further and further from the villages for:

- *Women*
- *The use of wild foods in the diet of families*
- *Building materials*

Write a paragraph examining the likely effects/consequences of the increasing shortage of agricultural lands.

Do some research on kunai grass.

- *How does it affect the soil?*
- *What is the effect on the soil after burning the kunai?*
- *What can be done to replace the kunai?*

(Refer to E. Cox and E. Fitzpatrick. (1981). *Good gardens, Good Food Good Development*.)

☞ 1.1 Portfolio Activity (4)

Lesson planning

- *Plan a thematic lesson for a Grade 6,7 or 8 class on the* ***Problems of scorched earth gardening*** *and introduce the children to practical alternatives*
- *Include science, language and mathematics with agriculture in your planning*
- *Plan for at least three to four weeks*
- *Plan for at least 50 percent of the time to be outside doing and experimenting*

Topic 4: Care and Maintenance

(Composting, mulching and using fertiliser)

Figure 17: Basket composting.

Objectives

By the end of this topic, you will be able to:

- identify appropriate farming systems for soil conservation
- plan measures for controlling soil leaching and erosion
- build different types of compost systems
- plan teaching activities for grade 6-8 children
- know how to use in organic fertilisers safely and wisely

Resources

- Student Support Material
- Student garden plots

Scope

This topic continues to examine composting and mulching, two methods briefly mentioned in the previous topic. It is vital to cover these with practical demonstrations and involving some experimenting. Much agricultural practice in Papua New Guinea is based on burning the soil – a destructive and wasteful practice. This topic is one opportunity to change this practice by asking you to look at alternatives and encouraging you to prepare resources and lessons for teaching children.

Agricultural movers and shakers

A mover and shaker is some one who makes things happen. Someone who people listen to. I am sure you can think of movers and shakers in your community. In terms of education and agriculture in particular, you can become a mover and shaker. Developing the skills to make a model school garden will give you the ability to make things happen for your children and their parents.

Composting is the main theme of this topic. It should be practical and enable you to learn new skills.

Soil improvement – compost

Compost is a mixture of partly broken down organic material, usually made up of leaves or grass cuttings. Its value as a source of plant foods depends on the composition of the materials making the compost. If compost is poor in plant foods, then its value as a food source is low and cannot increase the crop yield.

How compost adds to soil health

Compost can help create healthy soil out of every kind of soil, silt, clay, or sandy dirt. The two things sick soils lack are micro-organisms and organic matter. By adding nutrients to soil, vegetation becomes healthier and micro and macro-organisms are attracted to the ecosystem. The most beneficial organism is the earthworm, but there are many others. Once this ecosystem becomes balanced in the way nature intended, every aspect of the system works to create a good environment for vegetation.

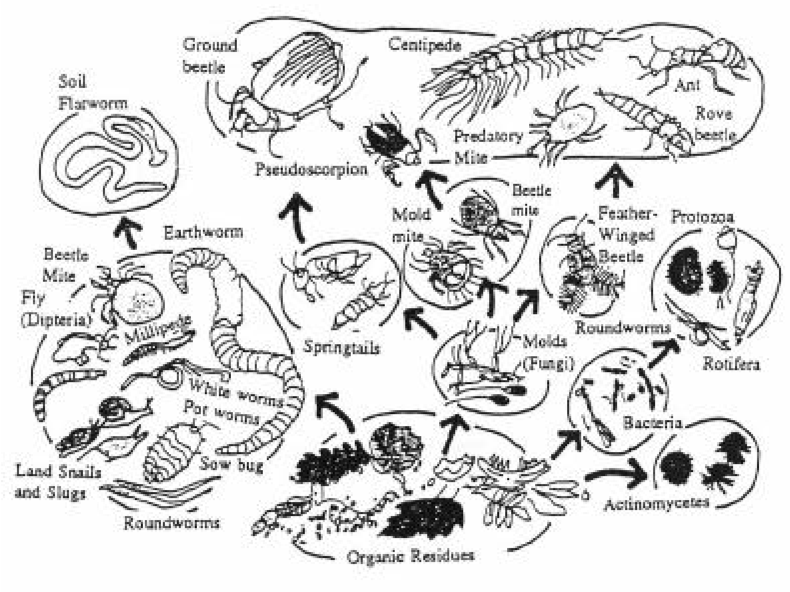


Figure 18 Micro-organisms living in humus.

The benefits brought about by this healthy ecosystem are:

- Encourages the formation of appropriately-sized aggregates which protect soil from erosion and compaction
- Eliminates (some say reduces) the need for chemicals which may pollute ground water
- Conserves water as penetration and retention are improved, erosion and run-off are reduced
- Stabilizes and regulates ph at optimum level for nutrient availability
- Allows better root penetration in clay soils
- Improves moisture retention in sandy soils so water loss and leaching are reduced or eliminated
- Improves drainage in clay soils
- Promotes fertility through higher quantities of macro and micro nutrition, as well as improving the availability of the nutrition
- Stimulates plant root development. Overall root environment is improved due to better structure, porosity, and density of the soil.
- Soil-borne plant pathogens are controlled or suppressed

The reasons for composting

- Supplies plants with food
- Helps let water into the soil and holds moisture
- Makes soil easier to work with

- Holds sandy soil together
- Supplies food for micro-organisms

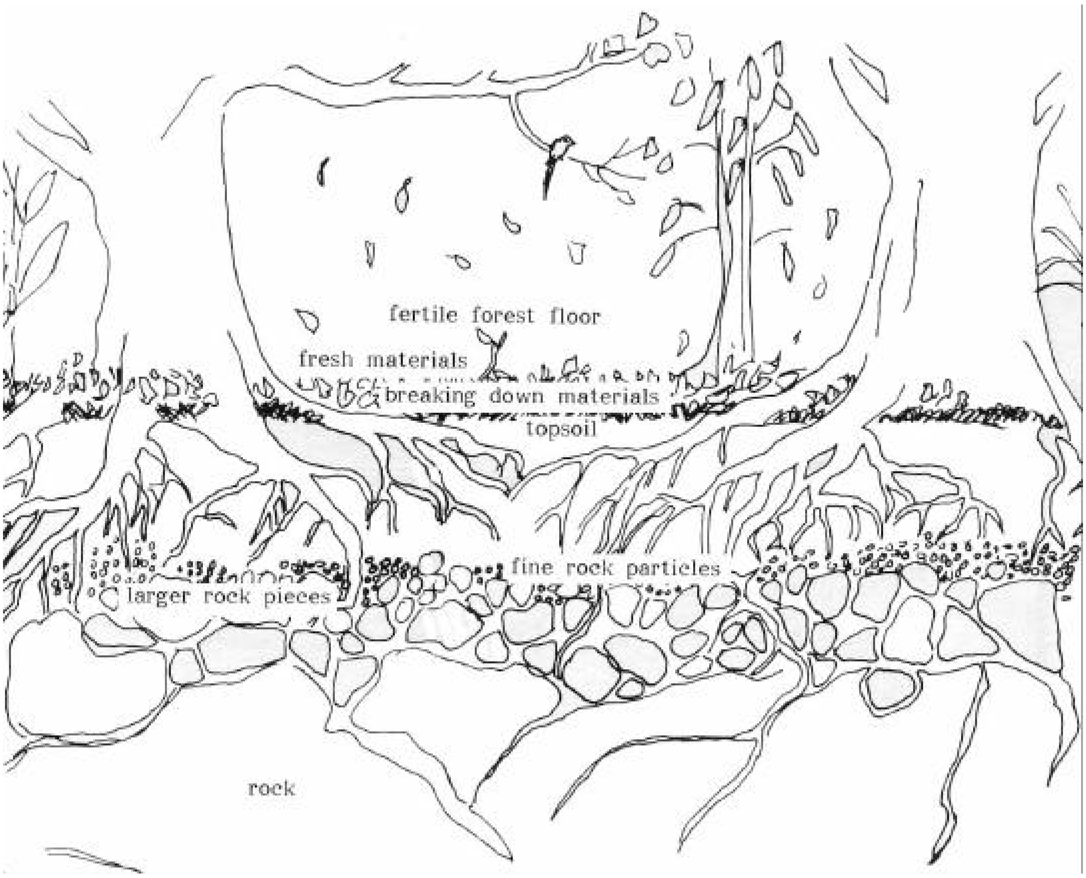


Figure 19 Rainforest nutrient recycling system.

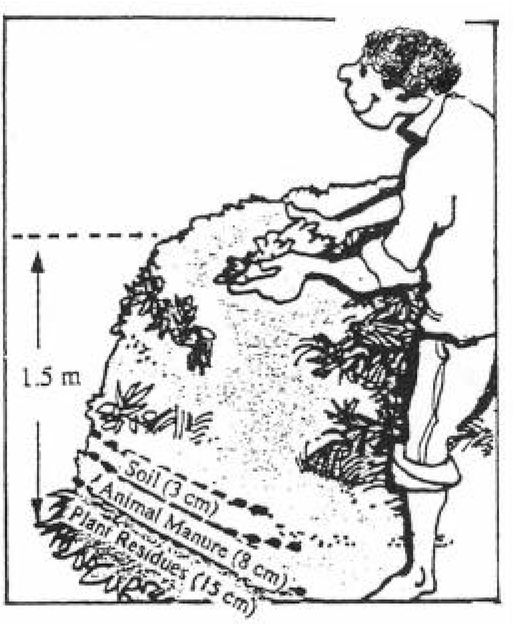
Much organic material is wasted

Every year throughout Papua New Guinea thousands of tonnes of compost material is lost by burning or just throwing away. The Lae City Council is making compost with the organic material that is collected around Lae everyday. They are using it for fertilizer on gardens. They are not wasting it. They know its great value

Composting methods

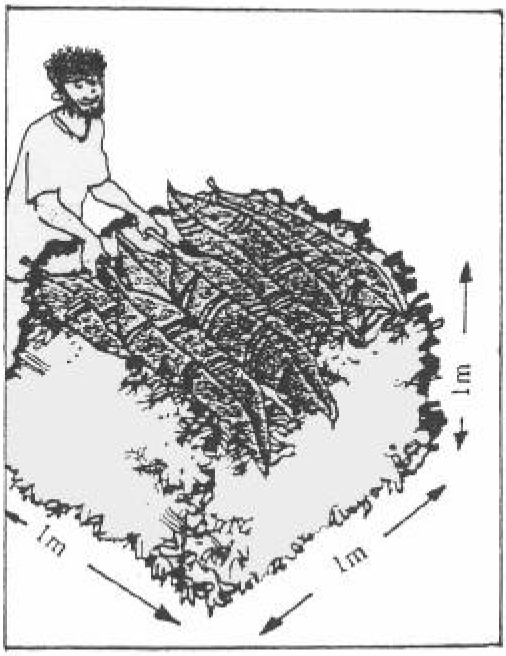
There are many different methods for making compost. On the following pages, five different methods are described and illustrated. You will be expected to be able to construct at least one method and demonstrate it in your college garden.

Conventional method of compost preparation



1. Choose a spot that is at least partially protected from rain.
2. Gather the crop wastes, animal manures and other wastes and bring them to the site.
3. Pile the crop and other plant wastes (15cm) thick first. For the next layer, spread the animal manure to a thickness of about 8cm, followed by about 3cm of good soil. Pile another layer of the materials in the same sequence and repeat until a height of about 1.5 meters of the compost heap is made.
4. Water the heap until it is quite moist. Water the heap regularly.
5. Turn over or mix the heap with a fork after three weeks, then again after five weeks.
6. Harvest the compost in three to four months.

The 14-day method of composting

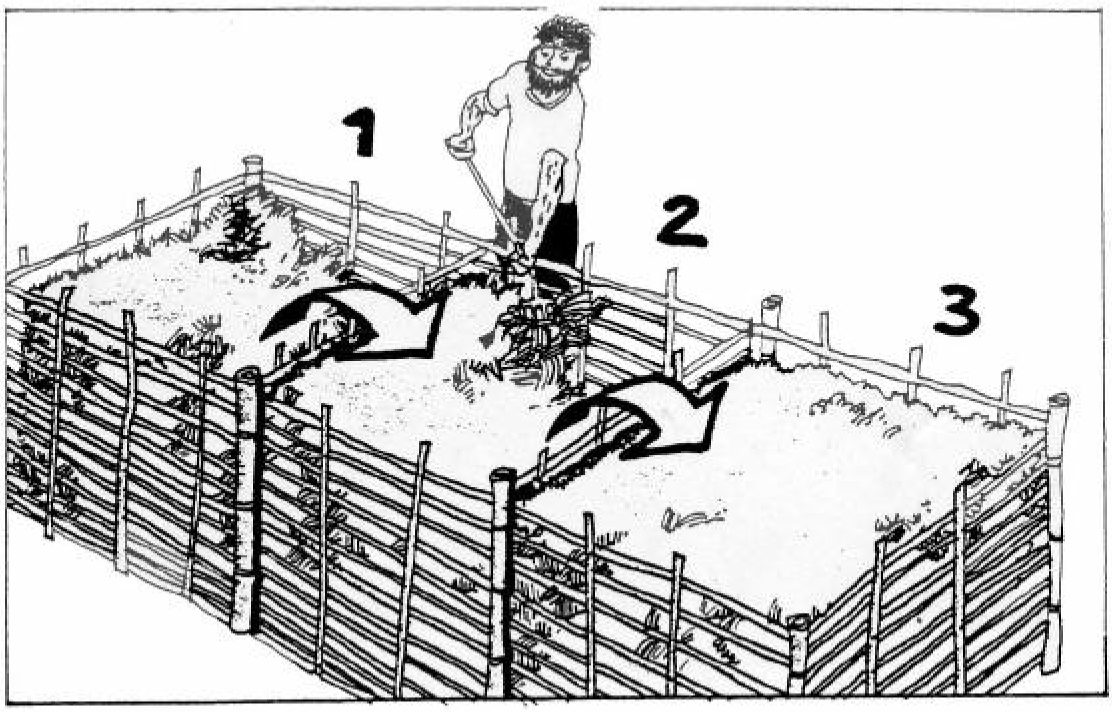


1. Chop the plant wastes (dry and green) into small pieces.
2. Thoroughly mix these with an equal amount of fresh manure.
3. Pile the mixture into a heap measuring at least 1m x 1m x 1m
4. Cover the heap with banana leaves or old coffee bags.
5. By the third or fourth day, the inside of the heap should be heated up. If not, mix more manure into it.
6. On the same day (3rd or 4th), turn the heap inside out.
7. Turn the heap every two days thereafter.
8. In 14-18 days, the compost should be ready for use.

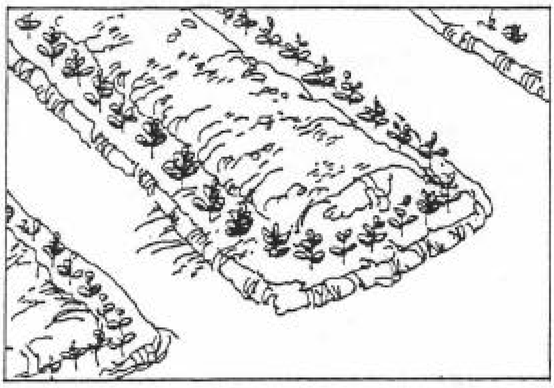
The Kiwi compost bin method

This method using three bins allows for continuous composting. Bin number 3 is ready for the garden while the others are still rotting.

1. Fill bin 1 with composting materials.
2. Add a small amount of soil or animal manure.
3. Continue in this way until the bin is full.
4. After about a month, empty the contents of bin 1 into bin 2, mixing, watering and breaking up the compost in the process. Remember the smaller the pieces the fast the compost will rot!
5. Cover the second bin with a layer of soil, which has to be kept humid and loose.
6. Once bin 1 is empty, the process of filling it should start.
7. After another month, fill bin 3 with the contents of bin 2.
8. Cover the third bin with a layer of soil.
9. Fill bin 2 with the contents of bin 1 and cover with a layer of soil.
10. Fill bin number 1 with composting materials and the cycle goes on.



Deep bed composting



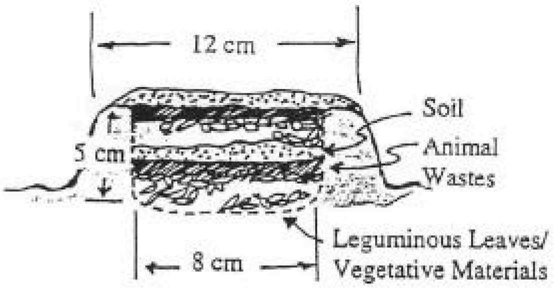


Figure 20: Deep bed composting.

Bed Construction

- Lay out garden beds at least 12cm wide.
- Dig a trench 8cm wide and 5cm deep along the centre line of the bed. Place the soil from the trench on both sides of the trench.

Addition of Organic Matter.

- Place a 15-20cm layer of leguminous leaves and other well chopped up plant matter.
- Spread a layer of animal manure over the plant matter.
- Cover with a layer of soil and shape the bed by raking.

Planting

- Soak the bed thoroughly with water.
- Plant seeds or transplant seedlings around the trench.
- After harvesting, remove the contents of the trench and work the compost into the soil around the trench. Place new compost materials in the trench for the next crop.

Figure 21: Covering and shaping.

Semi-sunken composting

1. Clean the selected area. Dig a hole 1 ½ meter deep.

Figure 22: Digging the hole.

2. Cut composting materials into small pieces. Mix them with manure at 5:1 ratio.

Figure 23: Cutting and mixing.

3. Place the mixture in the hole until it reaches one to two meters above the ground. Use a shove or your hands to keep the edges square.

Figure 24: Squaring the edges.

4. Cover the pile with dry grass, straw or smear it with mud to protect it. Add a layer of soil on top of the pile a make a series of holes on top of the finished pile. The compost should be ready in 1-2 months.

Figure 25: Covering and aerating.

Basket composting

A compost basket is suitable for any conditions.

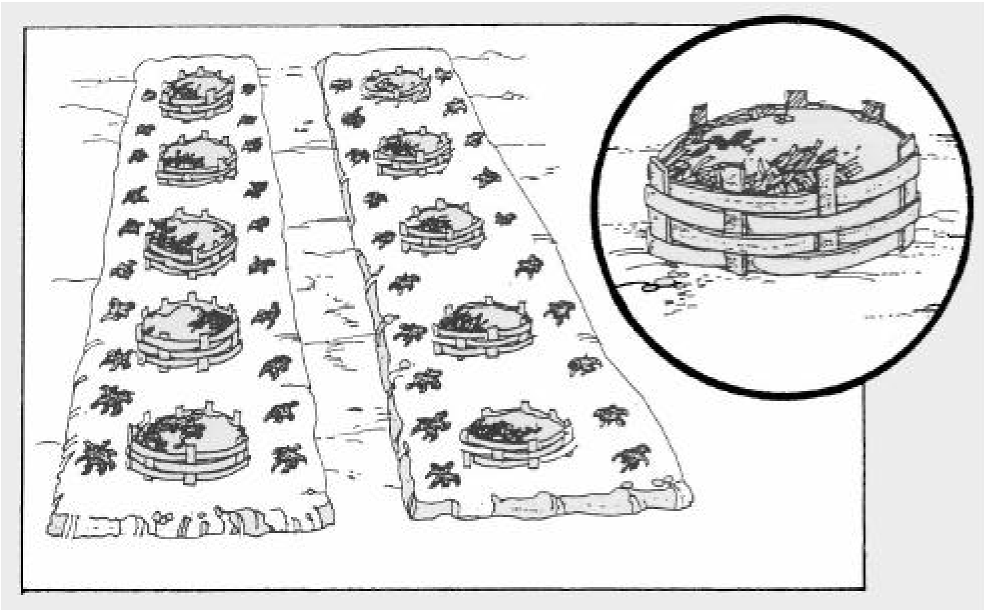


Figure 26: Basket composting.

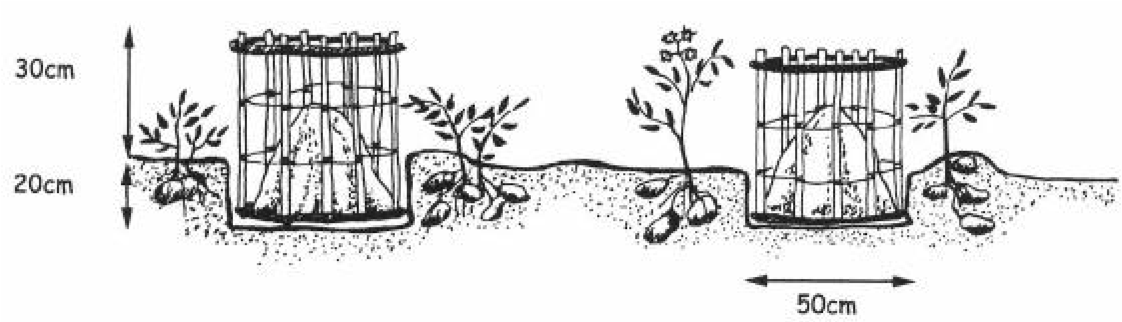
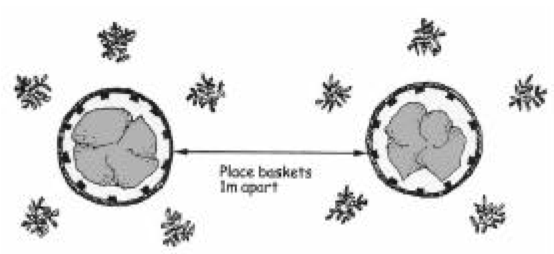


Figure 27: Size and spacing.



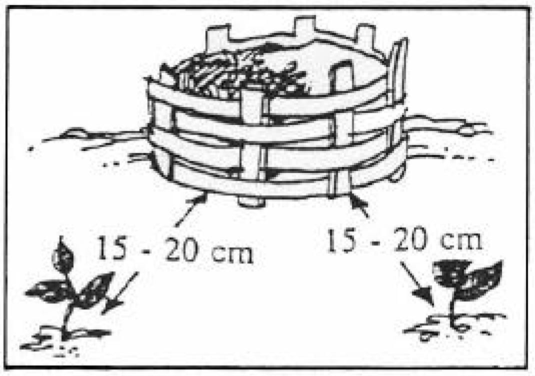


Figure 28: Bird's eye view.

Figure 29: Planting space.

☞ 1.1 Activity 8

1. *List at least five benefits of basket composting.*
2. *What locally available materials could you use to make the baskets?*
3. *Using the illustrations shown at Figures 26-29 write a teaching resource on how to set up basket composting for inclusion in your Teaching Portfolio for teaching Grades 6,7 or 8.*

   Include:

   Benefits

   Materials to use.

   Step by step guide with illustrations

   How to use and maintain?

☞ 1.1 Activity 9 - Practical activity

This is a practical activity in which you will be making a compost heap. Follow the following procedure and complete the activity questions. 1. Choose a compost method from this resource to construct.

2. Select a suitable site for making your compost heap

3. Follow the instructions for making the compost system.

Complete the following activities and questions before beginning to make your compost.

- Name the composition of the compost heap
- State how often you would turn your compost if appropriate.
- How you would know that the compost is ready for use?
- What are the common nutrients found in a compost heap?
- In your own words, describe the method of application of compost to plants.
- What is the pH of a well made compost heap?
- Describe the finished product of the composting process. Use all your senses.
- Learn the song ‘Wokim Kompos – write it out and include it in your portfolio.

Wokim Kompos

(can be sung in rounds)

Wokim kompos
Welpim gaden
Hipim pipia
Hipim pekpek
Karamapim gut tru
Grisim gaden tru
Apim kaikai tu

Mulching, manuring and green manure

Mulch is a mixture of dried grass, green cut leaves, coffee husks, sawdust or even stones placed around the growing plants to slow down the growth of unwanted weeds. Mulch is also used to cover new garden beds to retain moisture from evaporating into the atmosphere.

Mulch -an alternative to burning

Covering all bare soil with mulch prevents rain from washing away topsoil. It also buffers the soil from temperature extremes, controls weeds, and helps to retain moisture. Valuable micro-organisms necessary for soil health are also protected.

Other reasons for using mulch are:

- It protects the surface feeder roots by keeping the upper layer of the soil cool.
- Adds humus to the soil as the mulch decays.
- It protects the surface of the soil from rain and water damaged.

Figure 30: Garlic mulched with sawdust. Note the garlic is growing as an alley crop between rows of leucaena. Explain the significance of the alley cropping and mulch to the garlic.

If we mulch our school gardens well, the work of growing food will be much easier. Mulching is a simple method all children can learn, use in their family gardens and teach others. Planting a bean such as makuna before school holidays can provide excellent mulch and keep the weeds down while the children are away.

Figure 31: Lemon grass mulch.

☞ 1.1 Portfolio activity (5)

Make a series of lessons on mulching. Develop resources to accompany the lessons.

Aim the lessons at Grades 6-8.

*Remember, your lesson must involve practical activities in the school garden. Theory and classroom based teaching alone is **POINTLESS**!*

*Here is a song –'**Mulching Action Song**'. Try writing your own.*

This is the way we mulch the garden

Mulch the garden, mulch the garden

This is the way we mulch the garden

1. *So that the weeds can't grow*
2. *So that our soil stays wet*
3. *So that our crops grow well.*

Using animal manure

1. It helps in forming humus.
2. It helps to make the soil easier to work with.
3. It contains small amounts of three of the most important plant foods – nitrogen, phosphorus and potassium.

How to use animal manure

1. If there are only small amount of manure, use it in the compost heap.
2. If there is plenty of manure available, spread about 5 cm on the top of the soil and dig it in so the plant food in the manure will not be destroyed by sun or rain.
3. Collect the manure in a place where rain will not wash the plant food from it – usually a bush roof.

Liquid manure /fertiliser

Liquid fertiliser is made by immersing a sack of fresh animal manure or fish guts in a drum of water and allowing it to ferment. When used to water the plants, this "tea" makes possible the easy extraction of nutrients by plants. Depending on the availability of materials, animal manure can be substituted with fresh leaves of nitrogen-fixing trees like *Leucaena (landro)* or with green grass and or fresh weeds.

☞ 1.1 Activity 10

The diagram at Figure 32 shows the procedure for making liquid manure. Follow the sequence of drawings and check that you understand the process.

Copy the drawings and add instructions which can be followed by a Grade 6-8 class. The resource you produce should be used as a wall reference in your classroom.

Remember to list alternatives to animal manure if none is available.

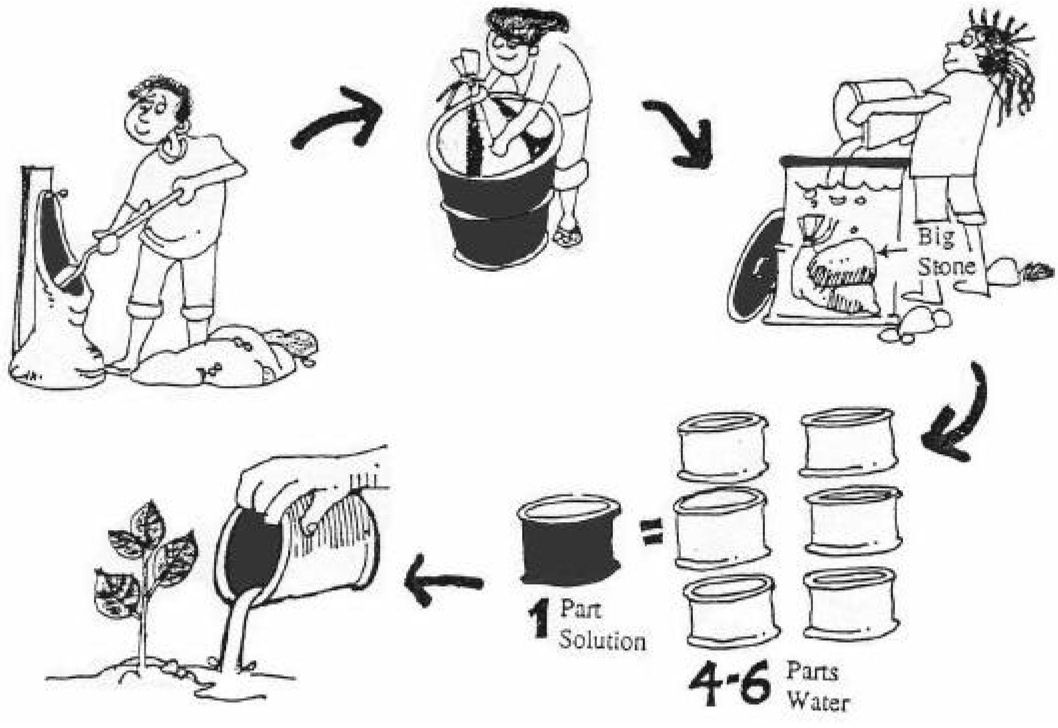


Figure 32: Liquid fertiliser.

Using green manure

This technique involves specifically planting a crop to cut or dig into the soil as high quality organic matter. Often gardeners do this in the winter. The green manure crop can be slashed two or three times while it is growing and then chopped into the soil before it flowers and seeds. This technique improves soil texture, as well as providing fertiliser.

Cover crops are very like green manure crops. They carry out the same functions (i.e. improve soil structure and texture); in addition they provide edible produce. Cover crops are especially good for hard, compacted soils. The root systems open up the soil to air and water and protects the surface from erosion and drying out. Pumpkins and kaukau are particularly good cover crops.

Figure 33: Green manure crop Flemingia grown as an alley crop for cocoa.

What plants are best to be used for green manure?

Green Manure crops are usually those, which belong to the bean or pea family for these plants help put more nitrogen into the soil than any other group of plants. Legumes are often the best green manure crops.

☞ 1.1 Activity 11 Questions on soil improvement

What is the importance of compost making in agriculture farming?

Why do farmers apply mulch? How?

How can we make sure that the green manure is ploughed / dug into the soil at the right time?

Soil improvement and maintenance

Trees are important for maintaining and enhancing soil nutrition. They are also a much undervalued food crop. Think of the different ways that you have seen trees used to protect and enrich the soil.

Planting trees

- Trees prevent the erosion of valuable top soil
- Trees keep the soil cool and moist
- Trees planted as wind breaks reduce wind damage and erosion
- Trees planted in kunai grasslands can transform the environment and restore soil fertility

☞ 1.1 Activity 12

Choose any one of the above statements/facts about trees as soil conditioners and expand it by explaining how and why.

e.g.

Tree fact	*How*	*Why*

Write to the one or all of the following institutions requesting specific information on species of trees suitable for planting in your area.

National Forest Research Institute PO Box 314, Lae. Fax: 472 4357	Regional Office (Highlands) PO Box 44, Goroka. Fax: 732 1106 /3806
Regional Office (Momase) Bulolo/Wau Forest Plantation PO Box 143 Bulolo. Fax: 474 5449	Regional Office (Islands) PO Box 172, Kavieng Fax: 984 2389

Fertilisers

The farmer adds nutrients to the crop in the form of fertilizers. Fertilizers are substances containing plant nutrients in high proportions.

They are of two types:

- Inorganic or artificial fertilizers
- Organic or natural fertilizers

Inorganic fertilizers

Inorganic fertilizers are either mined from underneath of the earth or chemically produced in factories. Some of these fertilizers are:

- Urea – containing the nutrient element nitrogen gas and carbon dioxide gas from the atmosphere
- Rock phosphates – used for making phosphate fertilizers (containing the nutrient element phosphorus) are mined from open pits
- Potash – containing the nutrient element potassium is mined from deep in the earth

The three nutrient elements which are commonly deficient in most crops are N, P, and K. Fertilizers containing these elements, mixed in various proportions, are sold commercially. These mixed fertilizers which are sometimes called compound fertilizers are labelled according to the proportions of the ingredients present in them.

A fertilizer mixture labelled 12-12-17 indicates that 100 kg of the mixture contains 12 Kg N, 12 kg P_2O_5, 17 kg K_2O. It is customary to indicate the percentages of the nutrients in the mixture in their oxide form. The percentages of the nutrient elements (P or K) in the mixture can be worked out using the following conversion.

$$\% P = 0.435 \times \% P_2O_5$$
$$\% K = 0.833 \times \% K_2O$$

The fertilizer mixture 12-12-17 has higher concentration of potassium than the other two nutrient elements. This mixture is used for crops having high requirements of potassium. A 24-10-8 mixture on the other hand contains higher concentration of nitrogen and this is used on crops requiring high levels of nitrogen.

Inorganic fertilizers are available in solid, liquid and gaseous forms. The liquid and gaseous forms require special equipment for storage and application and therefore are not commonly used in developing countries like Papua New Guinea.

Comparison of inorganic and organic fertilizers

Each of the two fertilizers has some merits over the other as shown below:

No.	Inorganic	Organic
1	Highly concentrated with respect to plant nutrients. Therefore, application of small quantities is sufficient.	Not highly concentrated with respect to plant nutrients. Large quantities are needed. Therefore, transport, storage and handling costs are high.
2	Available in stores in many areas.	May not be available to meet the requirement of large farms which require high quantities.
3	Contain only specific nutrients	Contain all nutrients
4	Immediately available to plants on application.	Only slowly available to plants.
5	Some fertilizers may create acidity and pollution problems in soils.	Generally no adverse effects
6	If applied more than the specified rates it may create toxicity.	No toxicity problems.
7	No significant effect on the physical condition of the soil.	Improve the physical condition of the soil (increase water holding capacity, improve soil structure, reduce erodibility of soil).

Note: That organic manure contains many nutrients other than N, P and K.

Rate, tome, method, frequency and form of fertilizer application

Rate
Time
Method
Frequency and
Form of application

depend on →

Crop
Soil
Climate and
Nature of fertilizers

Before application of fertilizer. The farmer should have information on the rate (amount of fertilizer per hectare), time, method and frequency (how many times) of application of the fertilizer to his crop. This information varies according to the type of crop, soil and climate of the area and can be obtained from the local Department of Agriculture and Livestock. Sandy soils with low organic matter content generally requires higher rate of fertilizer.

Fertility rich soil → Apply less fertilizer

Fertility poor soil → Apply more fertilizer or compost

More precise knowledge on the rate can be obtained by analyses of the soil for their nutrient contents and finding out how much of the plant available nutrients are already in the soil and how much more needs to be added. Fertilizers must be applied when the soil is wet after few rains so that they will dissolve in the soil moisture and make available the nutrients they contain to the plants. Fertilizers are normally split applied. The first dose is applied before planting and the other doses at different stages of the growth of the crop. The method of fertilizer application also varies depending on the soil, climate and the crop root system. Broadcasting and side dressing are common methods of application. After application, it is good to mix the fertilizer with the soil to reduce losses to atmosphere under adverse climatic conditions.

The macro-nutrients which the soil supplies are:

- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)
- Magnesium (Mg)
- Calcium (Ca)

The plants required these nutrients in large quantities.

The micro-nutrients which the soil supplies are:

- Sulphur (S)
- Manganese (Mn)
- Zinc (Zn)
- Copper (Cu)
- Molybdenum (MO)

The plants need these nutrients in much smaller quantities.

The functions of nutrients in plants are:

CHO – These three nutrients are usually components of carbohydrates, fats and cell walls.

Nutrient	Sign of deficiency	How lost	What to do
Nitrogen			
Potassium			
Zinc			

☞ 1.1 Activity 13

Questions on the use of fertiliser

- *How would you recognize nitrogen deficiency on a corn plant?*
- *How would you distinguish potassium deficiency from deficiency on the field?*

State one function of each of the following nutrients:

- *Iron*
- *Chlorine*
- *Boron*
- *Copper*

Glossary

Acid	Sour soil usually has a pH of 4.0-6.0. Potatoes and peanuts prefer acidic soils
Alkaline	A substance like ash which is capable of neutralising acidic soils. Usually has a pH range from 7.0-7.5
Aerated static pile	Composting system that uses a series of perforated pipes as an air distribution system running under the compost pile and connected to a blower. The pile is not turned.
Aeration	Bringing about the contact of the compost with air through turning, or ventilating to allow microbial aerobic metabolism.
Aerobic	Occurring in the presence of oxygen. For successful composting, sufficient oxygen should be provided to keep the system aerobic. This ensures that the composting proceeds rapidly and with minimal odour.
Ambient temperature	Temperature outside the compost pile.
Anaerobic	Occurring in the absence of oxygen. Anaerobic composting proceeds slowly and is odiferous.
Biodegradability	The potential of an organic substance to be broken down into simpler compounds or molecules through the action of micro-organisms.
Bulking agent	Material, such as wood chips, added to compost primarily to help create good pore structure for airflow. Often provides part of carbon source as well.
Bulk density	The mass of a unit volume of soil, generally expressed in gm/cm^3. The volume includes both solids and pores. Thus, soils that are light and porous will have low bulk densities, while heavy or compact soils will have high bulk densities.
Cellulose	The main material making up the cell walls or fibres of all plants.
Contaminant	Unwanted material. Physical contaminants of compost include glass, plastic, and stones, and chemical contaminants include trace heavy metals and toxic compounds.
Curing	The last stage of composting that occurs after much of the readily metabolised material has been decomposed. Provides for additional stabilization and reduction of pathogens and allows further decomposition of cellulose and lignin.
Decomposition	The breakdown of organic matter through microbial action.
Erosion	The process of loosing soil through wind and rain.
Friable	Easily crumbled into small pieces
Granular	Consisting of small particles or grains.
Green manure	A plant crop (legume) grown specifically to enrich the soil
Heavy metals, trace	Trace elements whose concentrations are regulated

metals	because of the potential for toxicity to humans, animals, or plants. Examples include chromium, copper, nickel, cadmium, lead, mercury, and zinc.
Humus	A complex aggregate made during the decomposition of plant and animal residues; mainly derivatives of lignin, proteins, and cellulose combined with inorganic soil parts.
Igneous rocks	Formed by volcanic action
Inorganic	Substances in which carbon-to-carbon bonds are absent. Mineral matter.
Leachate	Liquid that drains from the mix of fresh organic matter.
Lignin	A hard substance embedded in the cellulose of plant cell walls that provides support.
Loam	A rich soil of clay, sand and organic matter
Macro-organism	Large organisms which live in the soil. E.g. worms and beetles
Mature compost	The stabilized and sanitized product of composting; it has undergone decomposition and is in the process of stabilization. It is characterized as containing readily available forms of plant nutrients; it is low in phytotoxic acids.
Metabolism	Exchange of matter and energy between an organism and its environment and the transformation of this matter and energy within the organism.
Metamorphic	Rocks changed in structure under pressure or heat
Micro-organism	Tiny organisms that inhabit the soil. E.g. bacteria.
Mineral	An inorganic substance occurring naturally in the earth. E.g. copper, iron, sulphur,..
Moisture content	Weight of water in material divided by weight of solids in material.
Mulch	Substances spread on the ground to protect the roots of plants from extreme temperatures and moisture changes. Mulch may be manure, sawdust, leaves and grass, peat moss and even stones.
Organic	All compounds whose molecules contain carbon with a few exceptions such as carbon dioxide.
Pathogen	An organism including viruses, bacteria, fungi and protozoa capable of producing an infection or disease in a susceptible host.
Permeability	A measure of the rate at which water can percolate through soil.
Phenol	A caustic, poisonous acidic compound present in coal tar and wood tar; a hydroxyl derivative of aromatic hydrocarbons.
pH	The symbol for the degree of acidity or alkalinity
Porous	Full of pores (tiny holes) which fluids, air or light may pass.
Sedimentary rocks	Material carried by wind or water that deposited on the land and that one day may become consolidated as rock. E.g. limestone.

Soil ions	The atoms of the soil – electrically attracted
Soil texture	The feel and appearance of the soil
Source separation	The practice of separating waste generated within each household or commercial operation into separate fractions such as newspapers, glass etc., and placing them in separate containers for recycling, composting, and disposal.
Stability	The degree to which the composted material can be stored or used without giving rise to nuisances, or can be applied to the soil without causing problems due to incomplete degradation of readily biodegradable materials.
Sub soil	Soil lying immediately under the top soil
Tilling	Working the soil. E.g. ploughing
Tome	A section or segment
Top soil	The thin layer of surface soil up which life on the earth depends
Toxins	Substances that cause a reduction of viability or functionality in living things.
Trace element	A chemical element required in only tiny amounts by living organisms for normal growth.
Windrow system	Composting mixture is placed in elongated piles called windrows. These windrows are aerated naturally through the chimney effect, or by

Appendix 1

Ideas for Student Research Projects and teaching activities with Grades 6-8

Compost ingredients

- Garden supply stores and catalogues often sell compost "starters," which supposedly speed up the composting process. Develop a recipe for a compost starter and design a research project to test its effect on the compost temperature profile.
- How well do human nutrition concepts apply to compost micro-organisms? For example, will the microbes get a "sugar high," demonstrated by a quick, high temperature peak when fed sugary foods, compared with a longer but lower peak for more complex carbohydrates?
- Measure the pH of a number of different compost mixes. How does the pH of initial ingredients affect the pH of finished compost?
- Some instructions call for adding lime to increase the pH when compost ingredients are mixed. Other instructions caution to avoid this because it causes a loss of nitrogen. How does adding various amounts of lime to the initial ingredients affect the pH of finished compost?

Compost physics

- When constructing compost bins or piles, some people incorporate perforated pipe, wire mesh, or other systems to increase passive air flow. What is the effect of different methods of aeration on the temperature profile of any one compost system?
- How do various means and schedules for turning a pile affect the temperature profile and the time needed for production of finished compost?
- What is the effect of layering versus mixing organic ingredients on the compost pile temperature profile?

Worm composting

- Do organic wastes in compost break down more readily in the presence of worms than through composting that depends solely on microbial decomposition?
- In some experiments, plants have not show increased growth when planted in fresh worm castings. Does aging or "curing" worm castings increase their ability to enhance plant growth? Are there chemical differences between fresh and older worm castings? Should worm compost be mixed with soil before being used to grow plants?

Effects of compost on plant growth

- Some leaves, such as those of pine needles or eucalyptus trees, contain chemicals that inhibit growth of other plants. Are these compounds broken down by composting?
- Finished compost is near neutral pH. Can you design an experiment to answer one or more of the following questions: Is compost detrimental to use on acid-loving plants such as coffee, marigold or peanuts? Does compost buffer the soil pH, making it harder to provide acidic conditions? How does it compare to peat moss in this regard?
- Water in which compost has been soaked (often called compost tea) is said to be beneficial to plants. Can you design experiments to test whether different types, concentrations, and amounts of compost tea enhance plant growth?

In China, farmers dig parallel trenches and fill them with organic wastes mixed with cocoons of Eisenia fetida (red worms). Soybeans planted in rows between the trenches are highly productive. Can you design and test a planting system using a similar system?