WWF Intensive homestead food production learning manual: March 2021

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1 WATER AND SOIL CONSERVATION PRACTICES FOR SMALLHOLDER FARMERS.

1.1 WATER HARVESTING AND CONSERVATION CASE STUDY

The practice of *rainwater harvesting* for domestic use and crop production supported early civilisations some 3000 years ago. Today, rainwater harvesting remains a highly productive and sustainable practice which is widely used by small producers and commercial farmers alike.

What follows is a description of the well-known case of Mr Phiri Maseko, a Zimbabwean *farmer* whose 3 ha *farm* is an excellent example of rainwater harvesting and water *conservation.*

Poor soil conservation practices and deforestation in the upland areas of Zimbabwe have led to massive soil erosion and land degradation. The result is that in a country where 70% of the population relies on agriculture for a living, only 20% of the land can be used for this purpose. Many farms have become unproductive, and those which are marginally productive cannot survive recurring drought. As a result, many farmers have abandoned their farms, while others have been forced into subsistence farming.[1]

The V*ishavane District in the Midlands Province of Zimbabwe is a particularly dry area with frequent droughts, and the farmers who live here struggle with fragile soils and erratic rainfall. However, on one farm in this region, a three-hectare rural homestead located in a hilly area outside the small town of Zvishavane, crops grow quickly and bountifully. Here, enough food is produced to support a family of 15 and to raise money for other living expenses. This is the farm of Zepheniah "Phiri" Maseko, a farmer who views natural resources such as soil and water as precious gifts to be respected and protected, and whose innovations in soil and water conservation have drawn international attention and acclaim.*

Figure 1.1 A view from the top of the Maseko farm

When Phiri first began farming he found it very difficult to grow crops successfully, as he had few material resources and there were often periods of drought. He decided to pay close attention to what happened when it did rain, and through careful observation he learned how the water flowed over and into the land. Phiri then began to experiment with ways of capturing the water in the soil so that it could provide nourishment for his crops and trees.

The Maseko Farm:

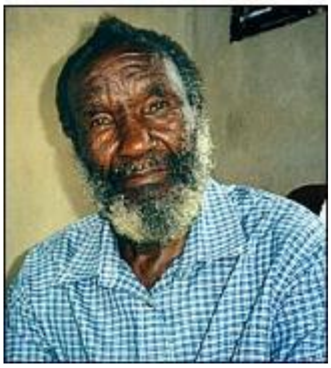


Figure 1.2 Mr Phiri Maseko

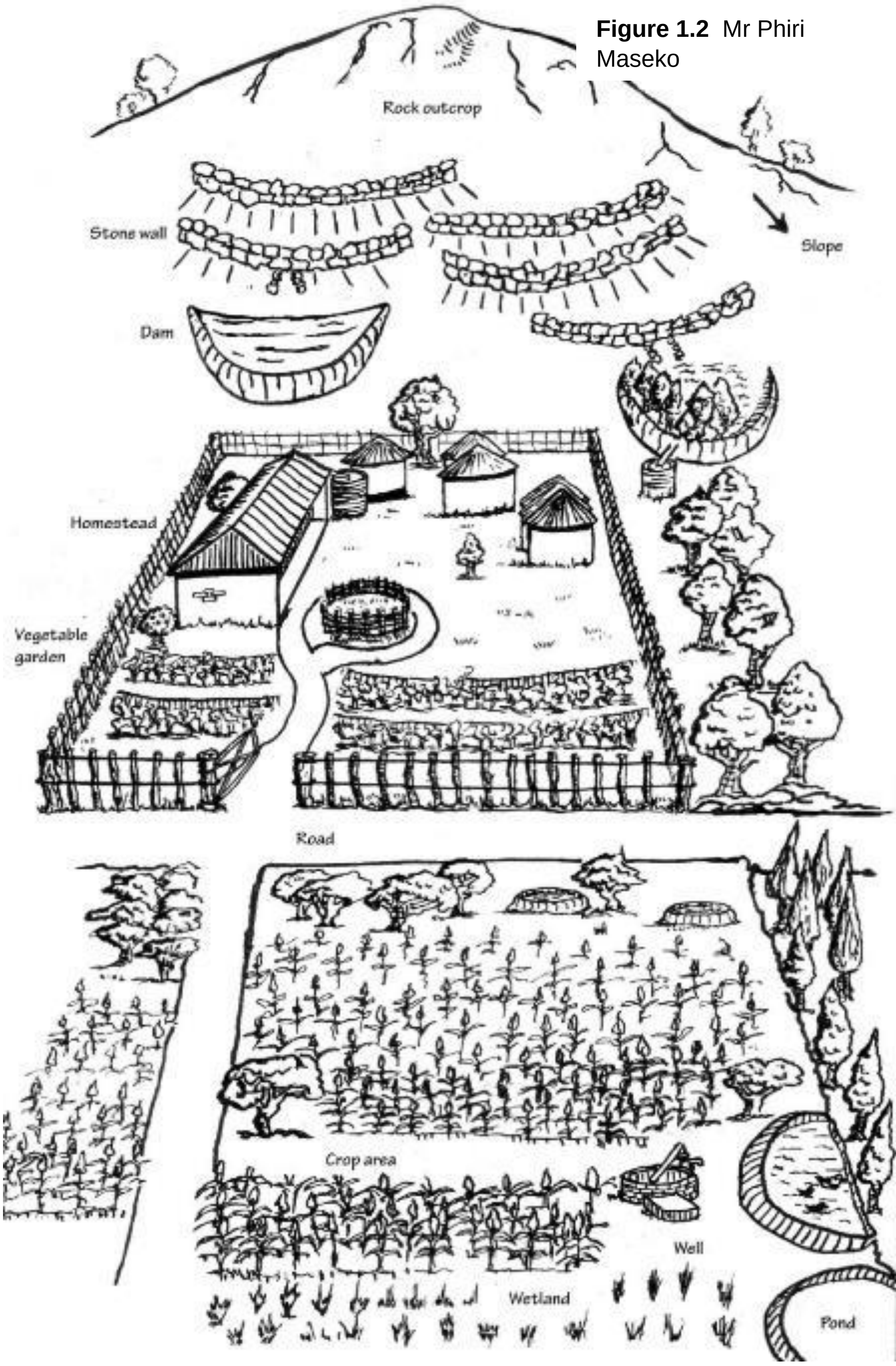


Figure 1.3 The Maseko family homestead

Phiri's plot is situated on the slope of a hill which faces north-northeast, providing good winter sun. At the top of the hill is a large rock outcrop (a granite dome). This rock outcrop posed the first challenge for Phiri. He observed that when heavy rains fell, the rock caused water to run down the hill in channels, taking soil with it and causing severe erosion. Phiri also noticed that although in this situation very little water was able to infiltrate the soil, the soil remained moist for longer in areas just above rocks and plants and in small depressions.

Based on these observations, Phiri decided to try and control the flow of storm water off the rock. He built some low stone walls at random intervals along contours below the rock outcrop. The walls slow down and spread out the flow of storm water. Patches of indigenous vegetation which grow along the walls also slow the water down and draw it into the soil.

Below the stone walls Phiri then dug two dams, into which the water could be directed. Phiri calls the larger of the dams his "immigration center". "It is here that I welcome the water to my farm and then direct it to where it will live in the soil," he says.[3] *Water in this dam seeps into the ground over a period of time, replenishing the store of water under the ground. The dam has also become a water gauge for Phiri, who has learned that if it fills up three times in a season, enough rainwater will have seeped into the ground to see his farm through two years of drought*.

Water overflow from the smaller dam is directed by pipe into a storage tank. This water is used to water the homestead garden, where Phiri and his family grow an unusually wide variety of fruit and vegetables such as pumpkins, beans, cabbage, tomatoes, garlic, peas, onions, carrots, chillies, guavas, oranges, naartjies, lemons, paw-paws, peaches and mangos.

Phiri also built a concrete tank next to the main house. When it rains, water runs down the roof and along gutters into the tank, where it is stored for drinking and household use. A granadilla creeper was trained to grow up and over the tank to keep the water cool. All of the water which the family uses for washing (called greywater) is drained into an unsealed underground tank, where it quickly seeps into the ground.

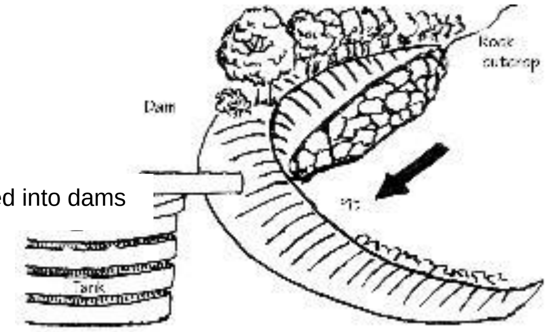
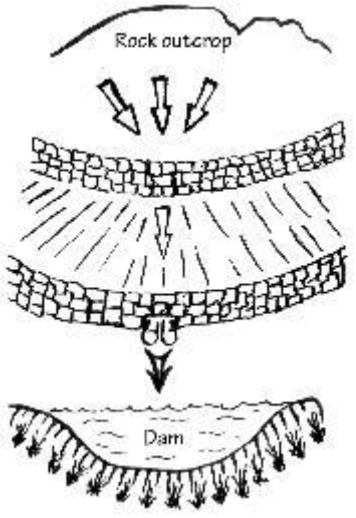


Figure 1.5 Water overflow is directed into a storage tank

cted into dams

Between the family homestead and the crop area is a dirt road. To control the water runoff from the road, Phiri dug large pits (4m long, 2m wide and 1m deep) at regular intervals just above the fields and planted indigenous vegetation around them. When it rains the pits fill with water, which seeps into the soil slowly, feeding the plants and replenishing the water table. The vegetation stabilises the pits and prevents them from collapsing.



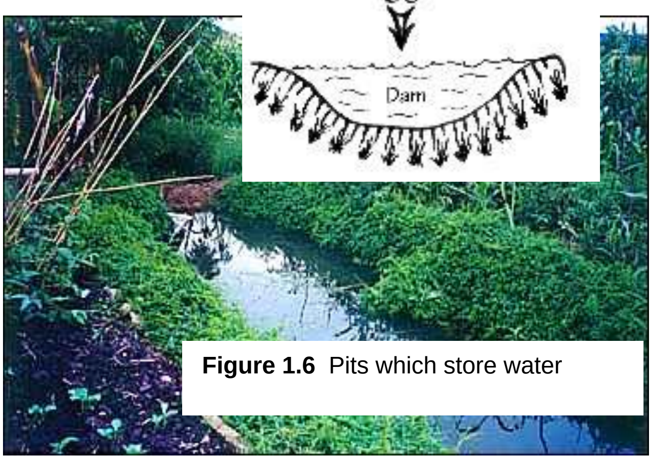


Figure 1.6 Pits which store water

The family grows many different crops in their fields, including maize, sorghum, beans, pumpkins, millet, watermelon, nuts, cassava, peas and sweet potatoes. This diversity gives the family food security because if some crops fail, others will survive. Their crop diversity also reduces the likelihood of pest attack and prevents the soil from losing its nutrients.[4] *Phiri also built three wells in the cropping area. One of these is carefully protected so that the water can be used for drinking. The other two are used for irrigation and for washing clothes. A network of pipes and canals has also been constructed so that crops can be watered during times of drought.*

At the lowest point of the farm lies a natural wetland, an area of land where the soil is saturated with water. Here, Phiri dug two ponds. The larger pond is stocked with fish which are caught for food, while the smaller pond catches water overflow from the larger one. Phiri planted reeds, bananas, kikuyu and elephant grass, and sugarcane around the banks to hold the soil in place. Water from the main pond can also be pumped out and used to water the crops.

As well as observing the ways in which water moves, Phiri also paid close attention to rainfall patterns and has experimented with numerous other water-harvesting methods over the years. Phiri uses the soil *as his "catchment tank" so all of his methods are designed to help water sink into the soil as quickly as possible.*

Through observation, inspiration, innovation and dedication, Phiri Maseko changed the landscape not only of his farm, but also of his life. In 1986 he founded the Zvishavane Water Project, a Non-Government Organisation (NGO) which was established to educate people about water harvesting and conservation and to promote sustainable farming. Phiri spreads his knowledge and skills freely and tirelessly to anybody who is interested in learning about water harvesting and conservation. Since 1997 more than a thousand people from outside the region have visited the Maseko farm, and "…local visitors are so frequent and numerous that he (Phiri) has ceased to count them."[5] In 2006, Phiri Maseko was presented with the prestigious National Geographic Society/Buffett Award for Leadership in Conservation, to acknowledge his outstanding work and lifetime contribution to further the understanding and practice of conservation in his country.[6]

There are many different ways to conserve water by protecting and managing it efficiently. In situations where water is used for irrigation, conservation involves getting as much water as possible to infiltrate the soil so that the amount of water lost to evaporation or runoff (water which runs over the ground) is minimised. One method of achieving this is to cover the soil with a mulch such as a crop residue, which increases water *infiltration* and reduces evaporation.

Other examples of water conservation practices include recycling and re-using water (e.g. using bath water to water vegetables); irrigating crops in sensible ways (e.g. watering less often but more thoroughly, and not watering during the heat of the day); eliminating water leaks (e.g. fixing leaking taps and pipes); and growing indigenous plants which are suited to the local climate and environment.

Figure 1.7 Members of the Phiri homest maize crop

Based on the above definitions, as well as the practices of people such as Phiri Maseko who harvest and conserve water, we can say that water harvesting and conservation involves:

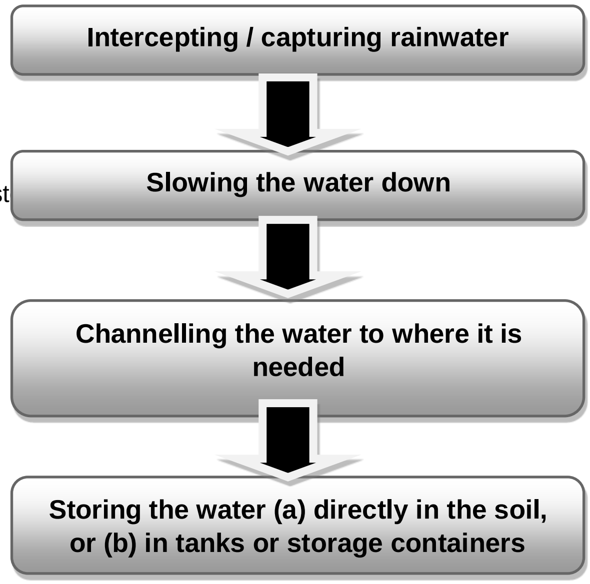


Figure 1.8 The water harvesting and conservation process

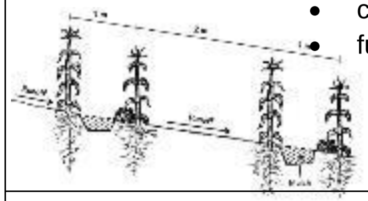
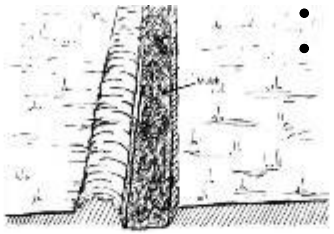
1.2 OVERVIEW OF WHC METHODS

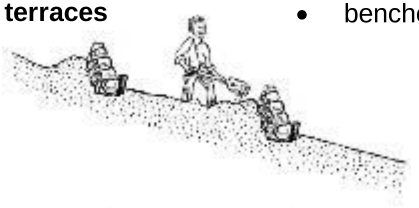
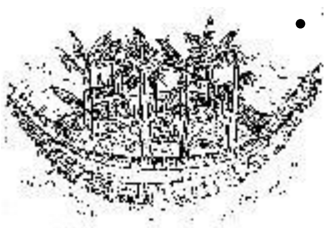
There are many different forms of water harvesting and conservation. The methods selected for this manual are summarised in below, along with a short description of what each method entails. Many of these methods can be used together and complement each other well. In this manual, the methods that have been grouped together have differences too small to detail. Alternate names have been listed. There are also some important and useful methods noted at the end of the table. These methods, many of which are commonly known like small earth dams, may be needed and suitable to some situations, but design and construction are somewhat technical. Water conservation measures and water storage structures are usually identified separately from water harvesting, although these are used as part of water harvesting systems.

Type	Water flow when raining	Collection area relative to growing area

Micro-catchment:	Sheet flow of water.	10 x growing area
Macro-catchment:	Channel flow of water	100 x growing area
Floodwater harvesting:	Flood events	up to 10,000 x growing area

Name Used in Manual	Similar to :	Description	Main purpose or comment	Type of Water Harvesting System
diversion furrows 	• run-on ditches • run-on RWH • ex-field RWH • feeder channels • diversion trenches	A ***diversion furrow*** directs rainwater runoff from gullies, grasslands or hard surfaces (such as paths or roads) to a cropped area or to a storage tank. This increases the water available to the plant.	• used for fieldcrops and in gardens • additional water diverted directly to soils and crops • additional water stored in underground tanks for later watering	Macro-system (collects water from an external catchment and brings it to the field).
trench-beds 	• deep trenching • fertility trenches	***Trench beds*** are 1m wide and 2 m long. They are dug to 1m deep then packed with dry grass/leaves, compost, manure and soil.	• used in food-gardens • create highly fertile soils which can absorb and store water. • provide an immediately usable planting bed even on shallow or poor soils. • often used with diversion furrows and mulching.	A micro-system when used alone. But these are usually connected to diversion furrows which collect water from an adjacent area and feed the trenches.
mulching 	• no other names	**Mulching** is the practice of spreading organic material like compost, straw, manure, dry leaves, grass clippings or wood chips onto the surface of the soil. It is usually concentrated around the plant.	• can be used on all crops and orchards, not pastures. • improves plant growth • reduces evaporation from the soil surface • improves soil temperature • limits weed growth and makes watering easier by protecting soil.	Water conservation method

Name Used in Manual	Similar to :	Description	Main purpose or comment	Type of Water Harvesting System
stone bunds 	• stone lines • stone banks • contour stone bunds	***Stone bunds*** are rows of tightly packed stones built along contour lines	• used to improve grazing land • slow down, filter and spread out runoff water • increase infiltration and reduce soil erosion. • sediment is slowly captured on the upper sides and they form natural terraces.	Macro-system: The contour ridges collect water from adjacent slopes.
tied ridges 	• in-field RWH • partitioned furrows[15] • cross-ridges • furrow dikes[16]	***Earth ridges*** are built along the contour at 3m spacing. Crops are planted on either side of the ridge. Rainfall from the unplanted sloping basin is caught in the furrow and ridge. Basins are created along the contour to further pond runoff using crossties – mounds of soil spaced along the base of the contour.	• Used in home-gardens, smallholder fields and when mechanised, at a large commercial scale. • the system has been fine-tuned to South African conditions and is called “in-field RWH” in local publications.	Micro-system when used without other methods. Can be used with diversion furrows and mulching.
swales 	• bunds • contour ridges • berm ‘n basin • contour ditches	A ***swale*** is an earth bank constructed along the contour with a furrow on the up-slope side – this is filled with dry leaves, compost and soil. The top of the earth bank is levelled off to allow planting. The swale intercepts runoff, spreads it out and helps it infiltrate deep into the ground.	• Used in home-gardens and smallholder fields. • widely used within permaculture systems. • good groundwater recharge	Micro-system, but like the above, often used with diversion furrows and mulching.

Name Used in Manual	Similar to :	Description	Main purpose or comment	Type of Water Harvesting System
terraces 	• benches	A ***terrace*** is a level strip of soil built along the contour of a slope and supported by an earth or stone bund, or rows of old tyres filled with soil. Terraces create flat planting areas and stabilize slopes which would otherwise be too steep for crop production.	• Used in home-gardens and smallholder fields. • mainly in steeper sloping areas, for cropping and orchards.	Micro-system used on steeper slopes. Diversion furrows not used to augment water – erosion risk on steeper slopes. Mulching can be used.
fertility pit 	• banana circles • circular swale • Katumani pitting	***Fertility pits*** enable runoff water to be captured and conserved in 1m deep pits that are filled with organic matter such as compost or manure. The organic matter increases the fertility of the soil and minimises the loss of water from evaporation.	• Used in home-gardens and smallholder fields. • often planted with wet-loving bananas / paw paws • often used in conjunction with greywater.	Micro-system which lends itself as a soak away around buildings – including greywater. Katumani pitting is a variation where multiple fertility pits are tightly packed across a field.
greywater harvesting	• recycling • re-use	**Greywater** harvesting is the practice of using non-toilet wastewater produced in a household – to water the root zone of the soil. Examples include tower gardens nad keyhole beds	• home-gardens • greywater includes the water used for bathing, washing, cleaning, cooking and rinsing.	Water conservation method
roofwater harvesting 		Collecting water from **roofs** for household and garden use is widely practiced across South Africa. Tanks and containers of all types – from brick reservoirs to makeshift drums and buckets – are a common sight in urban and rural areas.	• mainly used for domestic supply • surplus used in home-gardens • more greywater available	Macro-system – because it is a large collection area to storage.

1.3 Catchments

A ***water catchment*** is an elevated area of land from which water drains to a particular endpoint. Each catchment is separated topographically from adjoining catchments by geographical barriers such as ridges, hills or mountains; these barriers are called ***watersheds***. A ridge along a mountain, for example, creates two catchments, each of which faces a different direction. Elevated catchments drain into lower catchments, so a large catchment will include many smaller catchments at lower ***elevations***.

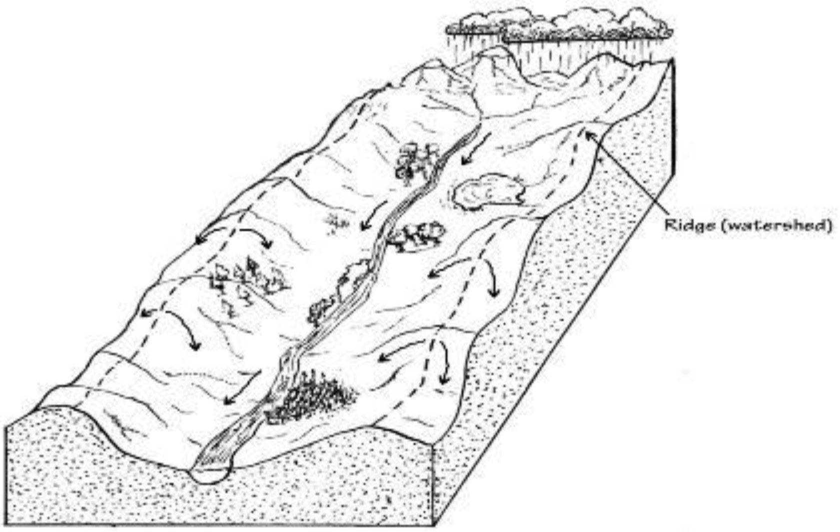


Figure A water catchment

No matter where you are, the ground on which you stand forms part of a water catchment. The figure below, for example, shows an urban water catchment. The crosses show the high and low points of the plot, while the arrows indicate the run-off water.

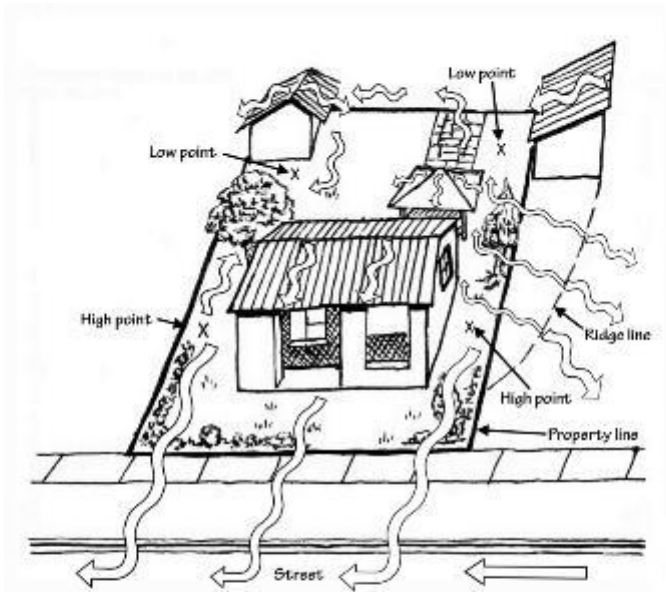


Figure An urban water catchment

1.4 Topography – Aspect and slope

1. *Aspect*

The direction which a site or slope faces is called its *aspect*, and aspect is important to consider when planning a vegetable garden. Plants need to receive at least 5 hours of *sunlight* a day, so it is important to choose a site where plants will get maximum sunshine all day long. Beds which lie in an east-west direction will get the full benefit of both the morning and the afternoon sun.

The following method can be used to determine the aspect of a site:

Point with your right hand to where the sun rises (east), and with your left hand to where it sets (west). When standing in this position, you will be facing north, and south will be directly behind you. Once you know where north is, you can determine the direction that the site faces.

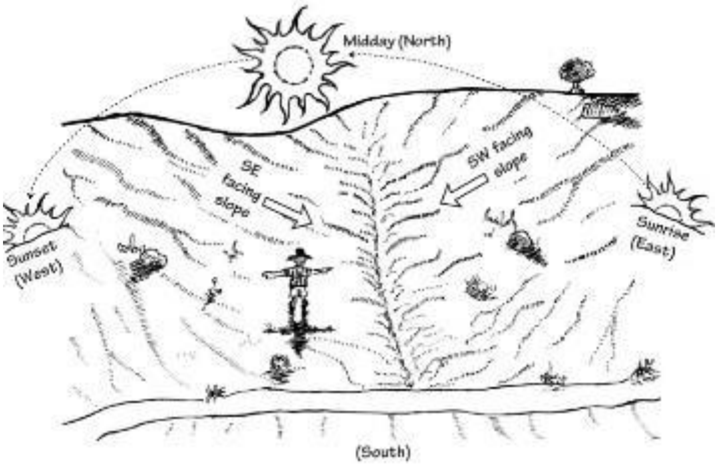


Figure 6.1 How to determine aspect (Method 1)

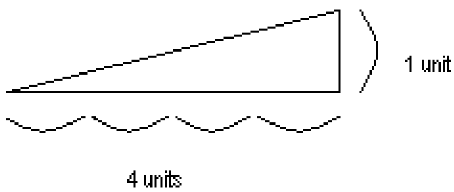
2. *Slope*

The slope of the land is the angle it forms with the plane of the horizon. Slope is important to take into account when planning a vegetable garden as flat sites are are easy to work on and soil erosion and water loss is minimised. Care should be taken, however, on flat sites with clayey soils as waterlogging may become a problem.

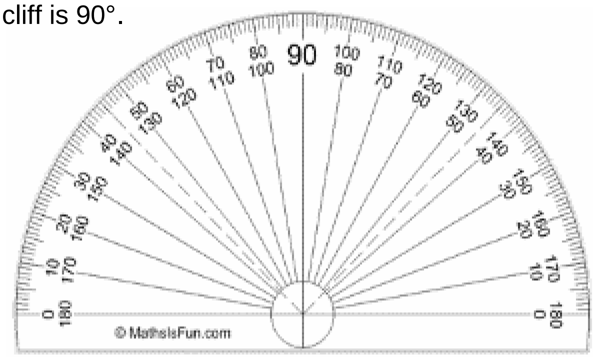
Slope also needs to be taken into account when planning and implementing most WHC methods, mainly to ensure that soil erosion does not occur.

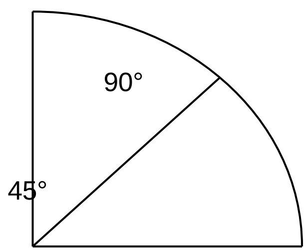
Slope can be expressed in the following three ways:

Proportion – this is the ratio of a slope's horizontal distance to its vertical distance.[1] For example, a 1:4 slope rises a vertical distance of one unit for every four units it extends horizontally.



Degrees – this is a measurement used to represent the angle of a slope. Degrees can be measured with a protractor or with survey instruments. Land that is completely flat (horizontal) is 0°, while a vertical cliff is 90°.

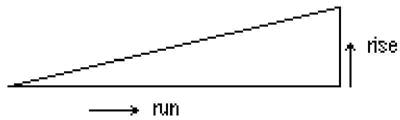




0°

Percentage – the percentage of a slope can be calculated using the following formula:

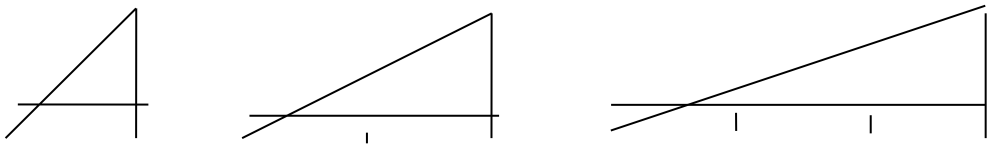
$$\text{Slope (\%)} = \frac{\text{rise}}{\text{run}} \times 100$$



Example: A slope of 1:4, where one unit equals 10 metres, has a rise of ten metres and a run of forty metres. The percentage of the slope (S) can thus be calculated as follows:

$$S(\%) = \frac{10}{40} \times 100 = 25\%$$

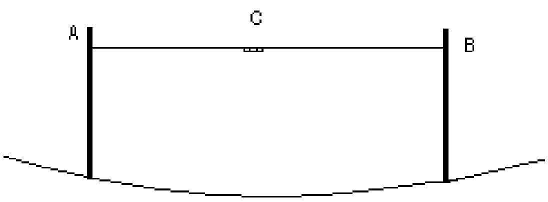
The following slopes are expressed in proportion, degrees and by percentage.[2]



1:1 = 45° = 100% 1:2 = 26° = 50% 1:3 = 18° = 33.3%

Marking out contour lines on a slope using a line level

Three people are needed to mark out contour lines on a slope using a line level (person A, person B and person C).



(Not to scale)

1, Start at the edge of the field. Person A holds their pole in a vertical position and stands still, while person B moves up and/or down the slope until the line level, which is read by person C, gives a level reading. Points A and B are then marked with pegs.

2. Person A then moves to point B, and person B moves further down the field and the process is repeated.

3. Note that when marking out contours using a line level, it is important that both poles are held vertically, and that neither pole is placed in a depression or on top of a minor high spot such as a rock or clump of soil.

Measuring slope using a line level

A line level is another levelling device which is also inexpensive and easy to make by hand (refer to Section 6 for information on how to construct a line level). Three people are needed to measure the percentage of a slope using a line level (person A, person B and person C).

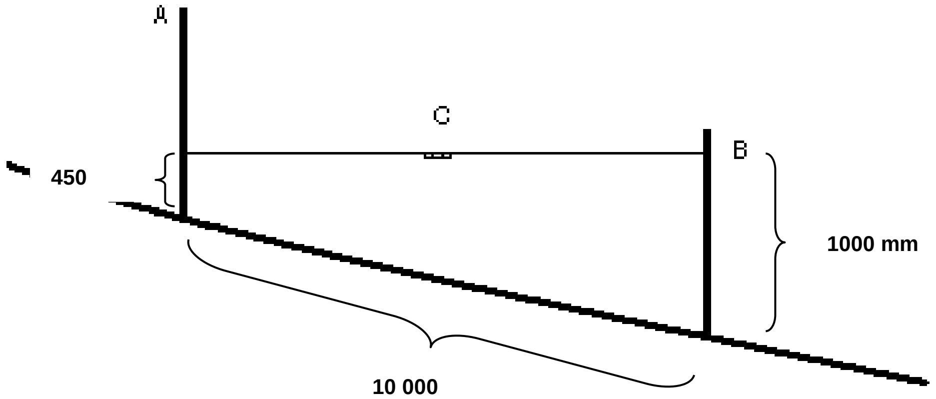


Figure 6.2 Using a line level to measure slope

Figure 6.3 A level reading on a line level

1. Person A stands upslope of person B and adjusts the string down the pole until the line level attached between the poles gives a level reading. This reading is taken by Person C.

2. The percentage of the slope is then calculated using the formula:

$$\text{Slope(\%)} = \frac{\text{rise}}{\text{run}} \times 100\%$$

3. The **run** is the distance between the two poles, which should be 10 000 mm (10 meters). The **rise** is the difference in height of the string, which is calculated by subtracting the height of the string on pole A (e.g. 450 mm) from the height of the string on pole B (e.g. 1000 mm).

4. $$\text{Slope(\%)} = \frac{1000 - 450}{10\ 000} \times 100\%$$

$$= \frac{550}{10\ 000} \times 100\%$$

$$= 5.5\ \%$$

5. Note that when measuring slope using a line level it is important that both poles are held vertically and that neither pole is placed in a depression or on top of a minor high spot such as a rock or clump of soil.

Table for the conversion of angles and degrees of slope to percentages, with the recommended distances between the contour lines.

Degrees	Percentage	Recommended distances between contour lines in metres (m)
1	1.7	57.3
2	3.5	28.7
3	5.3	19.1
4	7.0	14.3
5	8.8	11.5
6	10.5	9.6

7	12.3	8.2
8	14	7.2
9	16	6.4
10	17.6	5.8
11	19.4	5.2
12	21.3	4.8
13	23.1	4.5
14	25.0	4.1
15	27.0	4.0
16	28.7	3.6
17	30.6	3.4
18	32.5	3.2
19	34.4	3.1
20	36.4	3.0
21	38.4	2.8
22	40.4	2.7
23	42.5	2.6
24	44.5	2.5
25	46.6	2.4
26	48.8	2.3
27	51.0	2.2
28	53.2	2.1
29	55.4	2.1
≥30	≥57.7	2.0

2 HEALTHY SOILS

2.1 HEALTHY SOIL IS ALIVE.

Soils supply essential nutrients, water, oxygen (air) and root support to plants.

Healthy soil is living soil. It contains many living organisms. It is deep, loose, and easy to dig and full of air and water. Healthy soil has ***aggregates*** or structures (that look like bread crumbs) that create air pockets allowing water to ***infiltrate*** or move deep into the soil. Healthy soils act as giant moisture holding sponges, which is very important in times of drought and flooding.

Healthy soils are naturally fertile and able to supply sufficient amounts of nutrients to plants. To do this the soil needs a continuous supply and build-up of organic matter. Soil health and it’s fertility have a direct influence on the ***nutrient*** content of food crops.

We are what we eat. Healthy soils lead to healthy plants and healthy people

2.2 CARBON AND SOIL ORGANIC MATTER - THE MAIN BUILDING BLOCK OF LIFE AND SOIL

A key element of all living things, carbon, is constantly cycling through nature as either a liquid a solid or a gas. Soil carbon is sometimes also called organic matter. Because carbon is the main building block of all organic molecules, the amount in a soil is strongly related to the total amount of all the organic matter— the living organisms plus fresh residues plus well decomposed residues.

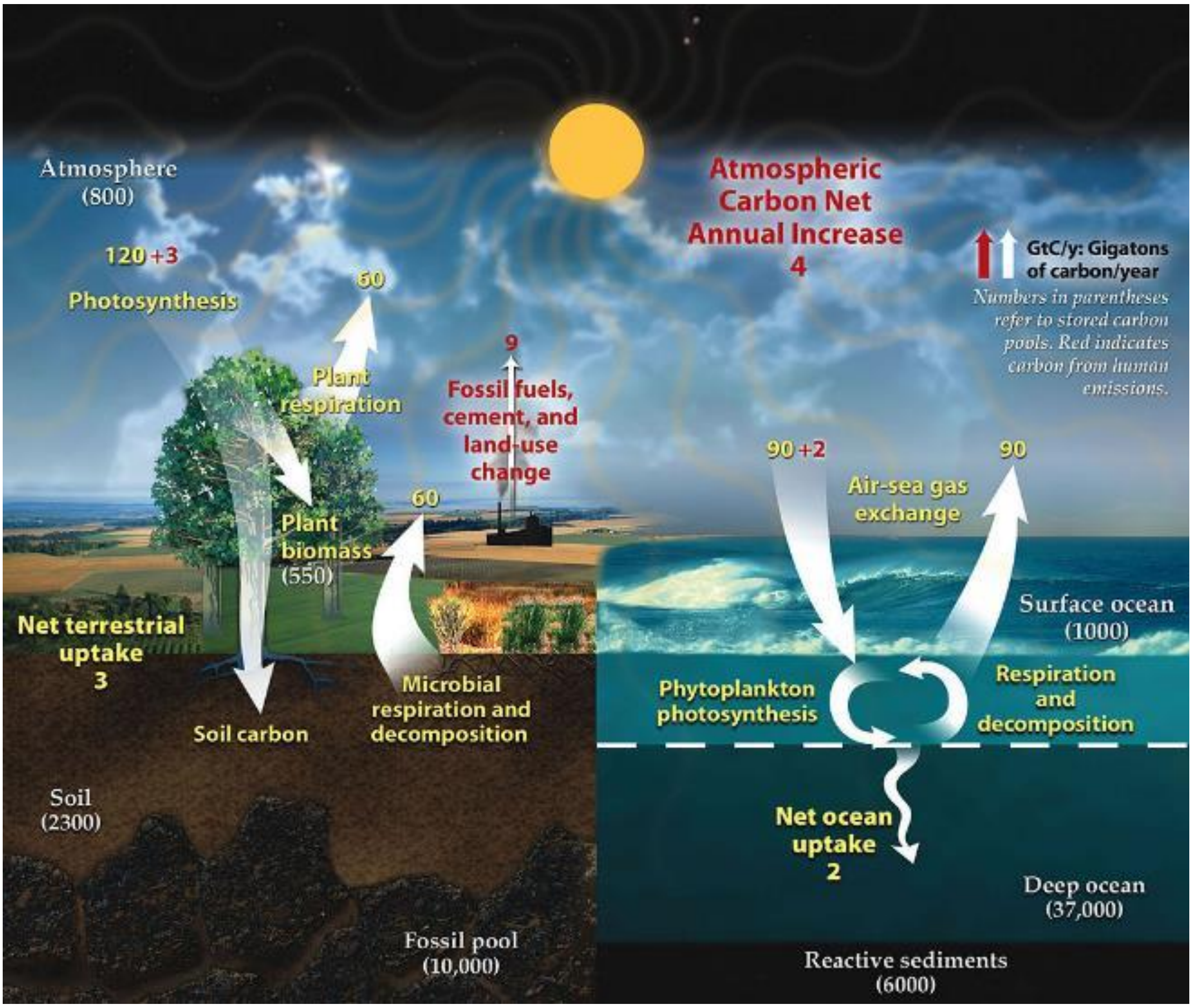


Figure 1: The Carbon cycle (From: https://commons.wikimedia.org/wiki/File:Carbon_cycle.jpg#/media/File:Carbon_cycle.jpg)

This diagram of the carbon cycle shows the movement of carbon between land, air and oceans in billions of tons of carbon per year. Yellow numbers are natural flows, red are human contributions and white numbers indicate stored carbon, usually in liquid or sold form.

More than 90% of the world's carbon is found in the deep ocean. ON land, around 805 of carbon is in the soil.

An excess of carbon dioxide (CO_2) in the earth's atmosphere is warming the planet and increasing the size, number and intensity of extreme weather events. Some of this excess CO_2 is dissolving into the world's oceans causing them to become acidic.

2.3 WHY SOIL ORGANIC MATTER IS SO IMPORTANT

Organic matter has an overwhelming effect on almost all soil properties, although it is generally present in relatively small amounts. A typical agricultural soil has 1% to 6% organic matter. It consists of three distinctly different parts—living organisms, fresh residues, and well decomposed residues. These three parts of soil organic matter have been described as the **living**, the **dead**, and the **very dead**.

SOM composition; Carbon = 42%, Oxygen = 42%, Hydrogen = 8%, Ash = 8%, Macronutrients (N, P, K, S, Ca, Mg),Micronutrients (Fe, Mn, B, Zn, Cu, Cl, Co, Mo, Ni)

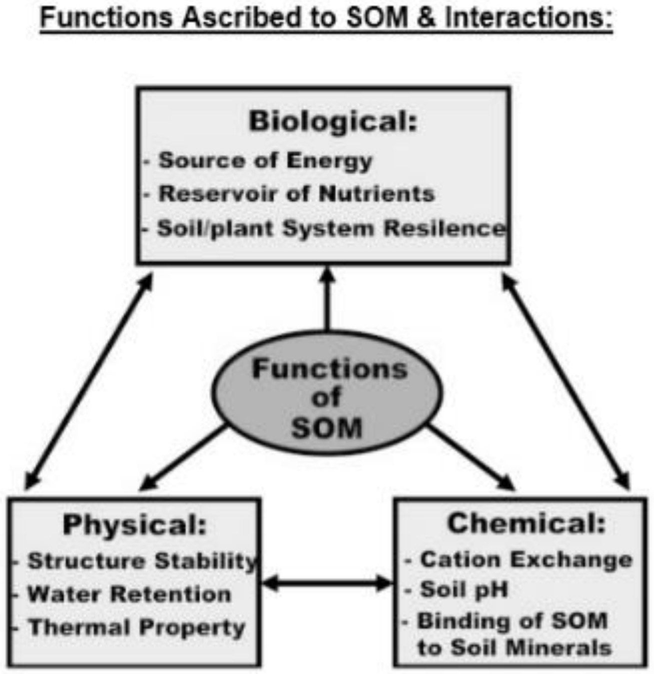


Figure 3: Functions of SOM

The **living part** of soil organic matter includes a wide variety of ***microorganisms***, such as bacteria, viruses, fungi, protozoa, and algae. It also includes plant roots, insects, earthworms, and larger animals, such as moles and rabbits, that spend some of their time in the soil. The living portion represents about 15% of the total soil organic matter.

These different types of organisms:

- Help to control insect pests, weeds and plant diseases
- Form beneficial ***symbiotic relationships*** with plant roots
- ***Recycle*** plant nutrients from soil organic matter and minerals back to roots and
- Improve soil structure.

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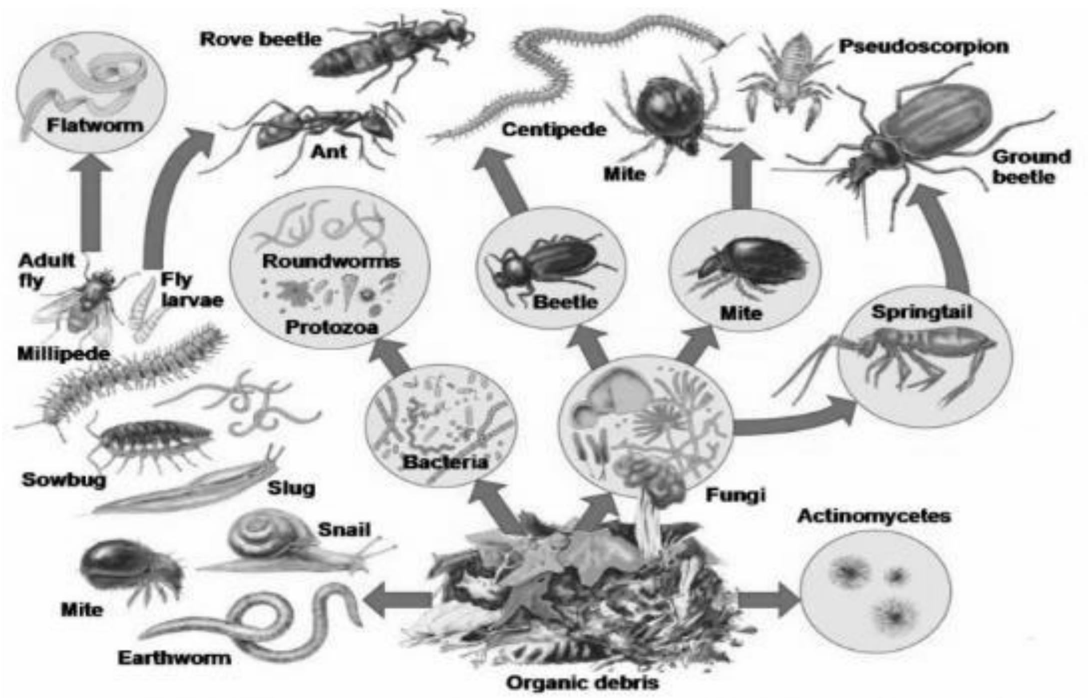


Figure 4: Micro-organisms and small living creatures in the soil (From: Life in the Soil – www.wunderground.com)

In a teaspoon of healthy soil there are more microbes than there are people on earth.

Microorganisms, earthworms, and insects feed on plant residues and manures for energy and nutrition, and in the process they mix organic matter into the mineral soil. In addition, they recycle plant nutrients. Sticky substances on the skin of earthworms and other substances produced by fungi help bind particles together. This helps to stabilize the soil aggregates, clumps of particles that make up good soil structure. Organisms such as earthworms and some fungi also help to stabilize the soil's structure (for example, by producing channels that allow water to ***infiltrate***) and, thereby, improve soil water status and aeration. Plant roots also interact in significant ways with the various microorganisms and animals living in the soil.

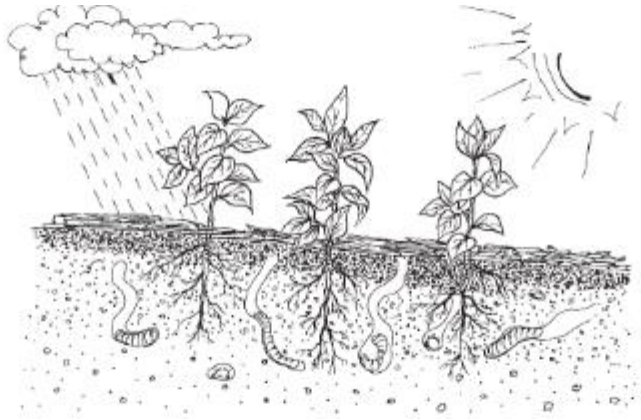


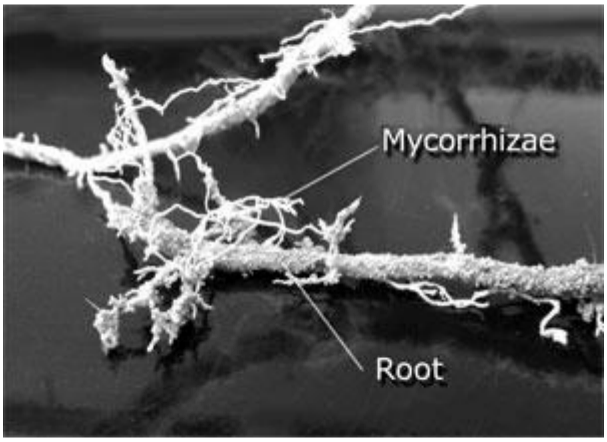
Figure 5: A healthy soil has lots of organic matter, earthworms and other tiny animals in it.

The fresh ***residues,*** or **"dead" organic matter**, consist of recently deceased microorganisms, insects, earthworms, old plant roots, crop residues, and recently added manures. This part of soil organic matter is the active, or easily decomposed fraction and is the main supply of food for soil organisms As these organic materials are decomposed by the "living," they release many of the nutrients needed by plants and they also create humus. Organic chemical compounds produced during the ***decomposition*** of fresh residues also help to bind soil particles together and give the soil good structure.

The well-decomposed organic material in soil, the **"very dead,"** is called **humus**. Micro-orangisms turn the simple sugars or liquid carbon exuded from plant roots into humus. These simple carbon compounds are joined together into more complex and stable molecules. The formation of **stable humus** requires a large number of different kinds of soil microbes, including mycorrhizal fungi, nitrogen fixing bacteria and phosphorus solubilising bacteria, all of which obtain their energy from plant sugars (liquid carbon).

The types of fungi that survive in ***conventionally*** managed agricultural soils are mostly decomposers; they obtain energy from decaying organic matter such as crop residues. Generally, these kinds of fungi have relatively small ***hyphal networks***. They are important for soil fertility and soil structure, but play only a minor role in carbon storage.

: One principle of nature is that the more biodiversity there is in a system, the healthier and more resilient it is



Right: Mycorrhizal fungi grow very closely associated with plant roots and create networks of filaments (hyphae) within the soil

(*From: http://www.heartspring.net/mycorrhizal_fungi_benefits.html*)

Mycorrhizal fungi differ from decomposer fungi in that they get their energy in a liquid form, as ***soluble*** carbon directly from actively growing plants. There are many different types of mycorrhizal fungi. Mycorrhizal fungi access and transport water - plus nutrients such as phosphorus, nitrogen and zinc - in exchange for carbon from plants.

Some of this soluble carbon is also channelled into soil aggregates via the hyphae of mycorrhizal fungi and can undergo humification, a process in which simple sugars are made up into highly complex carbon ***polymers.*** The soil conditions required for humification are reduced in the presence of herbicides, fungicides, pesticides, phosphate and nitrogen fertilizers - and enhanced in the presence of root exudates and humic substances such as those derived from compost.

Humus holds on to some essential nutrients, storing them for slow release to plants. Humus also can surround certain potentially harmful chemicals and prevent them from causing damage to plants. Because it is so stable and complex, the average age of humus in soils is usually more than 1,000 years. The already well-decomposed humus is not a food for organisms, but it's very small size and chemical properties make it an important part of the soil.

Good amounts of soil humus can reduce drainage and compaction problems that occur in clay soils and improve water retention in sandy soils by enhancing soil aggregation.

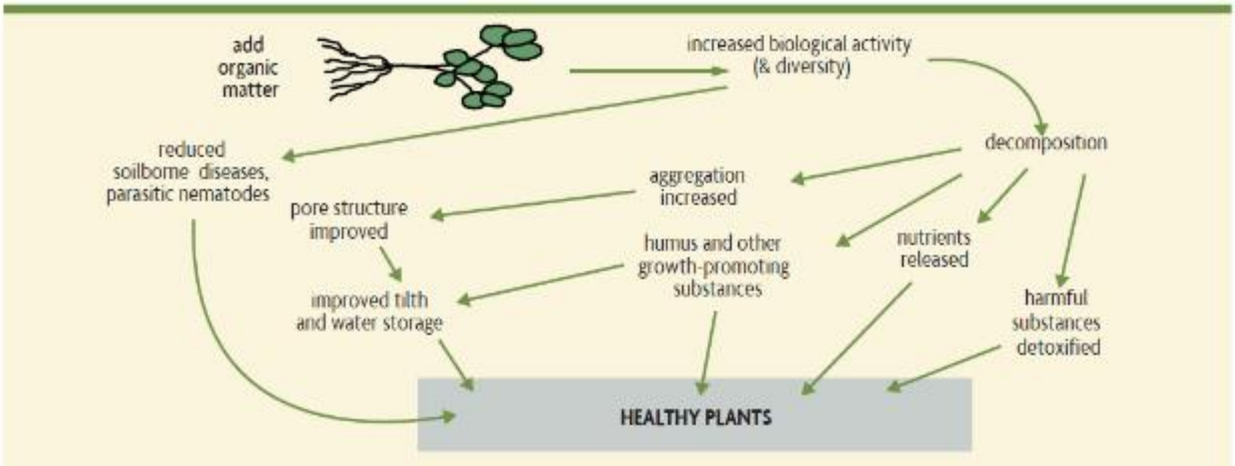


Figure 6: Adding organic matter results in many changes in the soil. (From Building soils for better crops, 2009)

ORGANIC MATTER INCREASES THE AVAILABILITY OF NUTRIENTS . . .

Directly

- As organic matter is decomposed, nutrients are converted into forms that plants can use directly.
- ***Cation Exchange Capacity*** is produced during the decomposition process, increasing the soil's ability to retain calcium, potassium, magnesium, and ammonium.
- Organic molecules are produced that hold and protect a number of ***micronutrients***, such as zinc and iron.

Indirectly

- Substances produced by microorganisms promote better root growth and healthier roots, and with a larger and healthier root system plants are able to take in nutrients more easily.
- Organic matter contributes to greater amounts of water retention following rains because it improves soil structure and thereby improves water-holding capacity. This results in better plant growth and health and allows more movement of mobile nutrients (such as nitrates) to the root.

2.4 TURNING AIR INTO SOIL

The process whereby carbon dioxide is converted to soil humus has been occurring for millions of years. Rebuilding carbon-rich ***topsoil*** is a practical and good option for productively removing billions of tonnes of excess carbon dioxide from the air. When soils gain in carbon, they also improve in structure, water-holding capacity and nutrient availability.

The formation of healthy soil requires ***photosynthesis*** to capture carbon dioxide in green leaves.

Plants use energy from the sun, carbon dioxide from the air and water and minerals from the soil to make up their food. Food is usually made in the green parts (often the plants leaves).The process of making food using chlorophyll and sunlight is called photosynthesis. When plants photosynthesize and make carbohydrates in their ***chloroplasts***, they use some of those compounds for their cells and structure, and some they burn for their life energy.
But they "leak" or exude a significant amount of these compounds as "liquid carbon" into the soil. Microbes use this energy to create complex stable forms of soil organic matter, or humus.

One of the more remarkable things that soil scientists are learning about plants and soil organisms is that they seem to have co-evolved in a mutually beneficial relationship. As we have learned more about soil biochemistry we have discovered that, through root ***exudates***, plants are able to control their local environment – to regulate the local soil microorganisms, to cope with being eaten by animals, to bring distant nutrients closer, to alter the ***chemical*** and physical properties of nearby soil, and to inhibit the growth of competing plants.

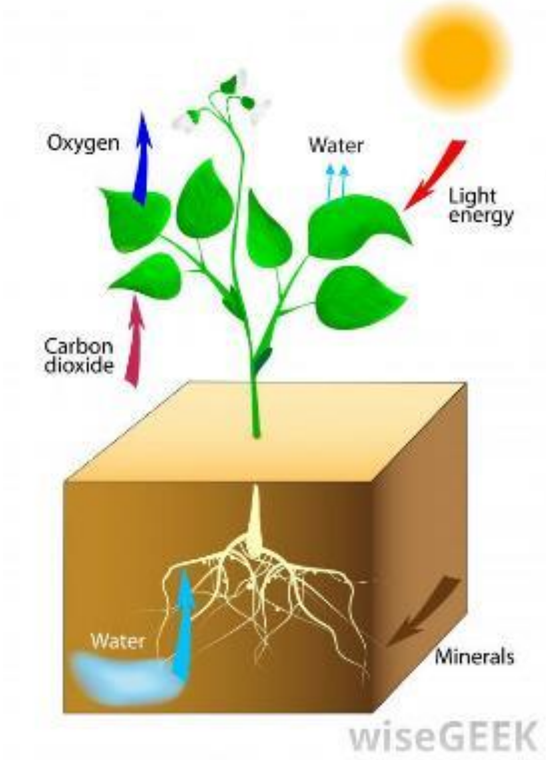


Figure 7: Photosynthesis (from: mages.wisegeek.com/photosynthesis-process-diagram.jpg)

Between 20-40% of the sugars produced by plants are exuded through their roots to the rizosphere.

The zone of soil around the roots (the rhizosphere) provides an ideal habitat and good supplies of energy-rich organic matter. In return, microbes around the root release nutrients and plant-growth promoting compounds, while at the same time providing a level of suppression against plant pathogens. As microbial activity increases, the conversion of soil organic matter to humus increases which also results in carbon sequestration. The formation of gum and polysaccharides by microbes and earthworms promotes the formation of stable soil aggregates and increases the ability of the soil to retain plant-available water and nutrients.

Everything goes round and round in a continuous cycle

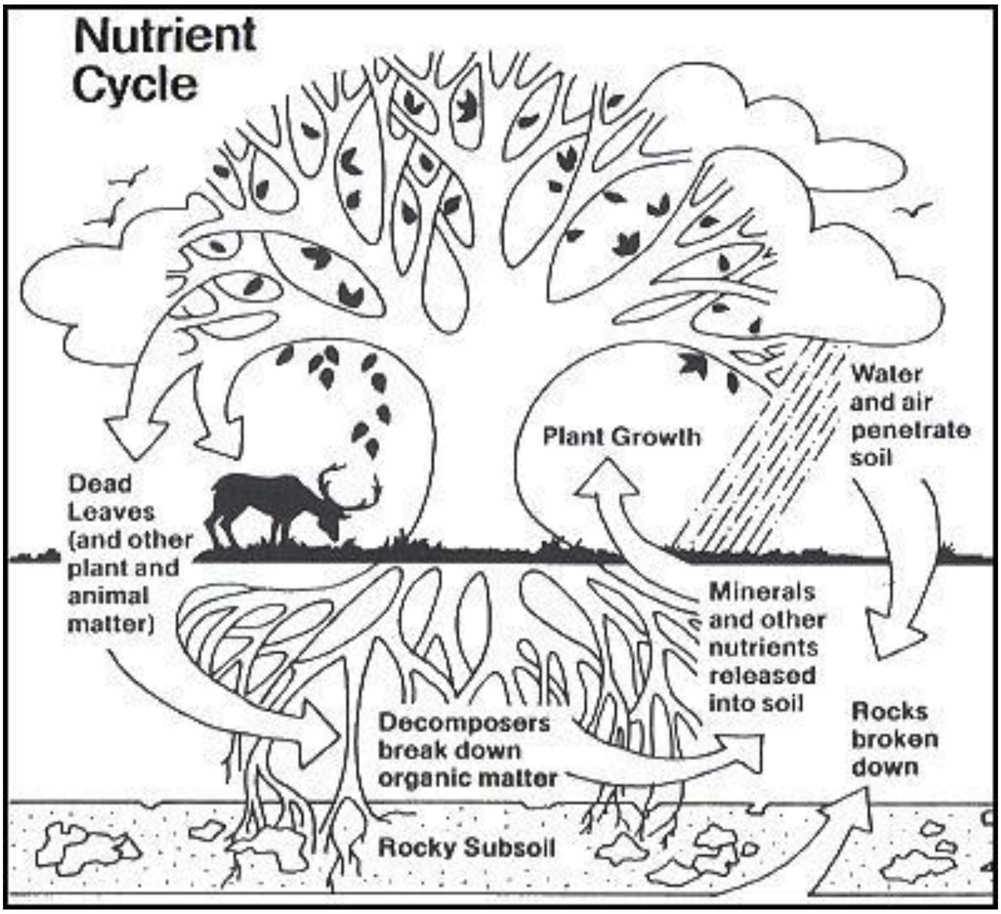


Figure 8: The Nutrient cycle> All the goodness (nutrients) from fruits, leaves, branches, whole plants, animal manure and dead animals decompose and go back into the soil. The nutrients are taken up by plants in the soil, with the help of microbes and in this way are recycled (used again and again). The life of a plant is therefore a cycle and nothing is ever wasted. (From:http://www.sswm.info/category/concept/nutrient-cycle)

2.5 CHARACTERISTICS OF HEALTHY SOIL

The complex interaction between the physical, chemical and biological properties of the soil has a major influence on soil fertility and health.

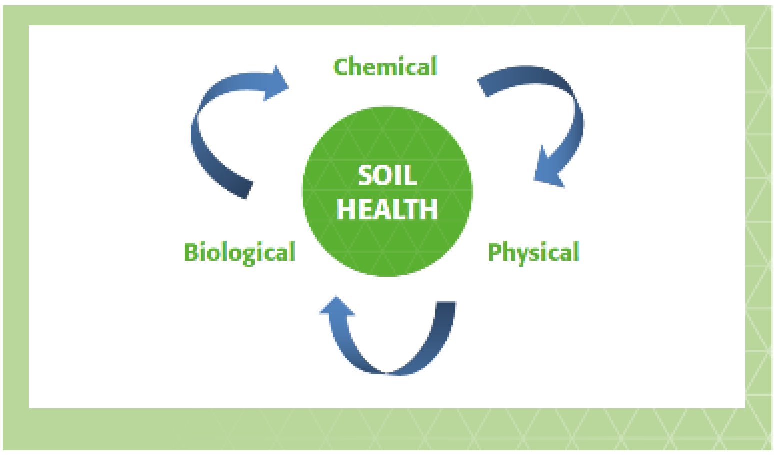


Figure 9: Soil Health depends on physical, chemical and biological characteristics

Although creating a healthy soil is mostly a biological process, it is influenced by the interactions that occur between the physical, chemical and biological components of the soil. Biological activity is driven by temperature, and requires appropriate levels of air, water and suitable nutrition. The physical properties of the soil will affect air and water exchange, which will influence biological processes such as ***respiration***. This in turn will influence the ability of soil organisms to decompose organic matter and release nutrients for uptake by plants. The activity and diversity of soil organisms is also influenced by soil chemistry e.g. ***pH***. The growing plant, and more specifically the activity of roots and material released from roots (exudates etc), also plays a significant part in maintaining microbial activity.

Physical components

The physical properties of soil are determined by the balance between sand, silt and clay particles, which determines soil texture. These particles combine with various forms of organic matter to form soil aggregates. The size and distribution of these aggregates through the soil profile determines soil structure, which influences soil stability, erosion risk, ease of cultivation and ***compaction***. Soil structure directly affects the movement of air and water through the soil profile, which in turn affects biological activity, root development, crop establishment and tolerance to environmental stress.

Chemical components

The ***mineral*** content of the underlying soil parent material has a major influence on soil chemical properties of the soil. Of particular importance from a soil health perspective is the impact that soil chemistry has on the development of plant-microbe interactions. For example, soils that are based on limestone have a tendency to be rich in calcium, andto also be also alkaline, which can restrict the uptake of nutrients such as phosphorus and manganese.

This in turn can reduce root mass and root exudate production, restricting both microbial activity and plant response to microbial growth promotion. Soil pH influences microbial populations, encouraging bacteria to dominate alkaline soils and fungi to dominate acidic soils. A better balance of bacteria and fungi can be found at more neutral soil pH values. Bacteria require simple sources of soluble organic matter and have high multiplication rates, while fungi can utilise more complex insoluble forms of organic matter and have relatively low multiplication rates.

Biological components

During its conversion from plant and animal residues to humus, soil organic matter has a direct impact on soil health. Un-decomposed organic material provides a food source for macro-organisms such as earthworms.

Earthworms mix partially decomposed organic matter with soil minerals as the material passes through the gut, creating channels for air and water movement as they go.

Microbes thrive in the earthworm casts, completing the conversion of organic matter to plant-available nutrients and humus. This humus can bind sand, silt and clay into stable soil aggregates, while at the same time providing exchange sites for nutrients and improving water retention. This results in increased soil fertility and yield potential.

Figure10; An earthworm in a clod of soil showing the soil channels, earthworm casts and soil aggregates. (From H.Smith, 2015)

2.6 WHAT IS SOIL?

Soil contains abundant plant and animal life, as discussed above. There are four main components of soil: mineral matter, organic matter, air and water.Soil **minerals** are made through the breaking up of the basic elements or minerals of the earth. These are initially found in the form of rocks or 'parent material'. Over a very long time, these rocks are broken down into small particles through rain, wind, sun and soil organisms and mixed with air and water. This becomes soil that can support plants and micro-organisms to grow. Like people, plants cannot live and grow without water, air and food.

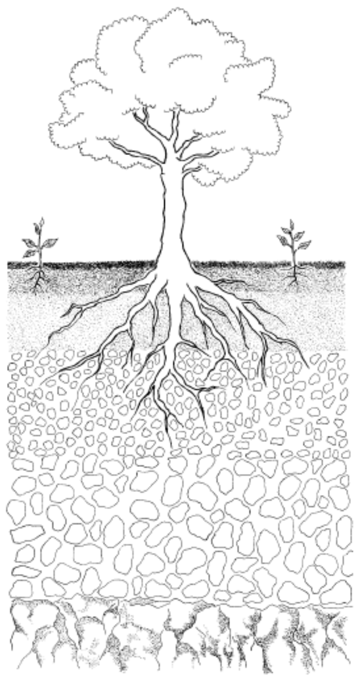


Figure 11:: A typcial soil profile (From: FARMESA2003. A study guide for FFS. Soil and water conservation.)

Parent material breaking down to form 1 cm of soil can take between 200-1 000 years

The **mineral** matter (45%) is made of sand, silt and clay size particles—the basic texture of the soil. The soil **water (25%)** contains dissolved minerals and is the main source of water and nutrients for plants. The **air (25%)** in the soil is needed for plant roots and soil microorganisms to obtain oxygen. **Organic matter (5%)** includes plant and animal materials in various stages of decomposition and is discussed above.

2.7 CHARACTERISTICS OF SOIL TEXTURE TYPES

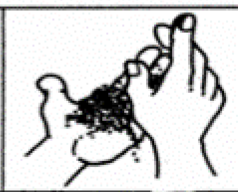
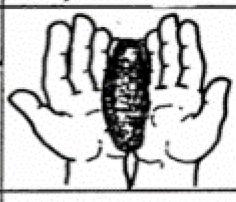
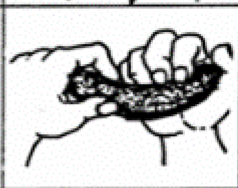
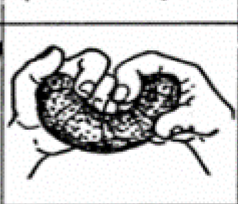
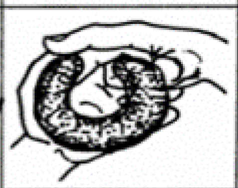
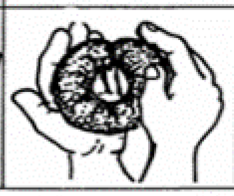
Sandy soil	
Good things about this type of soil	*Bad things about this type of soil*
It is easy to dig and work with It warms up quickly in spring after winter It is good for root crops Water and air can get into the soil easily	It gets dry quickly It does not keep much fertility It does not hold water well
Loam soil (Mixture of sand and clay)	
Good things about this type of soil	*Bad things about this type of soil*
Holds water well Best for root growth Contains organic matter, like …..	This soil can be hard when dry
Clay soil	
Good things about this type of soil	*Bad things about this type of soil*
Holds water well and for a long time Holds fertility well and for a long time	Hard to work; heavy Slow to warm up in spring Sticky when wet Hard when dry

2.8 HOW TO TELL YOUR SOIL TEXTURE TYPE

You can tell how much sand, silt or clay (commonly called texture) is in your soil by how it feels. Wet some soil and roll it into a ball between your hands. Then roll this little ball into a sausage

Below is a table that describes how you can tell what type of soil you have.

Table 1 : Different soil texture types

WHAT SOIL LOOKS LIKE	WHAT SOIL FEELS LIKE	WHEN ROLLED INTO A SAUSAGE		THE SOIL IS
VERY SANDY	VERY ROUGH	CANNOT BE ROLLED INTO A SAUSAGE		VERY SANDY 0-5% clay
QUITE SANDY	ROUGH	CAN BE ROLLED INTO A SAUSAGE BUT IT CANNOT BEND		SANDY 5-10% clay
HALF SANDY & HALF SMOOTH	ROUGH	SAUSAGE CAN BEND A LITTLE		SANDY LOAM 10-15% clay
MOSTLY SMOOTH	A LITTLE SANDY, QUITE SMOOTH BUT NOT STICKY	SAUSAGE CAN BEND ABOUT HALF WAY AROUND		LOAM OR SILT LOAM 15-35% clay
MOSTLY SMOOTH	A LITTLE SAND QUITE SMOOTH AND STICKY	SAUSAGE CAN BE BENT MORE THAN HALFWAY ROUND		CLAY LOAM OR SANDY CLAY 35-55% clay
SMOOTH	SMOOTH AND STICKY	SAUSAGE CAN BEND INTO A RING		CLAY More than 55%

- Sand makes the soil loose.
- Silt is very fine sand. It holds water and plant food better than rough sand, but it is easily washed out of the soil.
- Clay is the sticky part of the soil that holds it together. It holds water like a sponge.

The best soils according to texture class are called loams and they are an equal mixture of sand, silt and clay.

It is important to know which soil type you have. Crumbly and loose soil holds the most water and the most air, which is what plants need to grow. To make your soil more crumbly (whether it is sandy, loam or clay) you need to keep adding lots of manure, compost and mulch. Never walk on the planted areas, especially if they are wet.

All types of soil need organic matter to increase their fertility, or plant food. Sandy soil needs to be given organic matter to increase its ability to hold water and plant food or nutrients. Clay soil needs to be given organic matter to increase its ability to hold air in the soil and to release the plant foods that are there.

Another method of identifying the proportion of soil participles in a soil is to conduct a "bottle test".

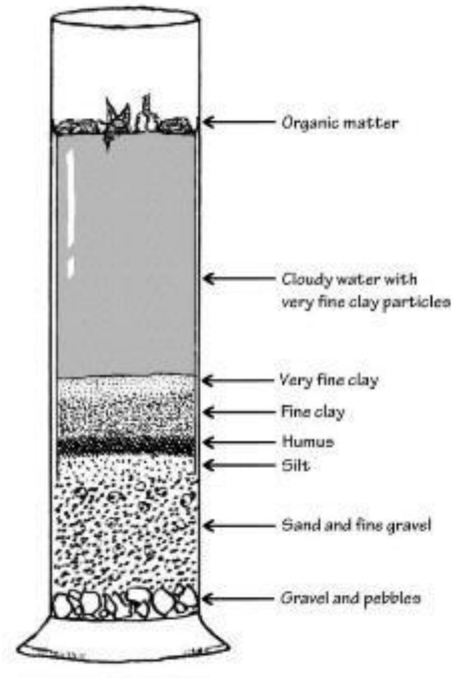
To do this, take a bottle and fill a third of it with soil. Pour water into the bottle until it is almost full, place a lid on and shake it vigorously for a few minutes in order to separate the soil particles. Leave the bottle to settle, and note what happens over the next few hours.

You will see that the substances settle in layers, the heaviest at the bottom and the lightest on top.

The layer of water above the settled material remains cloudy for a long time because it contains clay particles which are so small that they stay suspended in the water. Substances which are lighter than water (organic matter like leaves, seeds, spores, and insect and animal waste) float on the surface.

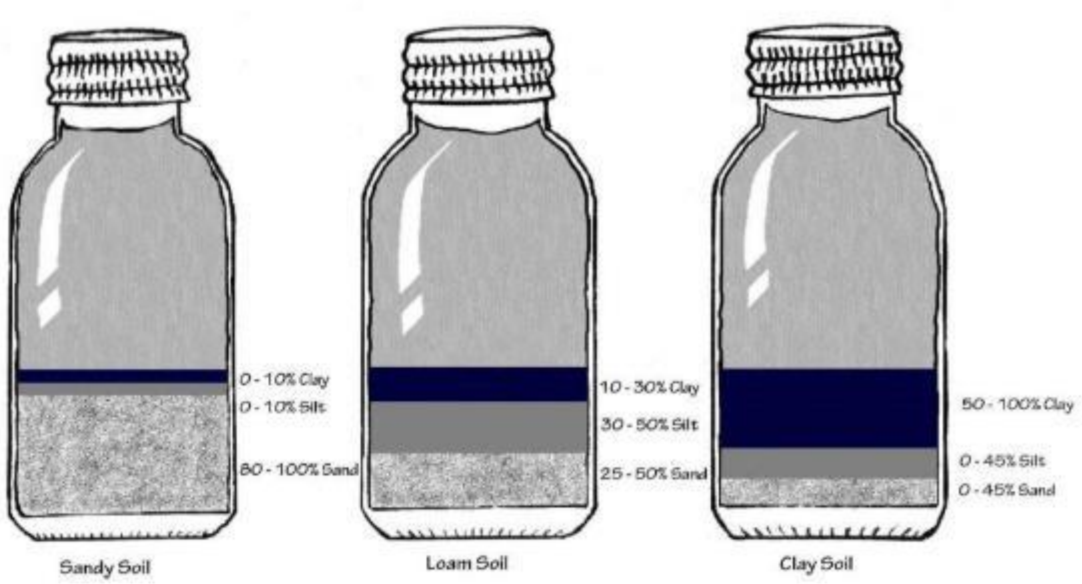
Heavy particles such as gravel, pebbles and sand fall quickly to the bottom of the bottle.

The finer elements then accumulate – first the silt, followed by humus and then the fine and very fine clay. These layers vary in colour and consistency.



Right: Bottle test showing proportion of soil separates (From: WHC Manual, WRC, 2010)

Below: Using the bottle test to estimate the proportion of soil components in a sample



2.9 SOIL STRUCTURE

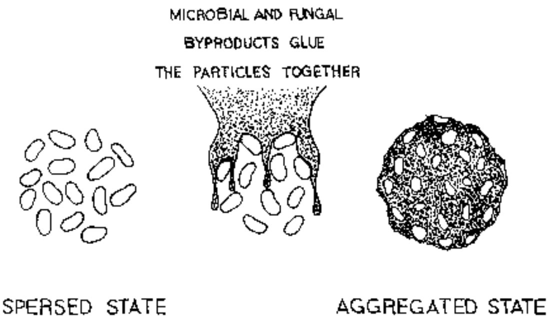
Soil structure describes the grouping or arrangement of primary particles (sand, silt, clay and organic matter) into larger, secondary particles called **aggregates**. It is the shape that soil takes, determined by the way in which individual soil particles clump or bind together.

Aggregates are the fundamental unit of soil function and play a role similar to that of root nodules in legumes, creating a protected space. The aggregate is helped to form by hyphae of mycorrhizal fungi that create a “sticky-string bag” that envelops and entangles soil particles. Liquid carbon exudates from plant roots and fungi enable the production of glues and gums to form the aggregate walls.

Inside those walls a lot of biological activity takes place, again fuelled by the carbon exudates. Most aggregates are connected to plant roots, often fine feeder roots, or to mycorrhizal fungal networks too small to be seen. The moisture content inside an aggregate is higher than outside, and there is lower oxygen pressure inside. These are important properties enabling nitrogen-fixation and other biochemical activities to take place.

Soil structure affects the movement of water and air in the soil, as well as root penetration and biological activity. For example, a dense structure greatly reduces the amount of air and water that can move freely through the soil and it is difficult for roots to penetrate such soil.

Right: The dispersed soil participles are clumped together into aggregates



http://www.soilandhealth.org/01aglibrary/010117attrasoilmanual/Soilmgt3.gif

Micro-organisms play an important role in soil aggregate formation and structure. Soil aggregates protect the soil against wind and water erosion.

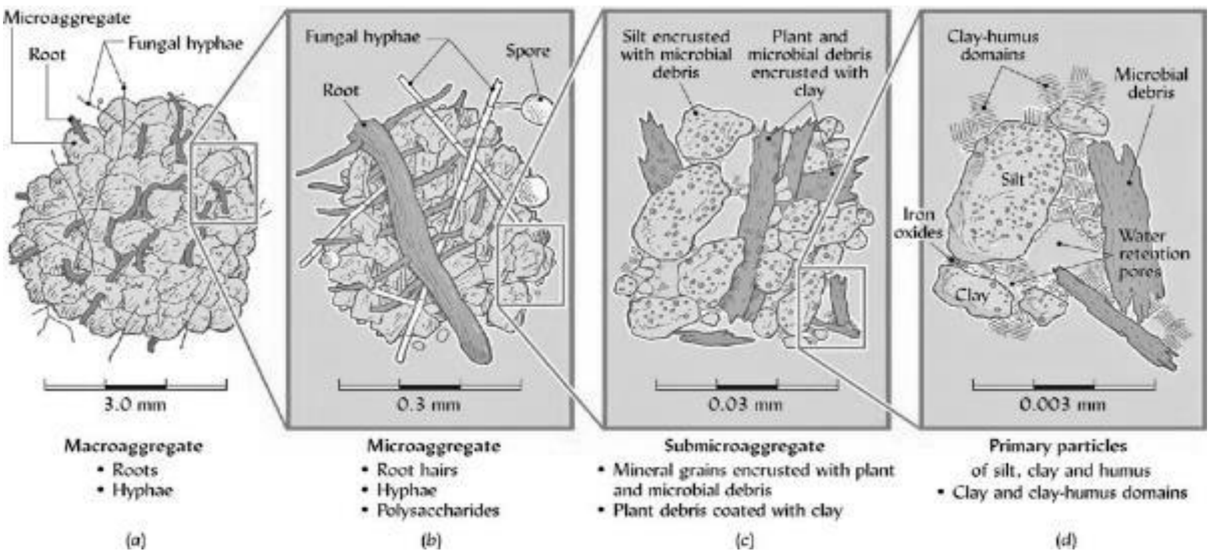


Figure 12: Soil aggregates are groups of soil particles that are glued together by microbial and fungal by products. Very small aggregates group together to form larger aggregates.

Figure 13: Roots, fungal hyphae, and their secretions stabilize soil aggregates and promote good soil structure, thus preventing compaction.

2.10 Identification of Soil Structure

The structure of the surface layer of the soil is usually weak to strongly granular or blocky, but a degraded surface layer can be crusted, platy, or structure-less (massive or single grained). This is important as soil crusting reduces water and air infiltration, destroys soil life and increases run-off and erosion.

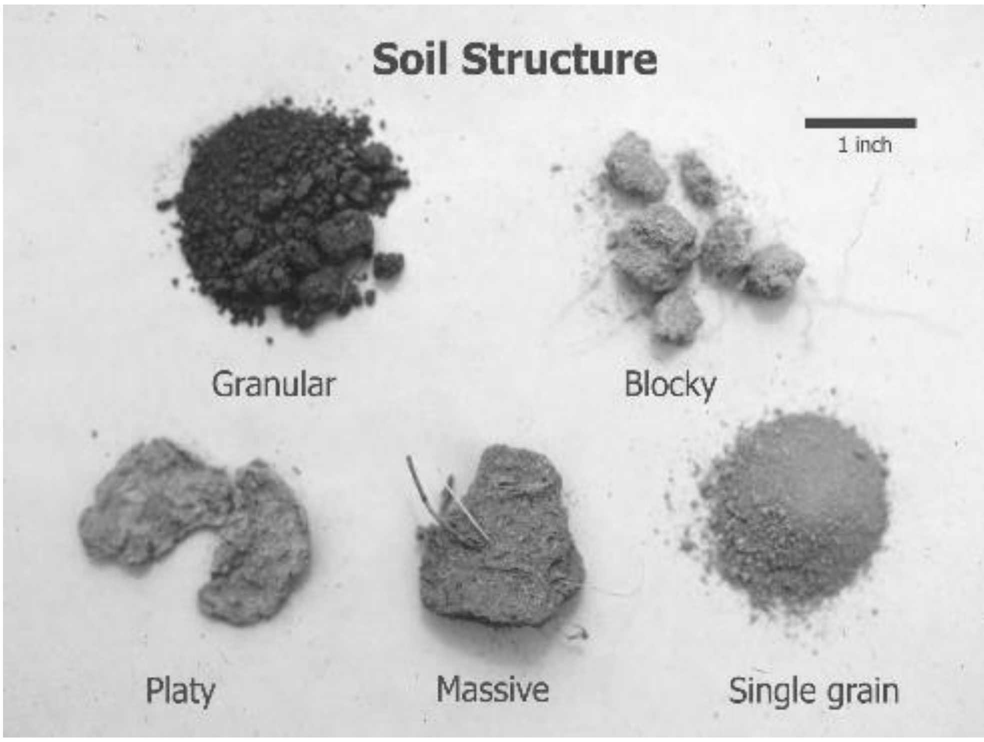


Figure 14: The different structures that soil can take

http://ecomerge.blogspot.com/2010/05/what-soil-aggregates-are-and-how-its.html

The more soil organic matter (SOM) there is in the soil, the more macro-aggregates can form and the better the soil structure becomes.

Left: The difference in colour and structure caused in a soil by increasing the soil organic matter. And cover crops growing through a thick layer of organic matter.

http://thegrowingclub.com/2015/02/article-moving-beyond-drought-in-mind-space/,https://iowaenvironmentalfocus.files.wordpress.com/2014/12/15127396042_c1b408b873_k.jpg

2.11 Soil Degradation

Degradation most commonly occurs when erosion and decreased soil organic matter levels initiate a downward spiral resulting in poor crop production. Soils become compact, making it hard for water to infiltrate and roots to develop properly. Erosion continues and nutrients decline to levels too low for good crop growth.

Tillage or ploughing usually starts this degradation process. Fields that have been ploughed a lot tend to crust, seal and compact more than non-till fields with lots of crop residues and a living plant cover with active roots and fungi. Tillage also reduces infiltration and the water holding capacity of the soil due to poor structure and thereby increases water run-off and erosion.

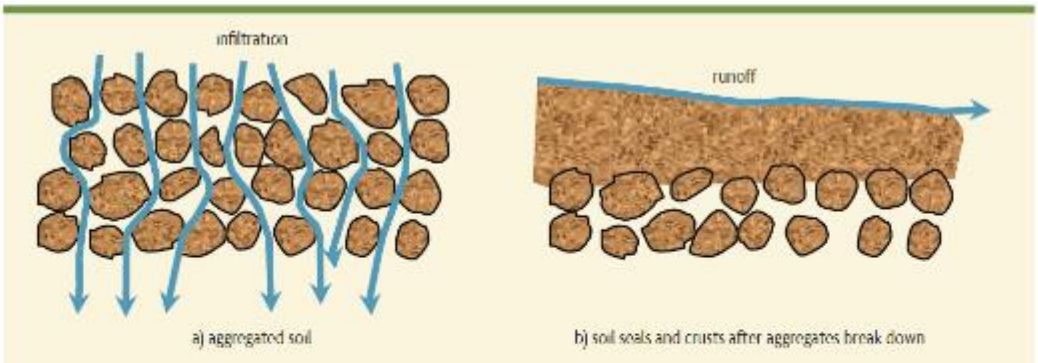


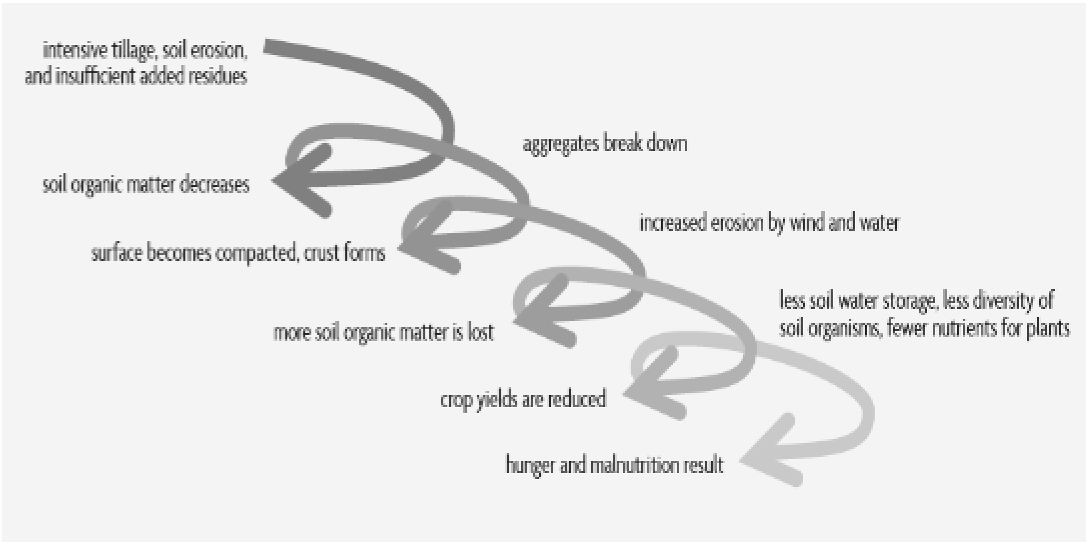
Figure 15: Changes in soil surface and water-flow pattern when seals and crusts develop

It can also reduce the germination of seeds and root growth. It makes the soil a lot more prone to wind erosion when it is dry.

Right: A dust storm on the farms around Bloemfontein in the Free State in October 2014.(From: GSA, 2015)

Right: Soil crusting caused by ploughing and breakdown of soil structure (From: http://cropwatch.unl.edu/archive/-/asset_publisher/VHeSpfv0Agju/content/should-you-apply-uan-and-residual-herbicides-in-a-tank-mix-on-emerged-corn-

Figure 16: The downward spiral of soil health due to intensive tillage or continuous ploughing



3 TURNING RUNOFF INTO 'RUN-ON'

This innovative technology is based on the work and experimentation of MaTshepo Khumbane, who has a beautiful working system at her present homestead near Cullinan. The remnants of a similar system in her former homestead plot near Tzaneen of some 20 years ago, still nourishes the fruit trees there, even though the present owners are unaware that there is a system at all! This system is the product of years of experimentation with practises in rainwater harvesting and storage. MaTshepo's run-on system has been studied and documented, so that it could be used as an innovation that could be introduced to other householders in their circumstances.

Compare this photo to the diagram overleaf.

Run-on is 'automatic irrigation when it rains.' The soil in the garden is shaped to catch rainwater runoff, slow it down and lead it gently to where it is needed. The water dams up in pathways between deep-trenched planting beds, giving it time to seep into the planting soil. The layout allows excess water to escape before it can erode the planting beds or the pathways themselves. Such excess water can either run further down-slope to a storage structure (tank or dam) for future use, or be released into the veld to continue on its natural course downstream to the river.

Interestingly, the run-on system works with water flows above and below ground.

In its simplest form, the run-on system concentrates surface runoff from adjacent areas into the root zone of the planting beds. This in itself dramatically increases the effectiveness of rainfall – even in high rainfall areas, where a large percentage of rainfall may run off unutilised once the top soil layers are wet.

Further, as people's understanding deepens on what happens to water below the soil surface in their own conditions, they can start manipulating these flows – with cut-off trenches and by creating strategically placed impermeable layers in their deep-trenched beds

1 A trench (the top ditch) is dug across the runoff slope of the land to catch rainwater.

2 Below the top ditch, the vegetable beds are dug 1m deep and filled with organic matter — grass, leaves, manure, and ash — and mixed well with topsoil. These trench beds are fertile and absorb and retain moisture.

3 The trench beds are edged with ridges. Some are re-enforced with stone to stop the soil washing away and to reduce evaporation.

4 Between the trench beds a network of depressions (rainwater flow paths) connect the top ditch to a second one at the bottom edge of the garden. The rainwater flows and pools in these channels/depressions during rain.

5 These rainwater flow paths are also the footpaths to access the trench beds.

6 In the rainwater flow paths the gradient is flat so that the water has more time to soak into the trench beds.

7 If it rains too much, the bottom ditch is breached to avoid flooding of the trench beds.

8 A water catchment area: concrete paving around the house is lipped and slopes down to pipes which lead to further ditches and deep trenches downhill of the house.

9 Lower down a 2 x1m hole (open pond) catches and stores more run-off.

10 Fruit trees are planted along the lower edge of a ditch so that their deep roots can benefit from the extra soaking.

3.1 SOIL FERTILITY

All living things are composed of the basic elements of the earth. Plants consist mainly of hydrogen, oxygen, carbon, nitrogen, phosphorus, potassium and smaller quantities of magnesium, sulphur and calcium as well as many other elements in very small amounts (these are called trace elements).

Plants need three main kinds of nutrients:
Nitrogen (N) – for healthy leaf and stem growth;
Phosphorus (P) – for healthy roots and fruit formation;
Potassium (K) – for general health and healthy flowers and fruit.

The capital letters in brackets (N, P, and K) are called the chemical symbols. If you buy fertilizer or other chemicals, they may use these letters instead of writing out the name in full.

All three of these foods are found in good compost or manure. You can also increase the amount of these foods in the soil by mulching with leguminous leaves like beans, peas, pigeon peas and Acacia (thorn tree leaves) or comfrey, using liquid manures, earthworm castings and effective micro-organisms. You will need to make the earthworm castings and effective microorganism brews and add them to your soil.These are different ways of improving fertility that you will need to be shown.

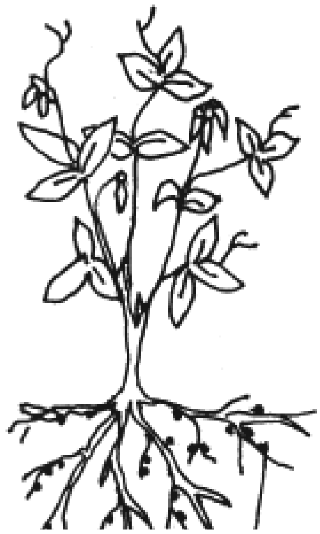
3.2 NITROGEN

1. ***How do you know if your soil needs more nitrogen?***

You will know your plants need nitrogen when the leaves are turning yellowish, instead of a strong bright green.

2. ***How can you add nitrogen to your soil?***

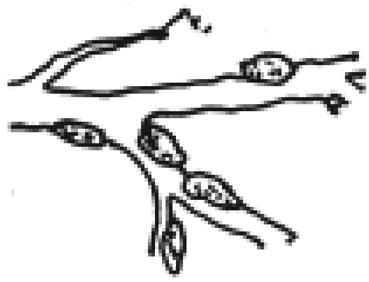
This element is found in most manures (cattle, sheep, pig, goat, chicken and rabbit). There is more nitrogen in chicken and goat manure. These must be dried before being used in the garden. Otherwise they can be too strong and 'burn' the plants.



Nodules on the roots that fix nitrogen

3. ***Nitrogen is also found in legumes***

These are plants that form nodules or little knots on their roots. These nodules 'fix' nitrogen from the air, so that the plant can take it up through its roots. There are microorganisms (bacteria) in the roots that help to 'fix' the nitrogen. After the roots of the plant die the nitrogen is released into the soil and can be used by surrounding plants.



The bacteria in the root knots binds free nitrogen from air in the soil and release nitrogen after the plant dies

Examples of legumes that we often grow:

Ground nuts, peas, cowpeas, beans (including soya beans)

There are less common crops and also many long living plants and small trees that also fix nitrogen. Some examples are chickpeas, mung beans, lentils, pigeon peas and tree lucerne.

Some legumes are grown only as green manures, and are not used for food. These include lucerne, clover, hairy vetch and lupins. These give a lot more nitrogen to the soil than our food plants, because we dig them into the soil when they are still green. This is why we call them green manures. We can also plant our food crops in between these legumes.

Soya beans

3.3 Phosphorous

1. How do you know if your soil needs more phosphorous?

You will know your plants need more phosphorous when they do not grow fast, as they should. The leaves may also start to show unusual red or pinkish colours, especially around the edges. If your plants are small and will not grow, even when compost is added, then you almost certainly have a severe phosphorous deficiency. This can also be caused by acidity in the soil.

2. How can you add phosphorous to your soil?

Many soils are poor in phosphorous. It is also a bit difficult to add phosphorous to the soil in an organic way, as most of the sources of phosphorous are tricky to work with. They include urine, bones, hair, feathers and blood. Usually ,we add these as ingredients to compost

Natural rock phosphate can be added directly to the soil. This is also not easily available. Another good source of phosphorous is bone meal. You can usually buy this from an agricultural supply store – but it is not cheap.

One other way of adding phosphorous is to place bones in a fire, for a few hours. You can then grind them into a powder more easily. This powder can be spread on your garden beds or your compost heap.

The manure from animals grazing in areas where there is not much phosphorous will also have little phosphorous. You may need to bring in phosphorous in the form of chemical fertilizer. The usual source is called Superphosphate. Another chemical fertilizer known as DAP (Di-ammonium Phosphate) can also be used.

3.4 POTASSIUM

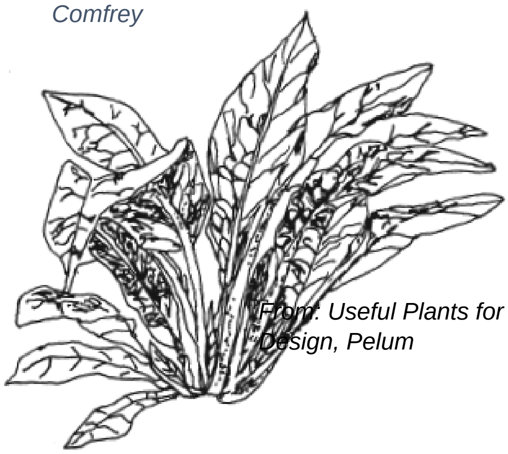
1. How do you know if your soil needs more potassium?

You will know your plants need potassium when the plants become brittle and the leaf edges become brown and dry. When fruit do not form properly, you should also suspect a lack of potassium. Other signs can be hard to distinguish. One of these is a yellowing around the veins of the leaves. This could also be caused by diseases – so it is difficult to know.

2. How can you add potassium to your soil?

Good sources of potassium are chicken manure and fresh woodash. Never use ash from coal, as this is very poisonous to the soil and plants. Another good source of potassium is a plant known as comfrey. This plant has large hairy leaves and grows in wet shady places. The leaves contain a lot of potassium. These can be used to mulch your vegetable beds and also to make liquid feeds for your plants (We will look at liquid feeds later in this section).

Comfrey



From: Useful Plants for Land Design, Pelum

The other elements or minerals needed in smaller quantities, such as Magnesium, Zinc and Iron, are found in most manure and in compost.

Comfrey is also a good medicine. A tea made from the leaves is good for high blood pressure and arthritis.

3.5 OTHER IMPORTANT NUTRIENTS:

Calcium (Ca) Promotes plant life and strong plant tissue, promotes early root formation and seedling growth, aids in the uptake of nutrients, balances pH

Magnesium (Mg) Essential for the formation of Chlorophyll and formation of sugars, a carrier of phosphate and starches through the plant, promotes the formation of fats and oils, vital for healthy growth.

Sulphur (S) Increases root development, helps maintain the dark green colour, stimulates seed production, necessary for protein production, flavor and odour in many fruits and vegetables.

3.6 MICRO OR TRACE ELEMENTS (NUTRIENTS NEEDED IN SMALLER QUANTITIES)

Iron (Fe) Is an oxygen carrier, enhances chlorophyll formation, metabolizes RNA, enhances green color of produce

Boron (Bo) Promotes early root formation and growth, improves health and sturdiness, increases yield and improves quality of fruits and vegetables.

Zinc (Zn) Essential for enzymatic reactions in cells and promotes plant growth.

Copper (Cu) Is needed for Chlorophyll production, catalyzes several plant reactions and necessary for making protein.

Manganese (Mn) Activates many metabolic reactions, increases absorption of calcium, magnesium and phosphorus, speeds germination and plant maturity.

Molybdenum (Mo) Enhances absorption of nitrogen by plants

Chlorine (Cl) Involved in photosynthesis and chlorophyll production, stimulates enzyme activity, helps control water loss and moisture stress.

Cobalt (C) Is needed in nodules of legumes for nitrogen fixing bacteria

Sodium (Na) Helps in water regulation and photosynthesis

These nutrients are important to plants for health and survival. They are equally important to animals and human health. This is because we get our nutrients from plants who take up essential nutrients from the soil. If our soil is healthy our plants benefit by being healthy and we in turn benefit from the variety of nutrients available.

3.7 SOIL ACIDITY

1. What is soil acidity?

Soil acidity is can influence plant growth and limit crop yield. Minerals or nutrients needed by plants to grow are dissolved in the water inside the soil. This is a bit like salt or sugar dissolved in a glass of water.

Soil acidity is when the soil is sour. It is a bit like a glass of water that has vinegar dissolved in it. In places where it rains a lot, some of the minerals can be washed out of the soil. The soil then becomes acidic. The use of chemical fertilizers over a long period of time, can also make the soil acidic.

If there is too much acid in the soil, some minerals or plant food will dissolve too quickly and the plants cannot use them. Other minerals will not dissolve at all, so again, the plants cannot use them. Phosphorus is one of the minerals that cannot be used by plants when the soil is acidic – even if it is in the soil.

What causes of acidity?

Acidic parent rock material, high rainfall and leaching elements like calcium (Ca), magnesium (Mg), and phosphorous (K), decay of organic matter leading to release of organic acids into the soil, harvesting high yields (therefore removing plenty of Ca, Mg and K from the soil), widespread use of nitrogen (N) fertilizers.

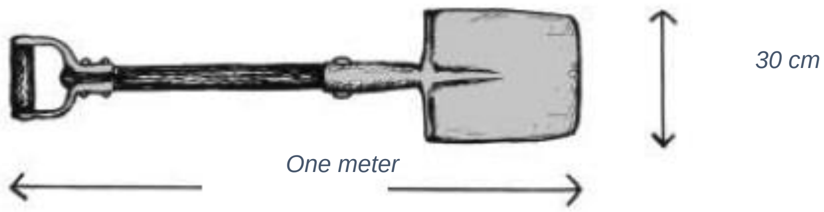
2. How do you know if your soil is acidic?

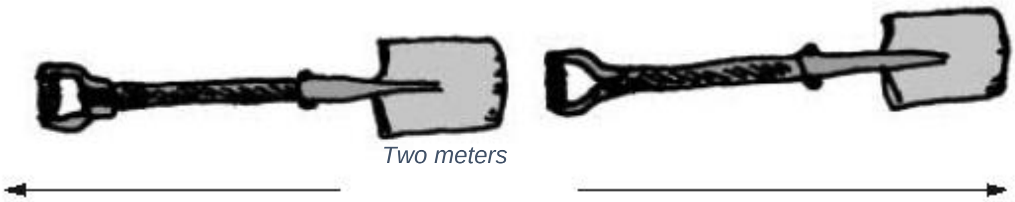
You will know your soil is acidic if you provide compost or manure and water for your plants, but they do not grow. The plants remain small and stunted. This is a common problem.

3. How will you solve the problem of acidity?

The only practical way of dealing with soil acidity is to add lime to the soil. Lime can be bought and is a white powder, or grey granules.

It needs to be dug into your soil, at least as deep as the roots of the crop you are growing. For vegetables this is between 30 - 60 cm. This is the width of 1 or 2 spades. You will need to add 1 kg of lime for every square metre of soil. 1 Kilogram of lime is a spade full. It needs to be heaped high.





For field crops like maize and sorghum that have deep roots this is from 60 cm to 1 meter deep. 1 meter is the length of a spade.

Usually Lime is added 2 or 3 months before planting, as it is slow acting in the soil. If you add Lime at the same time as you are planting your crop, you will only see the main effect of the Lime in the next season.

4. *Advantages and disadvantages of Liming*

Advantages	Disadvantages
It is easy to apply, stays in the soil for a few years, combats soil acidity by reducing metals' toxicity, makes P more soluble and microbes more active, supplies Ca, Mg to plants, improves soil structure and water infiltration (reduces energy needed by roots to penetrate the soil), improves harvest	It is not easy to determine soil pH, might not be easy to get, costs money,

Other (easily available) ways of naturally improving soil quality and balancing pH: bone meal, dried and crushed egg shells, finely crushed sea shells

4 SOIL ENRICHING METHODS

4.1 TRENCH BEDS

1. *Introduction*

A trench bed is a way to increase soil fertility and water holding in your beds and garden. It is an intensive way of providing good soil for vegetables production on a small scale. It involves digging a hole and filling it with organic matter, so that your bed can be fertile for a long time (around 5 years).

You will need:

A spade, water, tins, old bones, plastic (if your soils are sandy), dried grass, wood ash, manure and organic matter.

Mandla (in Phuthadjithaba) is digging his trench bed and placing the topsoil on one pile (darker soil with more organic matter) and the subsoil on another (usually lighter soil with little or no organic matter).

4. *The method*

1. Dig a hole 60cm or deeper. It is usually about 1m wide (to provide easy access, without having to step on the bed) and can be as long as one likes.

2. Separate the topsoil and subsoil in piles while you are digging.

If your sub-soil is very in fertile it is not used in the trench. Spread this soil around the garden to help channel water towards your bed.

3. Place a layer of tins or branches at the bottom of the trench to help with aeration and also with supply of some nutrients.

The tins need to be squashed before putting them in the hole. Make a layer of tins about 3 tins deep. If there are no tins use thin branches instead.

Layer of tins at bottom of trench

4. Fill the trench with a range of organic materials and topsoil.
- First add dry grass or weeds (about 10 cm deep)
- Then add manure (about 2 cm deep)

- Add also some wood ash (a thin layer, less than 1cm deep).
- Then add a layer of sop soil (about 5cm deep)

A trench bed in Potshini being filled and mixed. Here the top soil is being added back into the trench Notice the yellow subsoil on the one side. It is not being used.

Mix these layers with a fork. Stamp them down by walking on them. WATER the mixture well! Then start the process again.

You can also add other organic matter like green and dry weeds and vegetable peelings, card board, paper and bones.

5. Continue to place the organic materials into the trench until it has reached ground level again.

6. Now build up the trench bed to about 10-15cm above soil level. Use a good mixture of topsoil and manure and or compost.

The organic material in the trench needs to decompose for about 2-3 months before planting.

7. The other option is to use your trench bed as a seed bed. In this way, when your seedlings are ready to be transplanted, the trench bed will be ready to be planted.

Growing seedlings from seed needs a well prepared bed. The roots of the small plants do not go down too deep. The materials in the trench can decompose while the seedlings grow on top.

Above, Carrot and onions seeds are being planted in a seed bed in Potshini. This trench has just been prepared.

Note; Fine soil is being used to cover the seeds in the rows. This is because the seeds are small and in this way they can germinate better.

Left: In this picture carrot seeds were planted in the smaller trench bed in the far corner. There are also two tubs of seedlings being produced. In the foreground is a recently completed trench bed into which bought cabbage seedlings have been planted. Again these grew well and did not show any negative effects from the decomposing material in the trench.

Right: In this picture a number of trench beds have been prepared in a garden in Potshini. The owner has used two of his trenches as seed beds. They are covered with grass to hold the moisture in the soil while the seeds are germinating. This grass will be removed when the seeds come up.

The middle bed is shaped like a horse shoe. This is a nice design that makes it easy to reach all sides of the bed. It also allows run-off water to run into the middle of the shoe and soak into your bed. Here the owner has planted swiss chard seedlings. They grew well; despite our fears that the decomposition of the organic matter in the trench bed may interfere with their growth

8. It is very important that the trenches are watered well while they are being made and afterwards. The organic material in the trench cannot decompose if it is dry.

Different ways of watering are possible; as long as a lot of water is given!

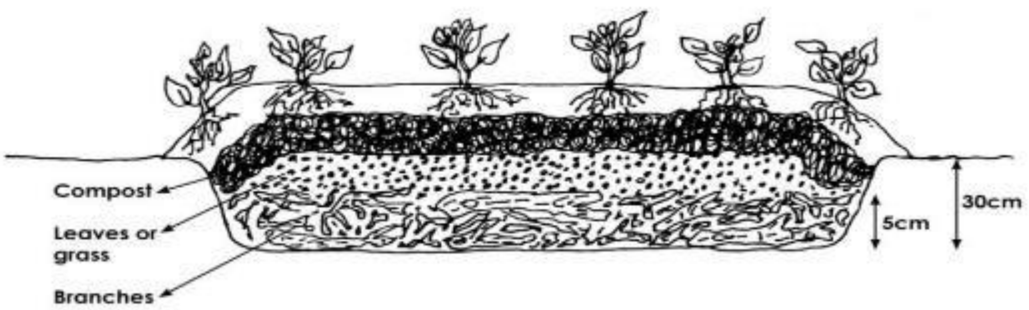
In this picture, drip irrigation is going to be used to water a trench bed.

Advantages and disadvantages of trench beds

Advantages	Disadvantages
This method really works as the soil is rich in nutrients, it is a good method for sandy soils (low in nutrients)	Difficult to dig trench beds in hard soils, it takes time and effort, some people are scared of this method because the trench looks like a grave.

2. *Shallow trench*

Shallow trench beds are shallower version of the deep trenches. This trench is dug to about 30cm deep. The bottom of the trench is filled with sticks and branches. This is covered by a layer of dead leaves or green leaves and grass (depending on what is available). Then the rest of the hole is filled with compost and finally it is covered with the topsoil that was dug out.



(from WRC; Homestead water Management Manual, 2009)

Advantages and disadvantages of shallow trenches

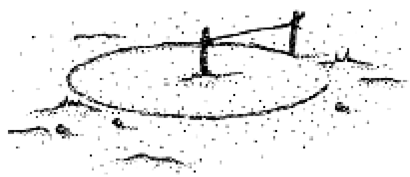
Advantages	Disadvantages
Easy to make, takes less energy than a deep trench, it also takes a shorter amount of time to create	This is a difficult method if you live in an area with hard soils and many rocks

3. *Eco-circles*

An Eco-circle is a unique, productive way of gardening. Eco-circles are (small) raised, circular garden pits beds.

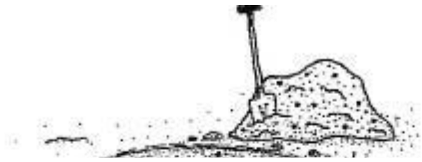
1. ***What you will need to make an eco-circle:***

String and a stick, a spade, compost and mulch, seedlings or seed to plant, a candle and matches, a piece of wire and used 2l bottle with a lid.



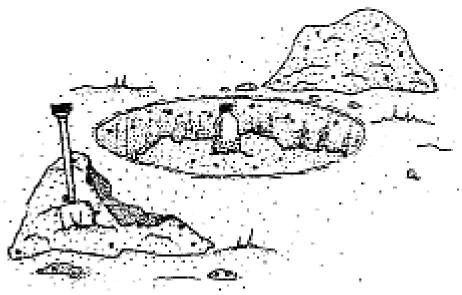
2. ***How to make an eco-circle:***

Mark out a circle (using a stick and some string) on the ground where you intend growing food. Remove the first 20-30cm of topsoil and put it in a pile next to the circle. Remove another 20-30cm and put it in a separate pile, next to the circle. The hole should be knee deep now (about 50cm)



Light a candle and heat up the wire (careful not to burn yourself). When the wire is hot, burn 16 tiny holes in the sides of the 2l bottle. (4 holes, in 4 vertical rows - going down the side of the bottle).

Place the bottle (upright) in the center of the circle. Now add a 2cm layer of compost, or decomposed kraal manure, kitchen waste or dry grass, into the base of the hole. Cover this with 8cm (4 fingers) of subsoil. Water the 2 layers well. Continue replacing the subsoil layering it with compost (grass and or whatever organic material you have) watering each layer as you go. Having added all the subsoil replace the top soil. The surface of the bed will be higher than the surrounding ground. Scoop the soil from the center of the circle to the outside to create a basin with the top of the bottle in the center. The basin shape funnels water into the center where it sinks into the soil. So it can't run off carrying precious topsoil with it. Mulch and plant.



Fill the bottle with water once a week. The water will slowly drip out the bottle into the soil.

3. Practical notes and tips:

The compost creates a sponge which retains water and the mulching prevents evaporation. In areas of high rainfall the surface of the bed should be flat to prevent water-logging.

You can make the eco circle bigger for example 1m by 1m

Advantages and disadvantages of eco-circles

Advantages	Disadvantages
Easy to make, effective method, small enough to maintain, saves labour once the circle has been dug, simple method, not much space needed, can grow lots of food in the small space, low tech, water saving method of gardening (there is a saving of up to 70% in water usage), A good method to use in dry areas	Could be hard to dig in hard soils

4.2 LIQUID MANURES

1. Brews for plant nutrition

One way of improving plant nutrition is to make liquid teas or brews that will add fertility to the soil. In this method nutrients (from plant matter or animal dung) are leached out (drawn out) into water and applied to the soil. This should be used as an additional soil fertility technique rather than the only one. Brews provide extra nutrients in case of small deficiencies, but cannot rectify major nutrient deficiencies.

Liquid manures/brews/ teas are a simple way of giving your plants a boost. The aim is to provide plants with natural plant foods quickly during their growing season. It is useful for heavy feeders like cabbages and to give seedlings a boost.

2. How to make liquid manures from plants

A good plant for liquid manure is comfrey. Most soft green leaves and stems can also be used and weeds are ideal. Avoid plants which are very strong smelling. Plants are made of different quantities of nutrients and take up different nutrients from the soil. It is best to use a range of plant materials to make your liquid. Make sure you only use healthy plants.

Make sure your container is clean before you use it. Collect the plant material and fill up the container. You must keep on adding material to the container every week.

Place a rock on top of the plant material in the container and put the lid on. Do not add water. The plant material will make its own liquid. If you are only using weeds, and no comfrey or banana stems, you may need to add a little water, to just cover the compressed plant material.

Place it in a sunny position and two weeks later check to see if the leaves have turned black. If you tilt the container you should find a black juice. This is the concentrated plant liquid manure.

This liquid is very strong and should be diluted as follows:

Seedlings: 1 tin of liquid manure for every 4 tins of water.

Bigger plants: 1 tin of liquid manure to 2 tins water. If you make the mixture too strong it can burn the leaves of plants.

Every two weeks pour the mixture on the soil around your plants, after you have watered them. You should pour at least one tin of this diluted mixture around each seedling or plant. The tin should be the size of a big jam tin.

3. How to make a foliar spray

This is brew made from a mixture of plant and animal material. It is used by spraying onto the leaves of plants from where it is absorbed. This brew contains antibiotics, microbes and plant hormones as well as plant nutrients (potassium, phosphate and trace elements). (*from :EMBRAPA; Brazilian Agriculture Research Institute)*

Place the following ingredients in a container with a lid:

30kg of fresh cow manure
50-60liters of water
5litres of milk (without salt)
5liters of sugar cane juice/ 15kg of chopped sugar cane/2kg of brown sugar (*personal variation*)
4kg of wood ash (not coal ash!!)

4kg crushed bones or bone meal (fish bones are ideal if available. If possible do not use chicken bones) (*We use bone meal bought from a gardening shop)*
3-5x 20l buckets of chopped weeds
2-3kg of agricultural lime/ crushed eggshells

Leave this mixture for 10-15 days. Dilute 2-10litres of this mixture in 100 liters of water.

This spray is highly effective. It is possible to keep the brew going for a period of time, by adding more weeds and manure and fermenting the mixture again for about 10 days.

Advantages and disadvantages of foliar sprays

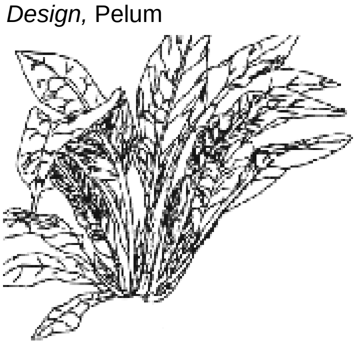
Advantages	Disadvantages
Foliar sprays are very effective and act quickly in the plants. If diluted properly, these foliar sprays do not harm plants Foliar sprays increase disease resistance in crops Foliar sprays provide a quick and cheap plant booster food Plant hormones and antibiotics are also supplied through the fermentation process in the making of foliar sprays	Some inputs for foliar sprays need to be bought; such as agricultural lime and potentially wood ash, sugar and milk This mixture is exceptionally smelly while it is fermenting Foliar sprays can "burn" plants if they are too strong

4. GOOD PLANTS FOR LIQUID MANURES

1. *Comfrey*

This plant has large hairy leaves and grows in wet shady places. The leaves contain a lot of potassium. These can be used to mulch your vegetable beds and also to make liquid feeds for your plants Comfrey is also a good spinach and medicine. A tea made from the leaves is good for high blood pressure and arthritis.

Comfrey From: Useful Plants for Land Design, Pelum



A brew made from comfrey leaves can be diluted as mentioned above and sprayed on plant leaves to protect against downy and powdery mildew. Mildews are a problem mainly on cucurbits, pumpkins and peas.

A brew made from comfrey and stinging nettle can be sprayed on plants to protect against early and late blight, which attacks tomatoes and potatoes.

In these cases, the brews are sprayed onto the leaves of the plants.

1. Stinging nettle

This is one of the best plants you can use in plant brews. It contains a wide variety of nutrients and trace elements and is a well-balanced plant food. It is best to collect these plants in the natural forests where they occur and plant a few in your garden. They do not survive frost, but otherwise grow almost anywhere.

2. Banana stems

These are chopped up and placed in the container with other plants and leaves. The stems have a high concentration of potassium and water and make a good liquid base for the brew.

3. Weeds

Black Jack, Amaranths, Chickweed, Galant Soldier. All fast growing weeds, with soft dark green leaves are good. Avoid using grasses and sedges.

Advantages and disadvantages of plant brews

Advantages	**Disadvantages**
Plant brews are easy to prepare and use If diluted these brews do not harm plants Plant brews increase disease resistance in crops Plant brews provide a quick and cheap plant booster food. Plant brews provide mainly potassium, phosphorus and trace elements. Nitrogen can be provided if the brew is used early in the fermentation cycle (after 1 week) and care is taken to avoid it's evaporation by keeping the containers closed and cool Plants drink their nutrients so nutrients immediately available, easy quick method. These teas are excellent to use on newly transplanted seedlings to help them recover from transplanting shock. Useful method for rainy season when there is lots of leaching. You can prepare fertilizer teas from animal manure, plant trees from parts of plants.	Resources such as containers with lids are required Plant brews can burn plants if they are too strong Effects of the brews on plant growth are only visible after 3-5 days. It is not possible to know exactly which nutrients these brews contain. Some people do not like the smell of these brews, which can smell very rotten Nitrogen is volatile and is lost from the brews quite early in the fermentation cycle

5. HOW TO MAKE LIQUID MANURE FROM ANIMAL MANURE

Manure can be used from chickens, rabbits, cows, goats and sheep. A mixture of manures is best.

Put your fresh manure mixture into an orange packet and tie the top of the bag.

Put the bag in the container and attach it to a stick or a rope. Then fill the container with water. For every 1kilogram of manure you will need 5 liters of water. This means an orange sack full of manure in a large bucket (50l), or half the bag in a normal sized household bucket (20l). This is a way of keeping the manure and the water separate, because you should not put the wet manure on your plants.

Cover the container with a lid. Stir every few days.

After two weeks the mixture will be ready to be used. It should look like weak tea. Before using the liquid, stir the mixture well.

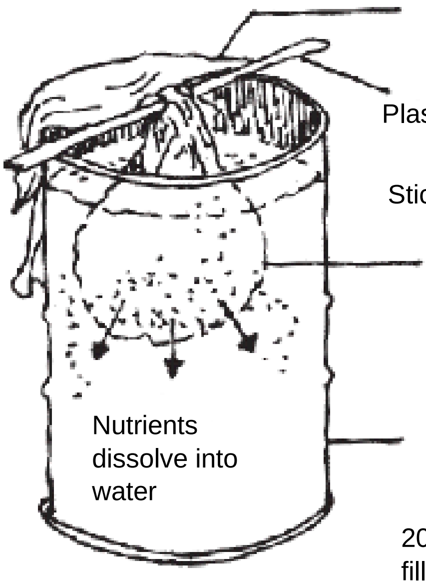
This liquid will be very strong and should be diluted:

Seedlings: 1 tin of liquid to 8 tons of water (or buckets or bottles)

Bigger plants: 1 tin liquid to 4 tins of water

If you make the mixture too strong it can burn the leaves of plants.

Every two weeks pour the mixture on the soil around your plants, after you have watered them. Again, use at least one big jam tin full for each seedling or plant. Avoid applying your mixture in the middle of the day or on very hot days.



6. **Good sources for animal liquid manures**

1. ***Kraal manure (cattle)***

Either use fresh manure or use manure that has been collected in a kraal. In this way you can ensure that the manure contains as many nutrients as possible and that the nutrients have not been lost into the air through baking in the sun and drying out. This is especially important if you need your liquid manure to contain some Nitrogen.

2. ***Chicken manure***

With chicken manure it is important to collect the droppings while they are fresh. Again this keeps the nitrogen and other plant food concentrated in the dry droppings. It is possible to collect the droppings daily and keep them in a sack in a cool dark place, until you have enough to make a brew.

Liquid manure made from chicken manure can burn plants, as it can contain a high level of Nitrogen. It is important to dilute this brew properly before use. If you are unsure, test the brew on a few plants only and come back the next day. If the edges of the leaves have gone brown and crinkly overnight, the brew is too strong and has “burnt” your plants.

3. ***Goat manure***

This is very mild manure and is well balanced. It is unlikely to “burn” plants, but may also be a little low in phosphorus, depending on the diet of the goats.

4. *Other manures*

Manure from rabbits can also be safely used. It is suggested not to use the manure from pigs, due to the possibility of carrying worm eggs that can infect people. Do not use manure from dogs and cats for the same reason.

5. *Urine*

Human urine is an excellent garden tonic. Urine (from healthy people who are not on medication) is collected, diluted and watered onto the soil around plants. Like plant based liquid manure, it should be diluted to a weak tea colour. Avoid using it in the same place regularly.

Advantages and disadvantages of animal liquid manures

Advantages	Disadvantages
Liquid manures are easy to prepare and use If diluted properly, these liquid manures do not harm plants Liquid manures increase disease resistance in crops Liquid manures provide a quick and cheap plant booster food Liquid manures provide mainly potassium, phosphorus and trace elements. Nitrogen can be provided if the liquid manure is used early in the fermentation cycle (after 1 week) and care is taken to avoid it's evaporation by keeping the containers closed and cool	The liquid manure is only as good as the manure of origin. If the animals are suffering from deficiencies these will be transferred into the manures. As an example, there is likely to be a lack of phosphorus in cattle manure, where cattle have only been grazed on veld. This means the liquid manure made from this source will also lack phosphorus. Liquid manures are generally low in nitrogen. Using chicken manure drastically increases the nitrogen content. The source manures have to be handled well to retain their nutrients before using as liquid manures. Effects of the liquid manures on plant growth are only visible after 3-5 days. It is not possible to know exactly which nutrients these brews contain. Some people do not like the smell of these liquid manures, which can smell very rotten

6. *Agroforestry Leaf tea Recipe*

This is an excellent nitrogen boosting liquid manure.Collect fresh leaves from trees such as Leucaena, thorn trees and wattle. Put about 30-40kg in a sack and tie securely. Suspend the sack from a stick across the top of a 200l drum filled with water. Cover the drum with a lid. Stir every 2-3 days by moving the stick gently up and down. This will release the nutrients into the water. Soak the leaves for about 2 weeks and be sure the sack is kept underwater the whole time. Remove the sack of leaves (add the leaves to the compost or use as a mulch) then dilute the tea by mixing 4parts of water with one part of the tea. It should look like weak tea. Apply by pouring it on to the soil around the plants or sprinkling over the leaves of plants.

4.3 MANURE AS A NATURAL FERTILIZER

Manure is an excellent fertilizer containing nitrogen, phosphorus, potassium and other nutrients. It also adds organic matter to the soil which may improve soil structure, aeration, soil moisture-holding capacity, and water infiltration.

Nutrient content of manure varies depending on source, moisture content, storage, and handling methods. The management of manure can also affect its value. For example; nitrogen is present in manure and gradually converts to ammonium and nitrate nitrogen. The ammonium form can be lost to the air if not contained and the nitrates can be leached by rainfall.

Table : Nutrient availability in different types of manure

	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Organic matter	Moisture content
	(N)	(P_2O_5)	(K_2O)	(Ca)	(Mg)		
FRESH MANURE	%	%	%	%	%	%	%
Cattle	0.5	0.3	0.5	0.3	0.1	16.7	81.3
Sheep	0.9	0.5	0.8	0.2	0.3	30.7	64.8
Poultry	0.9	0.5	0.8	0.4	02	30.7	64.8
Horse	0.5	0.3	0.6	0.3	0.12	7.0	68.8
Swine	0.6	0.5	0.4	0.2	0.03	15.5	77.6
TREATED DRIED MANURE	%	%	%	%	%	%	%
Cattle	2.0	1.5	2.2	2.9	0.7	69.9	7.9
Sheep	1.9	1.4	2.9	3.3	0.8	53.9	11.4
Poultry	4.5	2.7	1.4	2.9	0.6	58.6	9.2

Advantages and disadvantages of using manure

Advantages	Disadvantages
Manure helps to maintain the organic matter content of the soil, improves soil structure and water infiltration. However, manure is quickly decomposed under warm, moist soil conditions. Composting and stockpiling manure can reduce the number of viable weed seeds. Composting manure increases the nutrient content and safety for use considerably. Manure is cheap and readily available in rural areas.	Weed seeds are common in some manure.. Poultry droppings typically have fewer weed seeds surviving the digestive processes.. With the manure rates used for most crops, organic matter content in soil is only temporarily increased. Manure can cause a build up of salts in soils that are already highly saline or very badly drained. Fresh manure can burn young plants. Zinc deficiency can be induced or increased with repeated high rates of manure, especially on sandy soils.

5 NATURAL PEST AND DISEASE CONTROL

5.1 ENEMIES OR FRIENDS

Plants, animals and micro-organisms can influence the productivity in your garden. About 99% of all plants, animals and microorganisms are beneficial to agriculture and the general economy. It is only 1% of all living creatures that causes so much trouble in gardens around the world. If left undisturbed, natural enemies could mostly keep this troublesome 1% under control. Modern agriculture techniques generally do not consider the relationship between organisms, or the balance between different populations that keep pest explosions in check.

Small scale farmers may attempt to grow crops in poor soils under less than ideal conditions. Plants stressed in this way are easily susceptible to pest and disease attack.

5.2 PLANTS

Unwanted plants are called weeds. Weeds can cause damage to crops in several ways:

- They take up water and nutrients from the soil, in competition with the crop.
- They can shade crops from the sun. Sunlight is very important for the growth of crop plants.
- They can host insect pests that can damage the crops.
- They can reduce the quality of the produce, e.g. weed seeds found in cotton would reduce the price considerably.

Weeds aren't always pests

They can be used to your advantage:

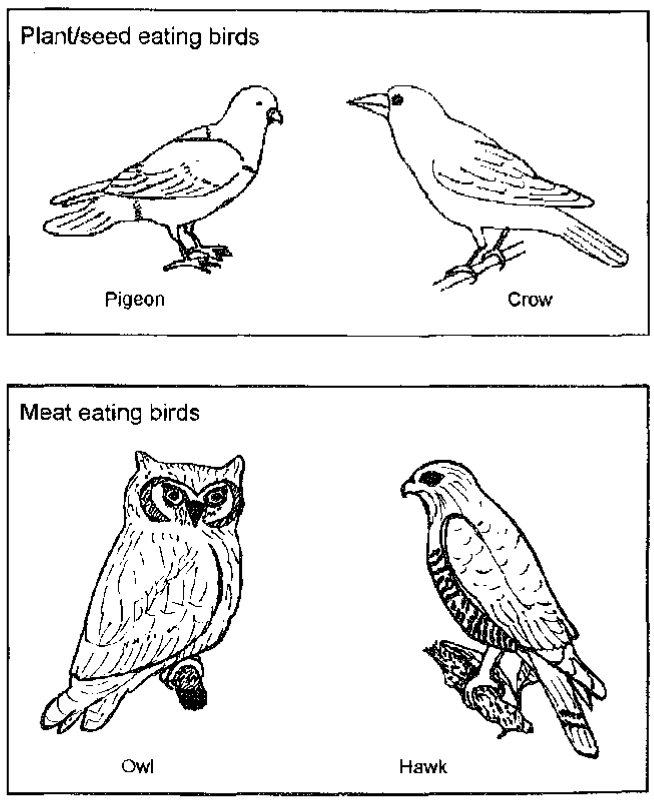
- Weeds can be slashed and used as a green manure to feed the soil.
- They cover the soil and can prevent soil erosion.
- They can attract and host very valuable beneficial insects (predators and parasites).
- They can act as wind breaks.

Animals

Birds

Birds can be divided into two large groups: the meat-eaters and the plant/seed eaters. The plant/seed eating birds can damage your crops by eating the seedlings, fruits and seeds of the crop. Such birds are: crows, sparrows, pigeons and finches.

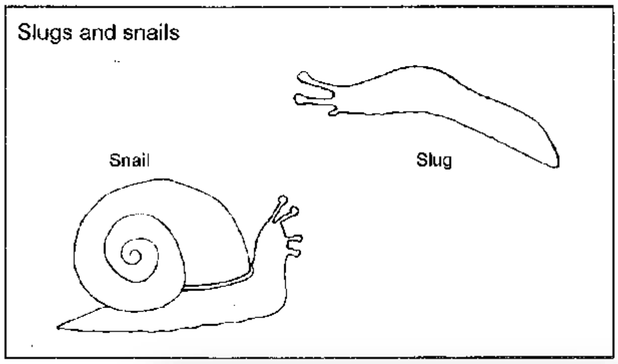
Not all birds are pests



The meat-eating birds can be very beneficial in your lands, as they will reduce the numbers of insects and rodents in the crops. Such birds are owls, swallows and hawks.

Slugs and snails

These creatures can cause considerable damage to your crops if they are not controlled.

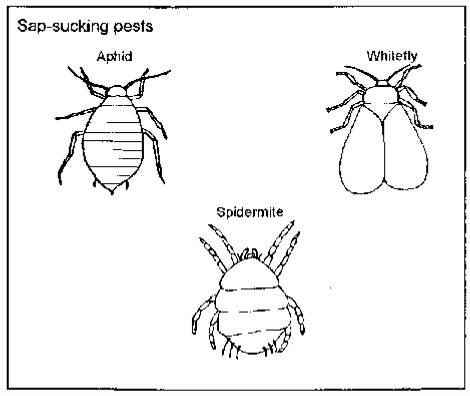


Insect Pests

Insect pests can be divided into two categories:

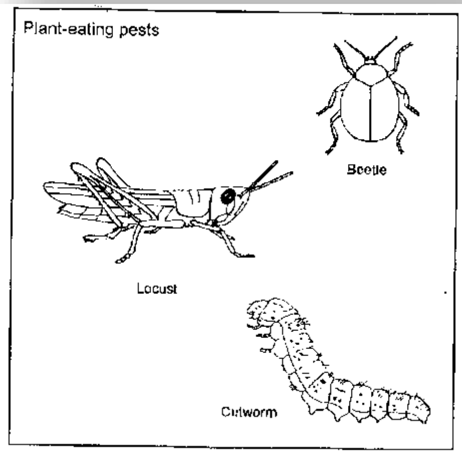
Sap-sucking pests

Examples are aphids, scale insects, mealy bugs, leaf and plant hoppers, whiteflies, thrips, mites and red spider mites.



Plant-eating/chewing pests

Examples are caterpillars (armyworms, leaf-miners, cutworms), beetles, locusts and crickets.



- **Not all insects are pests**

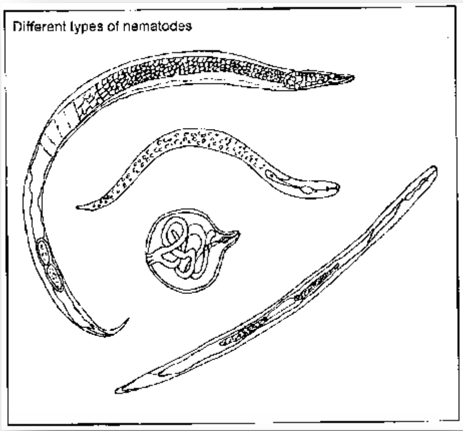
Some insects are beneficial to your crops, such as:
- Bees that pollinate crops,
- Predators that feed on insect pests (e.g. wasps) and
- Insects that help to decompose organic material (e.g. dung beetles).

Nematodes

Nematodes are very small worms that can hardly be seen with the naked eye. These tiny worm-like creatures feed mainly on the roots of plants. At first the damage will not be noticed, but as the numbers of these little creatures increase, the plants will decline and could eventually die.

- **Not all nematodes are harmful to plants.**

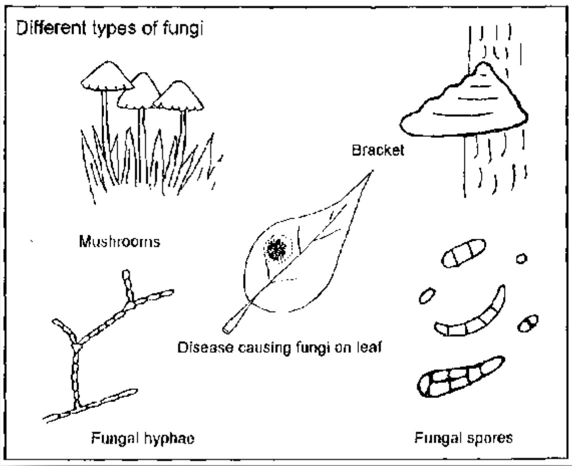
Only a small percentage of nematodes are plant eaters, the rest live on organic material in the soil or feed on small animals in the soil.



5. **Micro-organisms**

Micro-organisms are tiny creatures that can usually not be observed with the naked eye. They can, however, be seen when they occur in large numbers. Micro-organisms are responsible for diseases and can be classified as fungi, bacteria and viruses.

Fungi

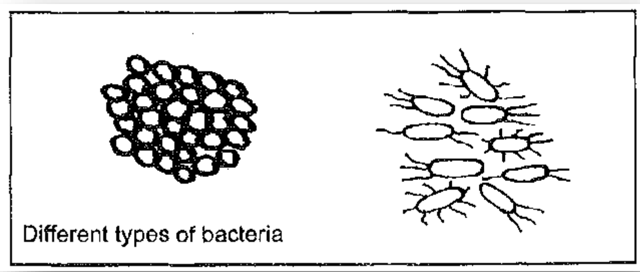


There are quite a variety of fungi that can influence our lives. Fungi that cause plant diseases are usually tiny parasitic organisms that grow on or inside plants. A mass of these usually consists of tiny threads (called hyphae), which infect the cells of the plant. Fungal spores can disperse through the air or with water or with the help of other organisms and cause new infections. They can lie dormant in the soil for several years, as sporing structures. Most fungi prefer moist, warm weather. Fungi can be devastating in a crop. Fungi cause diseases such as blights, mildews, and certain root rots.

Fungi are not always disease causing.

Some fungi are very useful and even crucial for life on earth. Some of these fungi are bigger and can be seen with the naked eye. For example the mushrooms and bracket fungi that are found on fallen trees. These fungi help with the decomposition of the wood and the nutrients in the wood are made available to other organisms. Other fungi are used by ants and other small insects as a food source

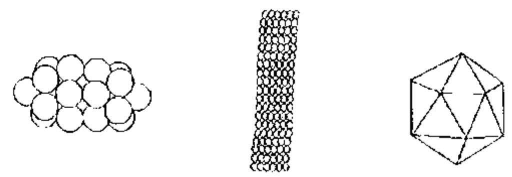
Bacteria



Bacterial diseases are caused by minute organisms that reproduce rapidly by division. Bacterial diseases in plants are difficult to cure. The best way to prevent serious damage is to destroy affected plants. Bacteria cause diseases such as soft rots and some leaf spots.

Viruses

Viruses are amongst the smallest of all living organisms. They cannot be seen with the naked eye. Only the symptoms can be seen on the plants. Viruses cannot reproduce without the help of another organism. They also need a vector to infect a plant. Many sap-sucking insects act as vectors. Generally there are no cures for virus diseases and affected plants should be destroyed.



Examples of different virus particles

- **Not all micro-organisms are pests**

Many species of micro-organisms can help plants by feeding them. Such beneficial micro-organisms are encouraged by healthy soils.

The symptoms of diseases are often similar to nutrient deficiencies and can easily be confused.

5.3 Diagnosing plant problems

Before symptoms can be treated it is important to have an idea of the cause of the problem. Damage to plants can be caused by insects, animals, micro-organisms, natural causes (such as drought and nutritional disorders), or by chemical injury.

It is not always easy to identify the cause of a problem immediately from visual symptoms. There are hundreds of causes of plant problems and two or more of the causes might produce the same symptoms. A single visual symptom can also be caused by a number of different problems.

Identification of the cause of a particular symptom requires years of experience, but guidelines can be given to make it easier.

It is important to note that the following are rough guidelines.

1. *Ways to identify insect damage*

SYMPTOMS	CAUSE
Ragged leaves, holes in wood, fruit or seed. Mining on leaves. Wilted or dead plants. The presence of larvae	Chewing insects
Foliage and fruit are off-colour and sometimes a bit distorted	Sucking insects removing sap [illegible] contents from the plant and injecting toxins into the plant
Black sooty substance covering the leaves, twigs, branches and fruit. The sooty cover can easily be removed by rubbing the leaves.	Honeydew excreted by certain insects leads to the growth of sooty mould. Leaves suffocate and plants do not grow well.
Galls on leaves, twigs, buds and roots	Gall forming insects
Scars on stems, twigs, bark and fruit. Fruit is sometimes infested with larvae	Insects laying their eggs in or on the plants.

2. *Ways to identify disease damage*

SYMPTOMS	CAUSE
Wilting, root rots and stunting	Clogging of water-conducting cells of the plant
Blotching, scab, black spots on leaves	Destruction of the chlorophyll in the leaves

Unusual growths on flowers, twigs and roots	Gall forming bacteria that disrupt normal cellular organization
Flower and seed rots	Fire blight and bacterial rots
Wilting, dwarfing and off-coloured foliage, usually patchy in appearance, leaves become distorted	Viral diseases carried from one plant to another by aphids and other sap sucking insects
Soft rotting of fruit, foul smelling.	Bacterial soft rots; usually in a wet environment

5.4 Bio-Indicators

Pests and diseases can be helpful in a way too. When these are spotted in the garden, they are indicators that something is wrong. In order to fix the problem, you need to know what the indicator is telling you. By just killing off the pests and diseases with chemicals, you will never fix the problem. The solution would be to make the plant and its environment healthy enough to fix itself. Healthy plants have a natural resistance against pests and diseases.

Weeds can also be used as bio indicators. They can tell us a lot about the soil they are growing in. Weeds with very strong taproots indicate soil compaction. The weeds grow there to break up the soil and improve the soil structure. Ferns and *Oxalis* indicate acidic soils, while nutgrass and sedges indicate that there is not enough air in the soil, because of compaction or water logging. *Amaranthus (shown alongside)* indicates fertile soil with bad structure, but very rich in nitrogen.. Weeds also take up minerals from the soil and keep them from washing away or leaching into the soil. Blackjack has the ability to take up nutrients that are not available to crop plants. If you take out the weeds from your land and bum them or just throw them out, you are losing vital minerals. Try to incorporate them back into the soil, so that the minerals can be used by your crops.

5.5 BIOLOGICAL PEST CONTROL

1. *Beneficial insects*

A relatively small number of insects can be regarded as pests. The majority of insects are harmless or do insignificant damage to crops.

Some insects are beneficial to the farmer in various ways. It is important to encourage the activities of these beneficial insects.

The beneficial insects can be divided into three major categories:

Praying mantid

- **Natural enemies**

Many insects eat other insects that are possible pests of crops. In this way the numbers of the pest insects are kept down.

Dragonfliy

These insects include:
Dragonflies - Feed on insects and worms.

Mantids - Feed on insects.

Ground beetles - Some species feed on aphids and caterpillars, snails, fly larvae, eggs or pupae, white others are vegetarian, living on seeds or green plants.
Ladybirds - Feed on aphids, leafhoppers, plant hoppers, scale insects and mites.

Lady bird

Lacewings - The adults and the larvae prey upon many pest species such as: plant hoppers, leafhoppers, aphids, scale insects, larvae of moths and mites.

Ant-lions - Feed on small crawling insects trapped in their pits.

Maggots of hover flies - Feed on aphids. The flies feed on pollen and nectar.

Lacewing

Robber flies - Feed on small flying insects and small grasshoppers.

Parasitic wasps - Parasites of pest species like caterpillars. They can also parasitise the eggs of pest species.

2. *Advantages of biological control*

- The agent targets the pest species and are non-toxic to other species and to human beings.
- Once the population of biological control agents are established, it normally retains itself.

Robber fly

- The development of genetic resistance is minimised, because the pest and the predator develops together.

3. *Disadvantages of biological control*

- Biological agents are slow to react. You will not get immediate protection from pests.
- Predators will have to be protected from pesticides sprayed elsewhere, because most pesticides kill all insects.

4. *Pollinators*

Bees are the main pollinators, but insects like butterflies, moths, several fly species and some wasps can also assist in the pollination process.

5. *Scavengers*

Some insects live on dead organic material and help in the breakdown of plant debris in compost heaps and in gardens. Animal wastes and dead animal tissue are also broken down in this manner, e.g. dung beetles.

6. Encouraging predators

It is important to recognize other predators of insects as well. The encouragement of predators can help control pests and diseases. A soil with a good structure can host a number of beneficial soil organisms.

Birds - Some birds feed on insects and can help in protecting your crop. Seed-eating birds will damage your crop.

Chickens feed on insects, but can damage seedlings.

Geese are used for weeding of orchards. They will eat fruit that has dropped from the trees, preventing them from rotting and contaminating other fruit.


Hover fly


Parasitic wasp


Bee


Diadem butterfly


Chameleon

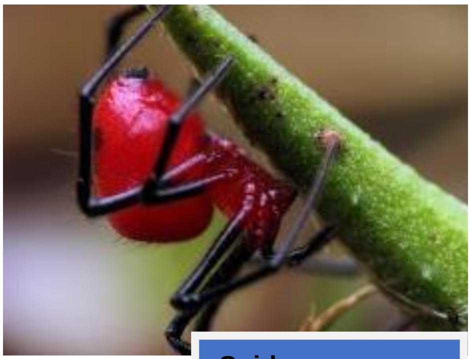
Chameleons - Feed on insects that can damage your crops.

Lizards - Predators of insects.

Frogs are good for controlling insect pests.

Snakes eat rodents and insects.

Spiders eat insects. The majority of spiders are harmless to human beings and they can be very helpful in keeping pests away.



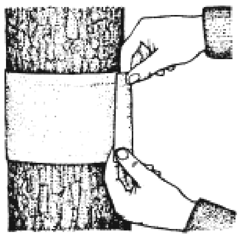
Spider

6. ***Physical control methods***

This is the use of physical methods to prevent or control the outbreak of pests or diseases. Physical control methods include barriers, traps and artificial guards. Some physical crop protection methods are still in use, but are mostly not regarded as important. Fly traps and sticky yellow insect traps are commonly used and very effective.

Right: A home made fly and fruit fly trap and Far right; a sticky yellow insect trap.

7. ***Protective borders and barriers***



Set up boards about 10cm high around your crop and paint them with fuel or oil, or use bands made of cloth or board on larger stems or trees. These boards or bands will discourage crawling insects from getting into the crop.

A tin can open at bothends, or toilet roll centers, can be placed over seedlings as collars to keep cutworms away from the seedlings. They should be pushed firmly into the soil *(Shown alongside)*.

8. ***Traps***

- **Snail and slug traps**
- Stale beer in a shallow plate or container, dug into the ground. The slug or snail will crawl into the liquid and drown. Other liquids containing yeast will also act as baits.

– An inverted cabbage leaf placed on the ground will attract snails, slugs, cutworms and other pests that hide during the day and forage at night.

Right: A beer trap for snails and slugs.

Ants can be lured into containers baited with sugar water, fats or any other food residue.

Grasshoppers are attracted by all kinds of scents: citrus fruit, lemon or vanilla extracts, beer, vinegar, salt, soap and smoke.

Cockroaches can be trapped by greasing the inner neck of a bottle baited with a raw potato or stale beer.

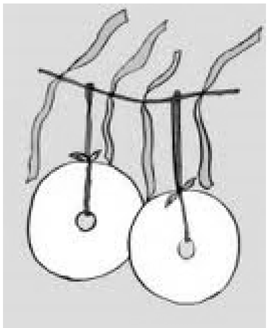
Some **flying insects** can be attracted by light. Red, orange and yellow lights are avoided or ignored by almost all insects.

Aphids, wasps and all kind of flies are attracted to the colour yellow. A trap can be made with a shallow yellow-painted bowl, filled with soapy water.

Many insects are attracted to different colours. Try experimenting with different colours. The collected pests can provide food for fish and chickens.

Rodents can be trapped in several ways. It is important to place the traps in the regular paths of the rodents, and they must be attractive to the rodents, so that they will investigate and not avoid the trap.

Rodents can be trapped and drowned when a large bucket is dug into the soil and almost filled with water. About 3 cm below the top edge a line of peanut butter is smeared. The animals fall into the trap and drown when trying to eat the peanut butter.



9. *Artificial guards*

Black cotton threads can be used to scare birds away from crops. The threads should be spread wide and loosely between the branches of fruit trees or around crops. The birds will fly into the threads and be scared away, without being trapped.

Scarecrows, cans and aluminium foil strips on strings,, as well as old cds' can be very effective in scaring birds and other animals away *shown alongside)*. Care should be taken to move them on a regular basis so that the animals don't get used to them.

Rodents and seed-eating birds can be scared by cutting out cardboard silhouettes of owls or other birds of prey and suspending them over the ground by attaching them to a rope and on top of a high pole. The shadow is cast on the ground and is mistaken for the real thing *(shown alongside)*.

Other physical control methods

Burning of infected plant material, ploughing back, etc., can be regarded as physical control.

Pupated maize stalk borers can be destroyed by making animal feed or fuel out of the maize stalks.

Stored beans can be protected by storing them in sand.

Weeds should be slashed before they flower to reduce reproduction by seeds.

Ants can be controlled by constantly destroying their nests and re-mixing the soil.

10. *Botanical remedies*

Spraying with herbal poisons or plant teas can control pests and diseases to a large extent. Some of the most widely used insecticides originally came from plants. The flowers, leaves, or roots have been finely ground and used in this form, or the toxic ingredients have been extracted and used alone or in mixtures with other toxicants. The active chemical from the plant was then identified and reproduced as a synthetic chemical in the laboratory and sold as a chemical. These synthetic chemicals have the same properties as the natural chemicals but do not break down as easily as the natural chemicals and can thus damage the environment.

Another advantage of natural or organic remedies is that they are cheap. **But it must be realized that some organic remedies are as poisonous as some chemicals and that some chemicals are less poisonous than some of the organic remedies.**

Many plants with control possibilities are known and probably many others are yet to be discovered. Leaves of many strong-smelling, bitter-tasting plants like gums, lantana, khaki weed, tomato or any other herbs have great potential for insect sprays. Plants that do not get attacked while in among affected plants are also potential remedies.

Hot water seed treatment to eliminate seed borne diseases

Seed can be treated using the following process:

- Place 250g of seed in a cotton back

-Soak the seed for 30 seconds in cold water and for 20 minutes in water heated to and maintained at 50°C (just too hot to touch)

-Cool the seed in fresh cold water

-Spread immediately in the shade to dry

Most plant material such as bulbs, rhizomes, tubers and cuttings can be treated in this way to reduce or eliminate disease.

General points regarding aromatic plant sprays

Sprays can be made up from the chopped up leaves of different strong smelling plants. Plants like garlic, chilli and onion work well.

The sprays have to be re-applied after rain or irrigation as they are washed off with water

Green bar soap can be added to make the spray stick to the plants and the insects

Generally the sprays are made up in 1 liter of water. They are diluted from there; 1 part solution to four parts water before being applied

Most botanical insecticides are contact poisons. Spraying has to be done rather intensively to ensure all insects have been covered by the spray.

Sunlight breaks down the sprays, so they should be prepared and stored out of direct sunlight

Some crops are damaged by sap from other plants and it is possible for some of these remedies to ‘burn’

6 MIXED CROPPING

Diversity in our gardens is important for family nutrition and for continuity. We also want to create as much diversity n pour gardens as possible to ensure a natural balance in the garden. We want to create a living soil, use water efficiently and minimize pest and disease attack on our crops.

To attain mixed cropping, corps can either be inter-planted (different crops in the same bed at the same time), or crops can be rotated (different crops are planted in the same place at different times). Using both practices in your garden is a good idea.

6.1 INTER-PLANTING

When planting a number of different crops together we need to consider the following:

- Nutrient consumption: We mix crops together that consume different amounts of nutrients. Some plants are heavy feeders and need a lot of nutrients. Other plants are light feeders and some even add nitrogen to the soil. A good example is the traditional practice of planting maize and beans together. Maize is a heavy feeder, while beans are light feeders as well as fixing nitrogen in the soil.
- Root depth: Plant deep and shallow rooted plants together to ensure that they do not compete for nutrients and water. A good example is planting maize and pumpkins together. Maize is an upright plant that has a deep rooting system and pumpkin is a creeping plant with a shallow rooting system. They do not compete for space either below or above the ground.
- Insect repellent plants: There are some crops which have a unique smell that repels some kinds of insects. For example, onion has a specific smell that butterflies dislike. If onions are inter planted with cabbage, this will reduce the attack from insects (worms). Combinations like onion and cabbage are called companion plants. Companion planting is an effective pest prevention measure.
- Timing: Some crops have a longer life cycle than others. It is possible to plant crops that mature quickly in-between crops that take longer to mature. In this way one crop can be harvested while the other crop is still growing and competition is reduced. An example is planting radish, mustard spinach and potatoes together. Radish matures quickly and is harvested within 6 weeks of planting. The leaves of the mustard spinach are harvested for 2-3 months. This reduces competition with the potato plants that are now growing large. Potatoes are harvested after 3.5-4 months. A combination such as this also includes that aspect of rooting depth, nutrient consumption and insect repellent properties.
- Shade tolerance: This becomes important when tall crops and perennial plants are also grown in the garden. These include fruit trees. Some crops such as comfrey, lettuce and strawberries are shade tolerant.

1. *Examples of inter-cropping in a vegetable garden*

The following combinations work well together in the same bed:

Plant carrots and onions together: Carrots protect against onion fly and onions protect against carrot fly. Carrots root more deeply than onions and are harvested earlier; giving the onions the space they need to mature.

Plant cauliflower or cabbage, lettuce, fennel and onion together: This combination gives complete control of aphids and diamondback moth (shown on the right) on the cauliflower. It takes into account nutrient consumption, rooting depth, insect repellent properties (onion and fennel), timing and shade tolerance.

Plant tomatoes, onion or garlic and carrots together: This combines insect repellent properties, nutrient consumption, rooting depth, timing and disease control. Tomato plants are scattered so that they do not touch each other, which reduces the incidence of early and late blight.

Plant swiss chard (spinach) and beans together: this combination takes into account nutrient consumption, rooting depth and disease control on the chard. Planting the chard in alternate rows with beans reduces the incidence of bacterial spot on the chard.

Many different combinations are possible. Below are two more examples:

Left: Swiss chard inter-planted with fennel and garlic chives

Right: A bed with onions, cabbage, lettuce and swiss chard planted together.

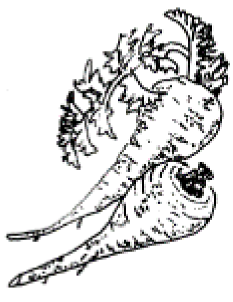
There are a number of crops that grow well together and some that do not. When planting a bed, use the diagrams below to choose combinations of crops that suite each other.

2. *Some plants which grow well together:*

Beetroot - onions

Carrots - peas, lettuce, onions, tomatoes

Onions - beetroot, strawberries, tomatoes, lettuce



Eggplant - beans

Cabbage - potatoes, beetroot, onions

Green Pepper - all vegetables

Lettuce - carrots, radishes, strawberries, cucumbers

Pumpkin - mealies

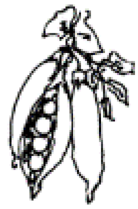
Swiss Chard - strawberries

Tomatoes - onions, carrots

Mealies - peanuts, peas, beans, cucumber, pumpkins, potatoes

Sunflowers - cucumbers

Beans - potatoes, carrots, cabbage, most other vegetables



3. *Plants that do not grow well together:*

There are some plants which do not grow well together. Try to avoid putting them in the same beds. Try and experiment for yourself.

Beetroot - pole beans

Onion - peas and beans

Cabbage - strawberries

Pumpkin - potatoes

Tomatoes - potatoes and cabbage

Beans - onions

Sunflowers - potatoes

Advantages and disadvantages of inter-planting

Advantages	Disadvantages
Efficient use of space below and above ground	Looks "untidy"
Reduces and avoids pest and disease build-up in the soil and in the garden	Can make harvesting of crops more time-consuming
Reduces weeds. Covers the soil and uses nutrients in an effective manner. Building of a healthy, living soil is possible.	Weeding can be more time consuming initially, as crops may be scattered, rather than being planted in rows

Plants support each other in a synergistic relationship that protects against pest and disease attack and increases vigour and growth	Some shading may occur if plants are not spaced well
Efficient use of water	Some plants may be over or under watered depending on their life cycle. For example, some plants may be seeding while others are still growing.

6.2 CROP ROTATION

The same crops are not planted in the same areas, fields or beds season after season. Different crops are planted in a 2-4 year rotation. These crops are chosen to have a mutually beneficial effect.

1. *Effects of crop rotation*

It prevents or stops the accumulation of insects and diseases. If the same crop is planted some insects and diseases will become more every year!

- Different crops use different nutrients or plant food stored in the soil. In this way you do not overuse some of the plant foods, while not using others.
- The soil can be covered all year round.
- Some crops add nutrients or nitrogen to the soil. Examples are beans, peas, broad beans, soya beans, peanuts, cowpeas, lucerne and clover.
- It prevents the soil from building up bad or negative reactions to specific plants. An example here is nematodes on tomatoes and swiss chard. Nematodes are very small worms that we cannot see with our eyes. They live in the soil and feed on the roots of your plants.
- There is no buildup of specific weeds.

There are a number of different crop rotation systems that can be used. Below is an example of a system that is easy to use and remember.

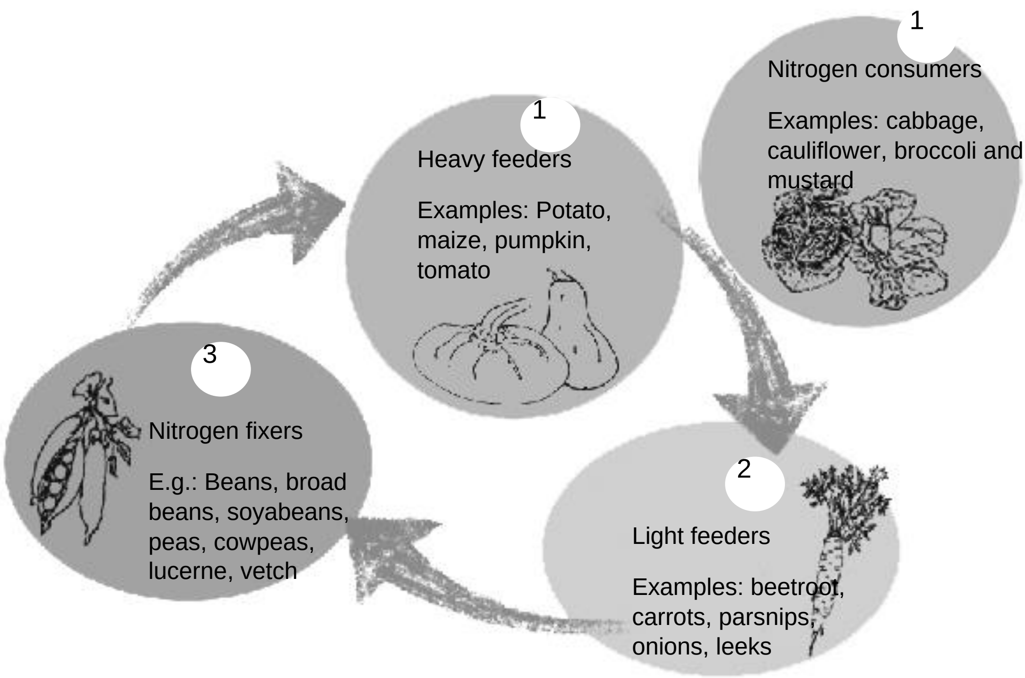
A 3 year rotation for vegetable and field crops: In the first season after applying compost and or manure heavy feeders or nitrogen consumers are planted.

In the second season light feeders are planted and

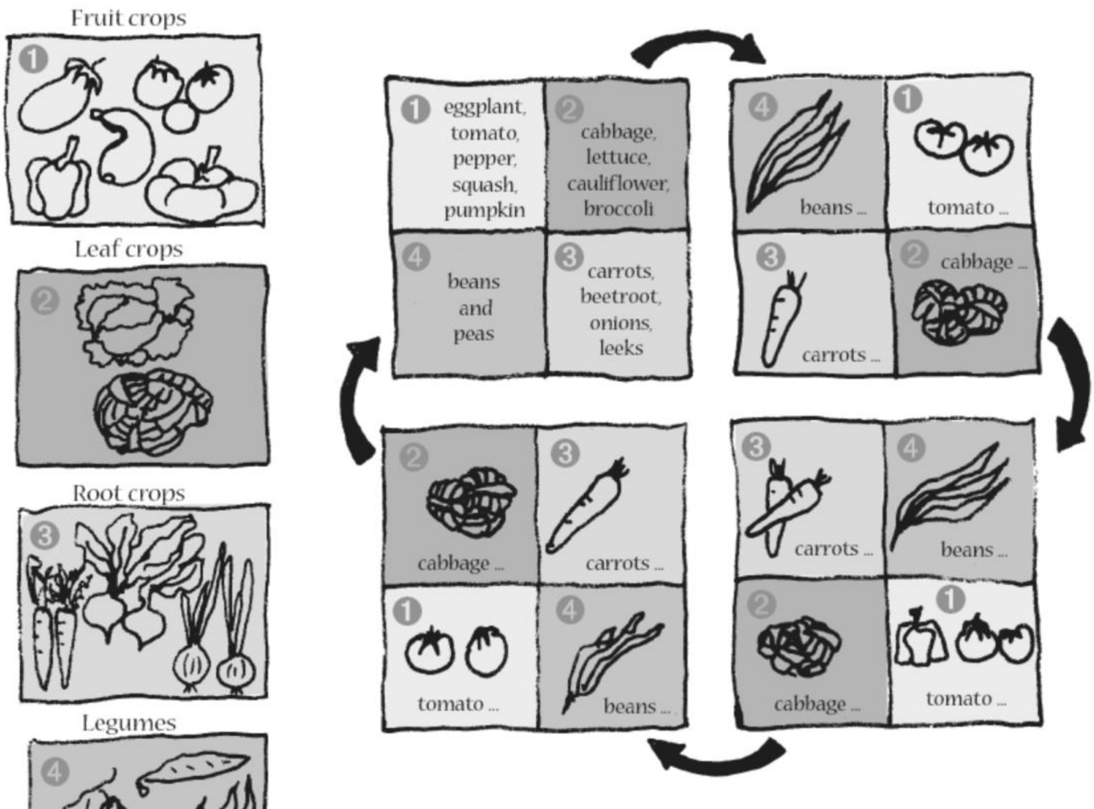
In the third season legumes are planted. This is followed by another application of compost or manure and the cycle is repeated.

> Preparing the bed well:
>
> This would mean trenching, or double digging or addition of a lot of compost/manure forked into the top 40cm of soil. You will need at least 4 full spades for every square meter.
>
> A general recommendation is to place 30 tons of compost to a hectare of land. This comes to about one half of a wheelbarrow load for every square meter (which is about the same as 4 full spades!)

In trench beds, where the organic matter is decaying slowly in the soil, you may want to start with legumes, move on to heavy feeders or nitrogen consumers and then move on to light feeders. This is because during the decaying process plant nutrients will take a while to become available for use by plants. The legumes can fix most of their own nitrogen and are thus a better starting point.



A 4 year rotation for vegetables.



A SIMPLE ROTATION: DIVIDE YOUR GARDEN INTO FOUR EQUAL PARTS. THE NEXT TIME YOU PLANT, MOVE EACH FAMILY OF VEGETABLES TO THE NEXT PLOT.

From: The People's Farming Workbook, EDA, 1995

Prepare the land or bed well. Put a lot of compost or manure in your bed (4 full spades/ square meter). Then:

Start by planting a fruiting crop. These plants need the most food.

Leaf crops need less and can follow fruit crops.

Then root crops can follow leaf crops without much addition of plant food. Root crops like fertile soil, but do not like fresh manure or compost. It has to be well rotted.

Then, nitrogen fixers can follow, with addition of little or no plant food. Then you need to prepare the land well again. Start once more with fruiting crops.

Advantages and disadvantages of crop rotation

Advantages	Disadvantages
No build up of pest and diseases Soil nutrients are used effectively Soil moisture is used effectively A healthy living soil can be built up over time	Without a plan, either drawn or written on paper, it is difficult to remember which crop is to follow It can be tricky to decide which rotation to follow when inter-planting is also used