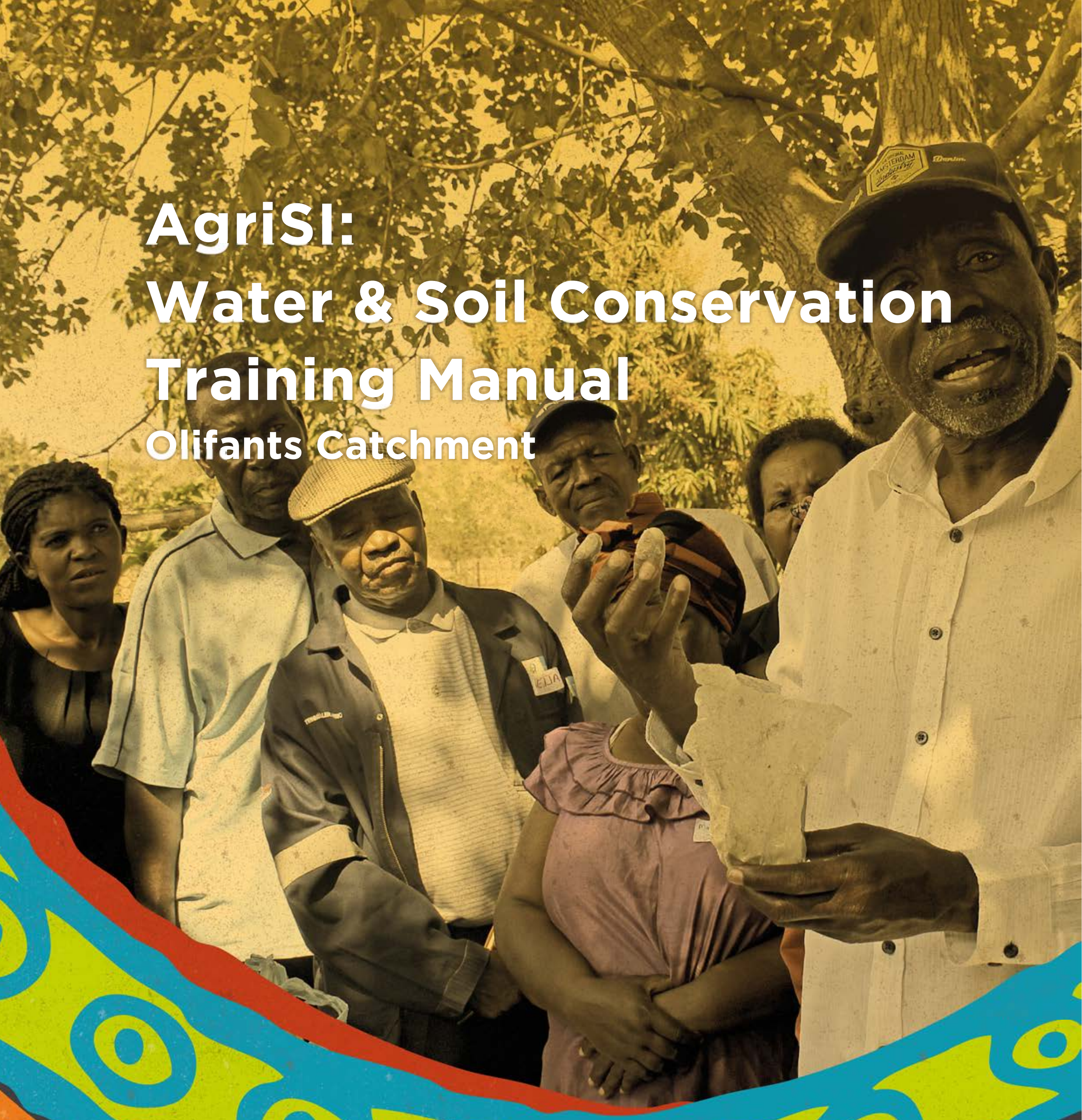
AgriSI: Water & Soil Conservation Training Manual

Olifants Catchment



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USAID: RESILIENCE IN THE LIMPOPO BASIN PROGRAM (RESILIM) - OLIFANTS

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Training outline

Topics to be covered in the learning process for each of the learning groups are summarised below. Learning activities include learning workshops with theoretical and participatory inputs, demonstrations and smallholder farmer experimentation and design.

Some activities take a concerted effort over extended time periods and will be handled on a once off basis as spate learning events. An example here is the construction of small dams or underground storage tanks.

Some activities are group based and will be implemented by the learning groups rather than individuals and will be handled in separate learning events. Examples are building check dams in eroded water ways, stone bunds along roadside verges.

Overall learning time for each learning group over the period of project implementation is 5 days. Sessions will be planned that are appropriate to the group's requests, immediate needs and seasonal requirements.

Day 1: WATER CONSERVATION AND HARVESTING

- **Garden layout**; catchment areas, run-off, trapping and storing, aspect, slope, wind, homestead drawing (walkabout), line levels and A-frames – measuring contours and slope, farmer experimentation… (3,5hrs);
- **Water harvesting in soil;** diversion ditches, swales, infiltration pits, banana circles (3,5hrs);
- **Soil and water conservation**: stone bunds, mulching, *drip kits, tunnels- check dams (Joint activities separate training;*
- **Harvest off a surface**- underground storage *(small dams, tanks)* 10hrs …*(Joint activities, separate training);*
- **Greywater:** Water filters, tower gardens, sack gardens and *keyhole gardens* (3,5hrs). *(Joint activities, separate training).*

Day 2: SOILS AND SOIL CONSERVATION

- **Soil type and structure:** Sausage and bottle test….. sand, silt, clay, OM, (1hr)
- **Infiltration test**: (how much – run-off,…) How long will it take before it runs off… (30min)
- **Natural soil fertility**: Practical demonstration of rooting depth and plant growth, local tillage pans, soil nutrients (macro and micro), nutrient deficiencies and deficiency symptoms. Working with manure, making compost…(3,5hrs)
- **Techniques currently used**; tips from farmers… (1,5hrs)
- **Bed design** – trenches (deep and shallow), eco-circles…(3,5hrs).
- **Liquid manures;** manure, banana stems and green stuff…

Day 3: INTENSIFIED HOMESTEAD FOOD PRODUCTION

NUTRITION:

- Go, grow, glow; analyse their diets, …gaps, suggest possible crops…(1,5hrs);
- Cooking; sweet potato bites, picallilly, atjar, ibece jam… (travel with gas bottle, I plate, pot, glass bottles, (2hrs);
    - Legumes – mung beans, lentils, split peas.
    - Drying; frame, blanching, (examples – greens, sweet potatoes, green peppers, carrot, onions) (30min);
- Different food crops; varieties, continuity, nutrients (protein, vitamins) (bring new seed options- small packets for each person. (1,5hrs).

NATURAL PEST AND DISEASE CONTROL:

- **Pest and disease problems** and how they deal with them now (1,5hrs);
- **Pest repellent plants and for brews:** wormwood, rosemary, lavender, lemon grass, irises, (1hr);
- **Physical control methods**: Cutworm collars, snail bait, … netting, moles…(two litre bottles, whirly gigs, …ditches around the beds garden, euphorbia, wild garlic, (1hr);
- **Make brews**; chilli garlic soap, onions and paraffin, … pyrethrum (pyrethrin)…(45min);
- **Experiments** (1,5hrs).

DIVERSIFIED CROPPING:

- **Continuity**; containers, seedlings, seasonal (seasonal calendar), out of season..
- **Intercropping/mixed cropping**; families, leaf, root, legume, fruit… (small groups design a bed or two);
- **Propagation**; cuttings, seedling mixes (1/3 ea of river sand, soil and compost/manure);
- **Plant the beds** – seed and interesting things ; marigolds (nematodes- tomatoes, spinach), parsley (Fe, helps with absorption of vitamin A), coriander (vit C, umbrella flowers- predators), different greens (kale, rape, turnips, mustard spinach ,Chinese cabbage, - indigenous greens – (visual aid – nutritional values), (amaranthus -…) spring onions, leeks, chillies, garlic, garlic chives …legumes…;
- **Seed saving**: Types of seed, planting crops for seed saving, harvesting and storage of seed;
- **Planting trees**; fruit trees, multipurpose species, windbreaks;
- **Conservation agriculture**: Planting basins, intercropping, inclusion of legumes and cover crops. Grains; maize, sorghum, millet.

1 Water conservation and harvesting practices for smallholder farmers

1.1 Water harvesting and conservation

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.

Figure 1.1: A view from the top of the Maseko farm

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.

Zvishavane 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.

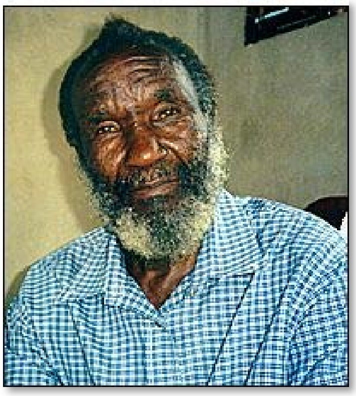


***Figure 1.2:** Mr Phiri Maseko*

Zepheniah Phiri Maseko was born in 1927. After he completed his schooling he went to work for the Rhodesian Railways in Bulawayo. In 1964 he was fired from his job for being politically active and was told by the government that he would never work again in any position.

At the time Phiri was married with six children, so in 1966 he started farming in order to try and support his family.
When Phiri first began 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:
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.

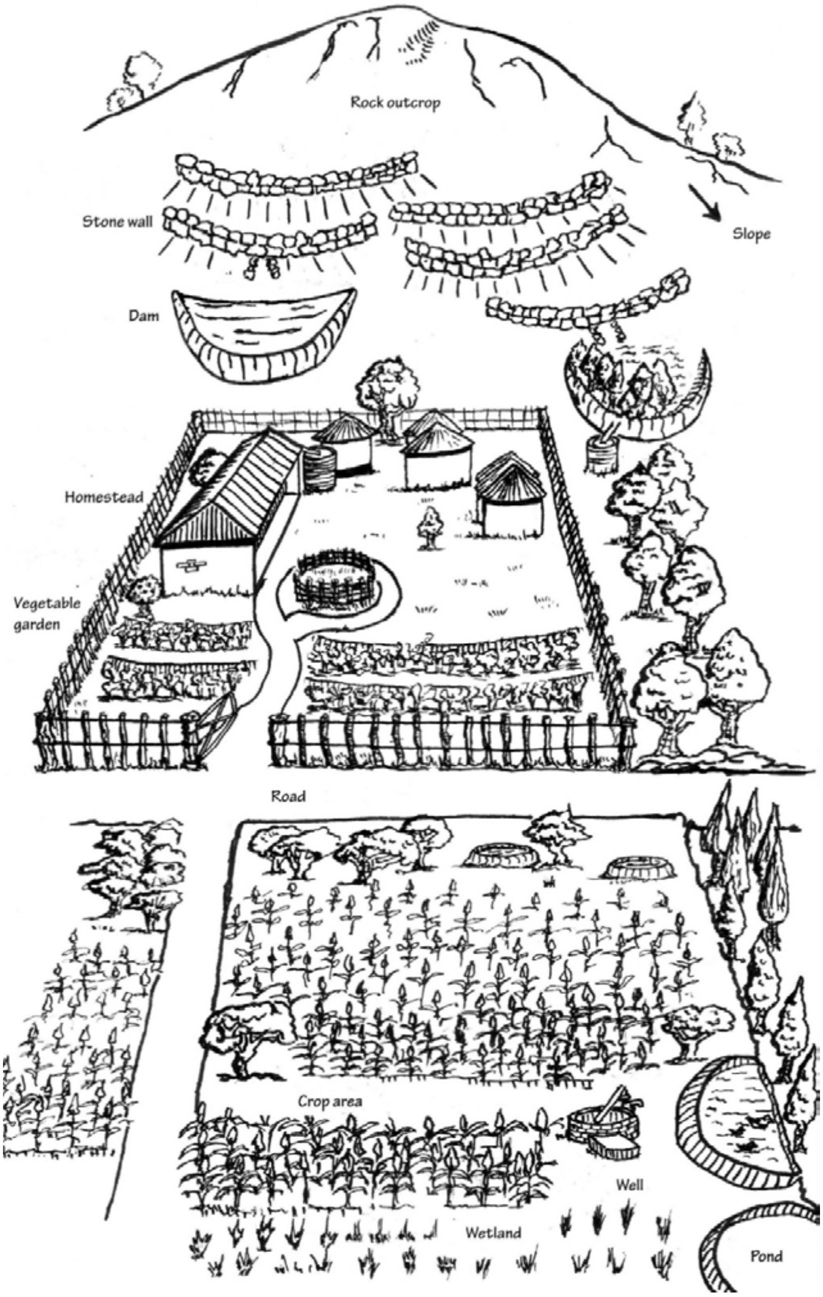


Figure 1.3: The Maseko family homestead

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.

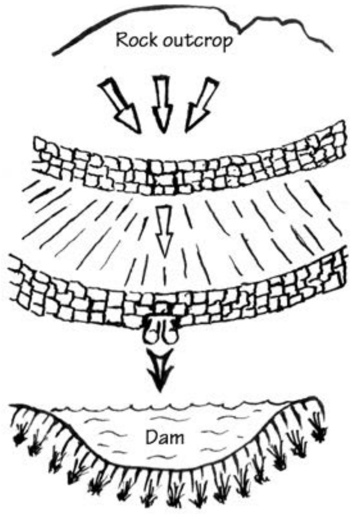


Figure 1.4: Rainwater is directed into dams

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.

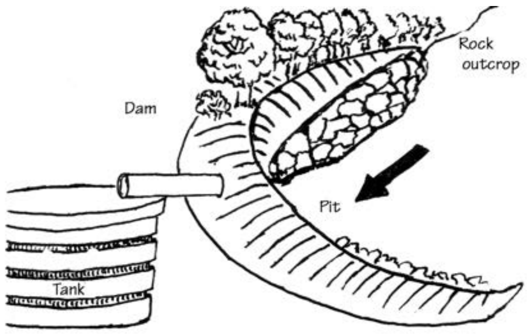


Figure 1.5: Water overflow is directed into a storage tank

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.

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. 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.

Figure 1.7: *Members of the Phiri homestead standing next to their maize crop*

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.

1.2 Principles of Water Harvesting and Conservation

Principle One: Begin with long and thoughtful observation

Phiri's water harvesting and conservation (WHC) began when he started observing and paying close attention to what happened when it rained. This action, which for Phiri was the obvious starting-point in trying to understand and then change his situation, is also the first principle of water harvesting and conservation.

Principle Two: Start at the top of your CATCHMENT and work your way down

After Phiri had spent time observing how water flows over and into the land, he began to experiment with ways of harvesting the water by capturing it in the soil. Because water flows downhill, Phiri began these experiments at the top of his property where water entered his landscape, and then worked his way down the slope.

Principle Three: Start small and simple

When Phiri began, he did not have the financial resources to invest in specialized tools or equipment, nor did he have the knowledge to develop a complex, extensive water-harvesting *system*. However, he did not let this deter him. Instead, he began with something small, manageable, and cost-free: he built – by hand – the low stone walls below the rock outcrop at the top of his farm.

Principle Four: Slow, spread and infiltrate the flow of water

Phiri built the stone walls in order to try and control the flow of storm water off the rock. His initial observations had made him realize that if he could slow the water down and spread it out, more of it would be able to soak into the ground. Over time Phiri learned that the best place to store water is in the soil, which is why his methods are designed to help water sink into the soil as quickly as possible.

Principle Five: Always plan an overflow route, and manage that overflow as a resource

Phiri did not want any water to go to waste, so he put structures into place to help manage water overflow when it did occur. He did this by directing excess water from the small dam into a storage tank, and by designing his ponds so that the smaller one catches water overflow from the larger one. Every drop of water on the Phiri farm is treated as a valuable resource.

Principle Six: Create a living sponge

Through observation, Phiri learned that groundcover such as grass, vegetation or *mulch* slows down water and draws it into the soil. Phiri set about planting a wide variety of indigenous vegetation around his property and spreading organic mulch over his soil, thereby creating a "living sponge" which maximises the amount of water that infiltrates the soil.

Principle Seven: Do more than just harvest water

Phiri learned about and experimented with different water harvesting methods, and over time he developed an entire farm *system* which is efficient and which maximises relationships that are mutually beneficial (for example, the vegetation which grows around the pond helps hold the soil in place).

Principle Eight: Continually reassess your system

Phiri learned by trial and error. He changed or altered strategies which did not work, and he built on those which did. His system, which evolved over a long period of time, was developed through continual reassessment. As Phiri said, “Sure, it’s a slow process, but that’s life. Slowly implement these projects, and as you begin to rhyme with nature, soon other lives will start to rhyme with yours.”

While each of these principles is important in its own right, it is essential that all eight are used together so that their effectiveness and value is maximised. You will learn more about the WHC principles as you work through this manual.

1.3 Defining Water Harvesting and Conservation

The term rainwater harvesting refers to collecting, conveying and storing rainwater for various end uses.

The following are some more comprehensive definitions: “Rainwater harvesting refers to the concentration and entrapment of rainwater runoff from a catchment. A catchment is any discrete area draining into a common system and thus can be a roof, a threshing floor or a mountain watershed. Similarly, the means of rainwater storage can range from a bucket to a large dam.”

“Water harvesting can be defined as the process of concentrating rainfall as runoff from a larger catchment area to be used in a smaller target area. This process may occur naturally or artificially. The collected runoff water is either directly applied to an adjacent agricultural field (ie. stored in the soil-rootzone) or stored in some type of on-farm storage facility for domestic use and as supplemental irrigation of crops.”

“Rainwater harvesting is the collection and/or concentra-tion of runoff water for productive purposes. It includes all methods of concentrating, diverting, collecting, storing, utilizing and managing runoff for productive uses. Water can be collected from natural *drainage* lines, ground surfaces, roofs for domestic uses, stock and crop watering.”

A definition of *water conservation* is: “The protection, development, and efficient management of water resources for beneficial purposes.”[12]

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.

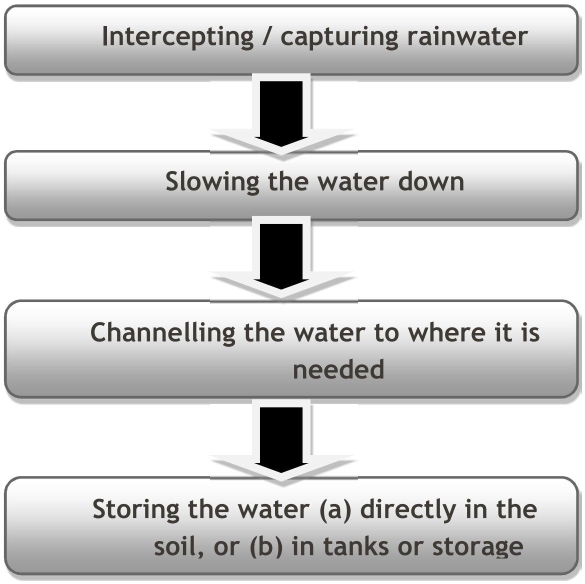


Figure 1.8: *The water harvesting and conservation process*

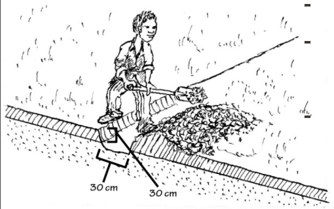
Based on the above definitions, as well as the practices of people such as Phiri Maseko who harvest and conserve water, we can say that water harvesting and conservation involves:

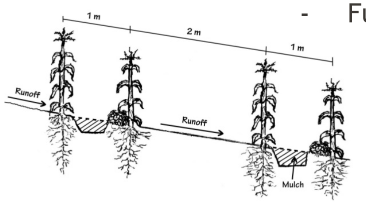
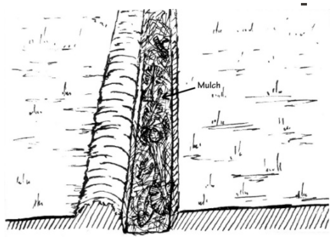
1.4 Overview of WHC Methods

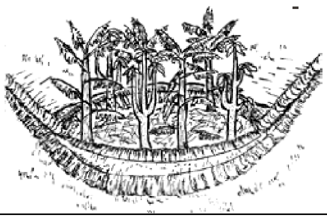
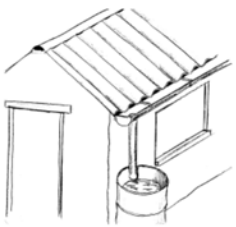
There are many different forms of water harvesting and conservation. The methods selected for this manual are summarised in below, along with a short description of what each method entails. Many of these methods can be used together and complement each other well. In this manual, the methods that have 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

TABLE 1.1 DIFFERENT FORMS OF WATER HARVESTING AND CONSERVATION

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.

Name Used in Manual	Similar to :	Description	Main purpose or comment	Type of Water Harvesting System
Ploegvore 	- Pitting - Zai - Chololo - Matengo - Ngoro	This water-harvesting method involves creating numerous small, well-formed **pits or "imprints"** in the soil that collect rainwater runoff, seed, sediment and plant litter. This provides a relatively sheltered microclimate in which seed and seedlings can grow.	Used widely outside of South Africa in more arid areas for crop production - where pits are made by hand. Inside South Africa, pitting is more commonly made with specialised ploughs for pasture rehabilitation.	Micro-system. Can be done by hand at a small scale for crops. Pasture rehabilitation requires specialist mechanisation because of the large scale.
dDomewater harvesting 	- Rock catchment	***Dome water harvesting*** is used to intercept and direct rainwater runoff from impermeable rock domes directly to a field where water is stored in the soil, or to a reservoir of some sort.	- The method provides valuable drinking water in arid areas. - Can be very effective for agricultural use where rock surfaces are located close to agricultural lands.	Macro-system.
Saaidam 	- Wadi floodwater system - Flood-spate - Rabta	the **saaidam system** entails the diversion of floodwater from non-permanent rivers into a series of flat basins which are used for cropping. Each flat field is completely surrounded by a low earth embankment (wall) of between 0.5 and 1.5 metres high. Diverted water from the flooding river is channelled into the fields and completely submerges the land for 1 to 3 days, where it fully saturates the soil.	- Used mainly for lucerne production, but also successful with vegetables. - Deep alluvial soils well utilised by deep-rooted lucerne.	Floodwater harvesting.

Useful but not covered by this manual	Similar to :	Description	Main purpose or comment	Type of Water Harvesting System
Conservation tillage	Includes: - no-tillage - low-tillage - gelesha	This includes any kind of planting, hoeing and ploughing practice that conserves water and soil. The aim is to minimise soil turning, to keep permanent cover, to mulch, and to rotate crops.	This is an integrated crop production practice which includes water harvesting and conservation practices. But the emphasis is on the crop selection, rotation.	Water conservation
Small earth dams	- water ponds - matamo	A (small) ***earth dam*** is a 1m to 5 m high wall built across a drainage line, stream or river to store water. They are made of compacted clayey material with a wide base and a narrow crest (top of the wall).	Seasonal and permanent water storage for cattle watering / domestic use. Small cattle dams on drainage lines are familiar part of all rural South Africa. Technical competence is usually needed to ensure stability and water tightness and experienced input to design and construction is advisable.	Water storage
Sand dams	- sub-surface dams	A ***sand dam*** is an underground wall across a dry sandy riverbed. The sand fills up to the top of the wall and water is trapped behind the wall, in the sand. A pump is usually used to get water out.	Sand dams are more easily built in arid, sandy areas than other dams. The water tends to be higher quality than other surface water sources because of the filtration effect of the sand. Sand dams recharge groundwater.	Water storage / groundwater recharge

2 Water in the landscape

2.1 The water cycle

1. **Evaporation:** Heated by the sun, water evaporates into the atmosphere from the surfaces of any open body of water such as oceans, lakes, rivers and dams. Because oceans cover three quarters of the Earth's surface, evaporation from the oceans contributes most of the water to the atmosphere. On land, as much as 90% of the water that reaches the atmosphere, comes from plants as they release water vapour into the air during a process called *transpiration*. Find out more about this process in the next section.

2. **Condensation:** The water vapour in the air condenses back into water when it cools down there. Clouds are formed that consist of very small droplets of water.

3. **Precipitation:** Water falls from the clouds back to Earth through rain, hail, sleet and snow. Dew, frost and mist are formed when water vapour condenses directly onto the land without first forming clouds. Precipitation falls back into the oceans and onto the land, where it flows as *surface runoff* over the ground down *water catchments*. Some of this runoff flows into rivers, while a portion *infiltrates* the ground and becomes a part of the *groundwater*.

   Some groundwater infiltrates deep into the earth and replenishes ***aquifers*** (porous layers of rock which hold water). Other groundwater does not penetrate as deeply. Some seeps back into bodies of water on the surface of the earth – such as lakes and the ocean – as *groundwater discharge*, while other finds openings in the surface of the land and emerges as freshwater ***springs*** or the sources of rivers or streams.

4. **Infiltration:** Water falls on the land and infiltrates the soil until all the soil pores/openings are filled and the soil is saturated. The water that infiltrates the soil becomes groundwater.

Groundwater plays a critical role in supplying water to streams and wetlands, but it is vulnerable to both *overuse* and *contamination*. Aquifers can be over-pumped, resulting in an area-wide lowering of the water table. Aquifers which are over-pumped can be permanently damaged, leading to their collapse or to the closure of their water-bearing factures. Over-pumping can also increase the salinity (saltiness) of the water.

There are many ways in which groundwater can become polluted. Seepage from broken sewage pipes and leaking pit latrines enters into the earth and contaminates the groundwater, a situation which is made worse when there is heavy rain or flooding, when the groundwater is close to the land surface, or where the ground is very permeable. Fertilizers and factory waste containing nitrates can seep into the soil or be washed into rivers and streams, and this runoff can cause serious illness in humans. Nitrates also cause the eutrophication of surface water, which means that the water becomes rich in mineral and organic nutrients. This promotes a proliferation of plant life, particularly algae, which feeds on the nitrates and reduces the oxygen content of the water, causing the extinction of other organisms such as fish. Poorly designed water points (places where people get their water from a tap or pump) are often surrounded by stagnant water where mosquitoes breed, animals drink, children play and women sometimes wash clothing. This dirty water seeps back into the groundwater, which in turn becomes contaminated.

Further rainfall runs off into puddles, streams, rivers, lakes and finally into the ocean. Ultimately all water will end up back in the ocean to start the whole process again. No new water therefore enters the cycle and no water ever leaves the cycle.
(QUESTION: So if it is getting drier – where is the water going?)

Evapotranspiration

This is an important concept in cropping and combines evaporation off the soil surface with transpiration of water vapour from plants.

The annual reference evaporation ranges from 1300 mm (1,3 metres) on the east coast, and 1500 mm (1,5 metres) in the North and interior, to 1800 mm (1,8 metres) in the West. Annual means for a period of one year. This means that the evapotranspiration values are higher than the rainfall values. Therefore the main function of irrigation and rain harvesting is to close the gap between low rainfall and high evapotranspiration. Crops need to get at least as much water as they lose in evapo transpiration in order to produce high yields.

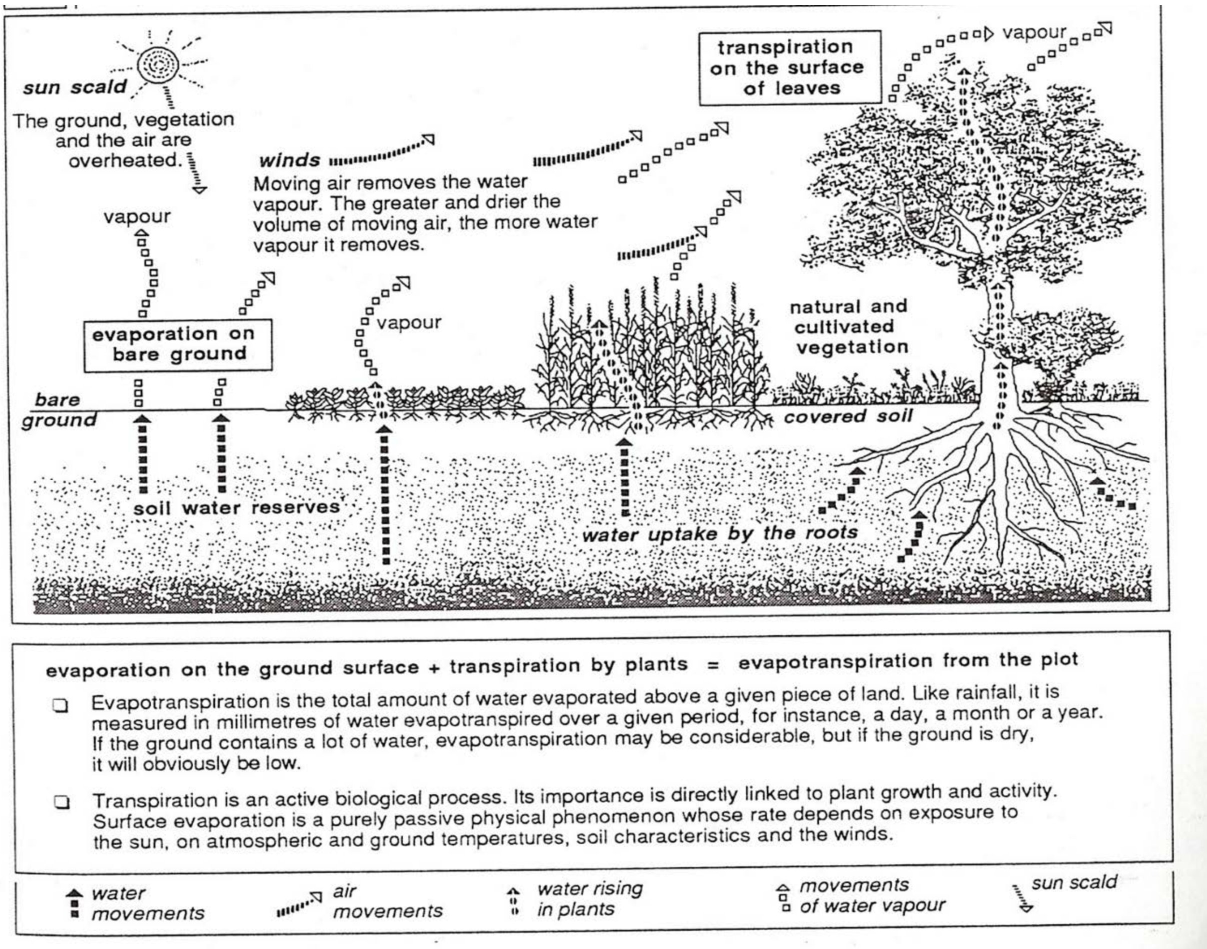


Figure 2.1: Evapotranspiration

South Africa has a number of different **water users**, as shown in the table below:

TABLE 2.1: CURRENT ALLOCATION OF WATER USERS.

WATER USERS	CURRENT % OF ALLOCATION	REMARKS
AGRICULTURE	62%	As the largest consumer of water, the challenge in this sector is to produce more food with the same or less water, enhancing the productivity of water.
DOMESTIC **- URBAN** **- RURAL**	27% - 23% - 4%	Population growth will lead to an estimated total of 53 million people by 2025. Growth in urban areas is larger than in rural areas and spatial variances need to be monitored to match future demand.
INDUSTRIAL	3.5%	Pollution through industry needs to be tightly monitored and control measures put in place and policed.
AFFORESTATION	3.0%	Timber-based products make a significant contribution to the economy. Afforestation is on the increase.
MINING	2.5%	Water usage in the mining industry is a major contributor to water quality problems.
POWER GENERATION	2.0%	Eskom has, with some clear directives from DWAF, progressed from the highly intensive wet-cooled systems towards the more efficient dry-cooled systems.

2.2 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***.

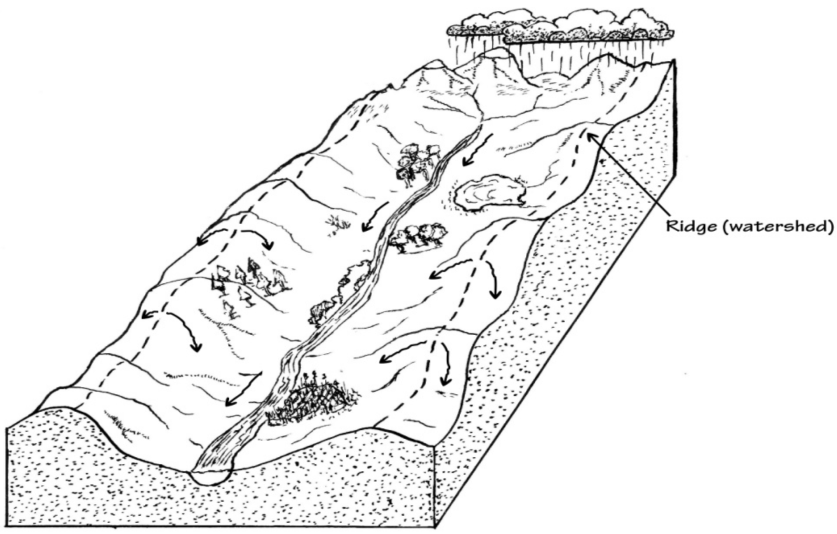


Figure 2.2: A water catchment

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.

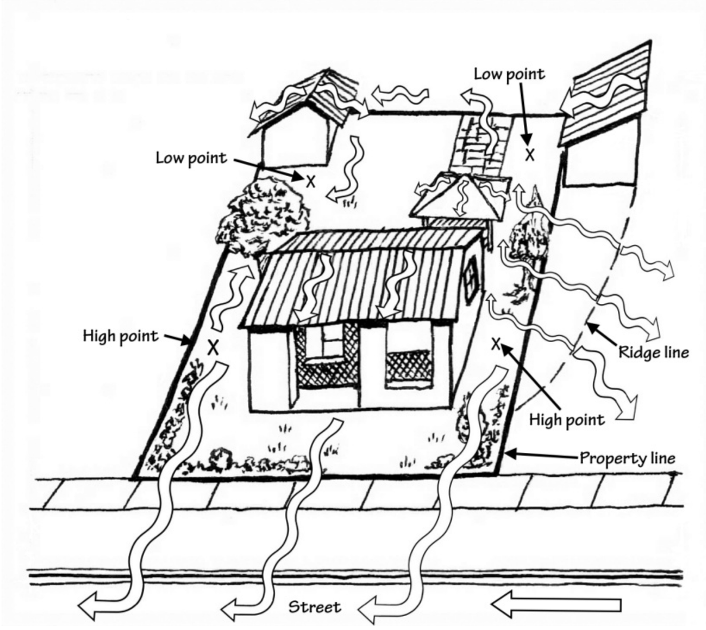


Figure 2.3: An urban water catchment

2.3 Topography – Aspect and slope

2.3.1 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.

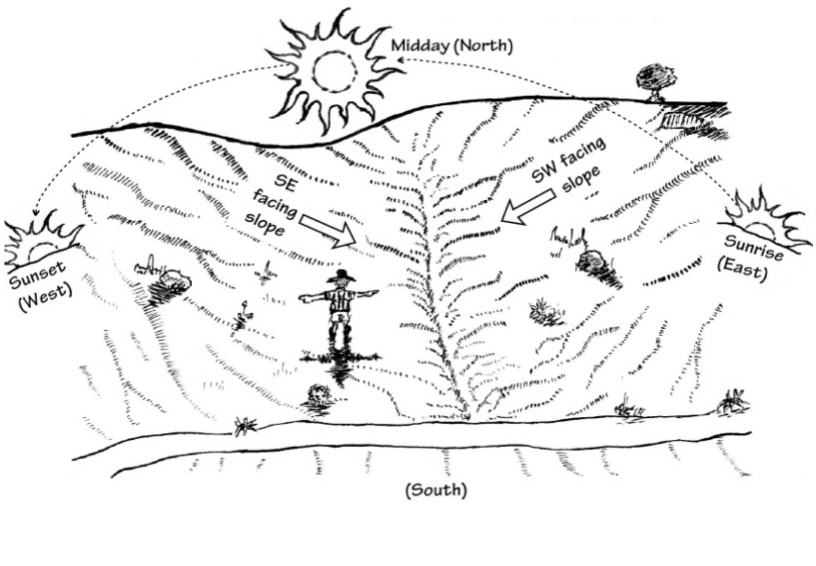


Figure 2.4: How to determine aspect (Method)

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.

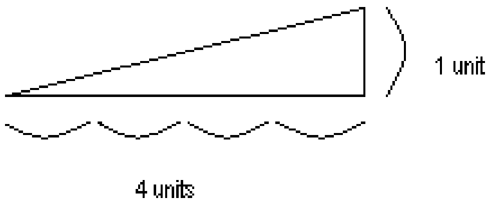
2.3.2 Slope

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.

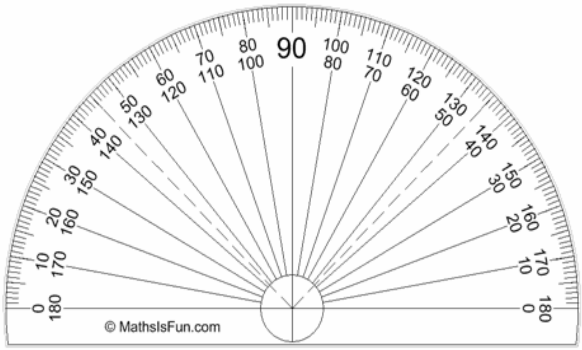
Slope also needs to be taken into account when planning and implementing most WHC methods, mainly to ensure that soil erosion does not occur.

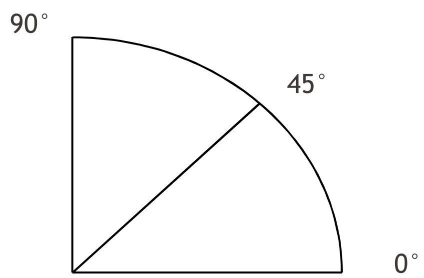
Slope can be expressed in the following three ways:

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



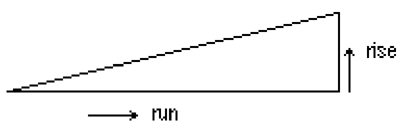
2. **Degrees** – this is a measurement used to represent the angle of a slope. Degrees can be measured with a protractor or with survey instruments. Land that is completely flat (horizontal) is 0°, while a vertical cliff is 90°.





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

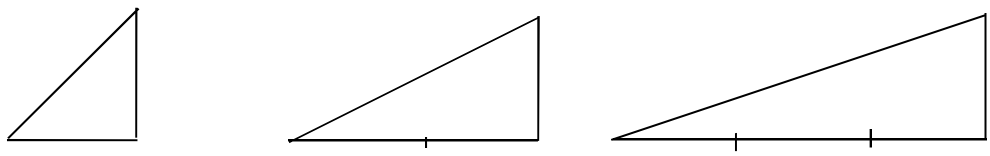
$$\text{Slope (\%)} = \frac{\text{rise}}{\text{run}} \times 100$$



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:

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

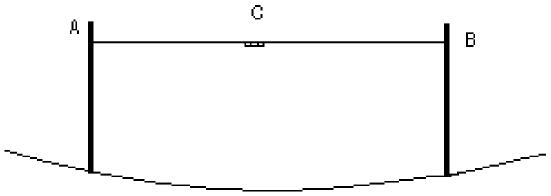
The following slopes are expressed in proportion, degrees and by percentage.



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

2.3.2.1 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)

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.

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

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.

2.3.2.2 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).

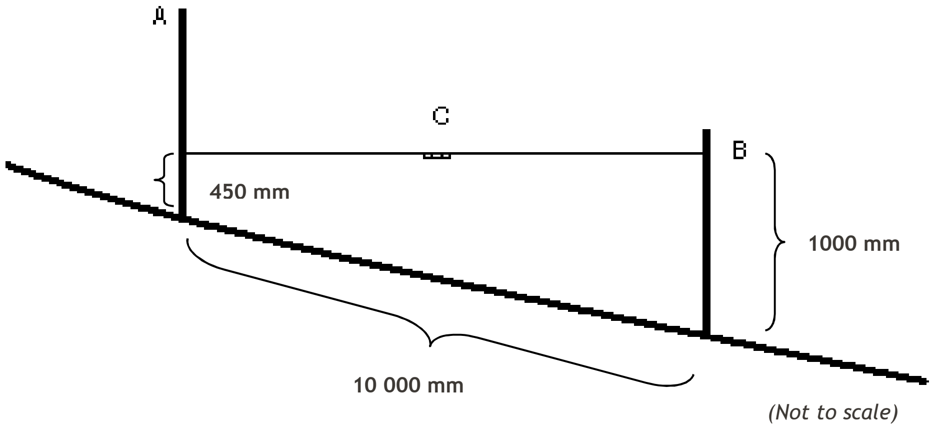


Figure 2.5: Using a line level to measure slope

Figure 2.6: *A level reading on a line level*

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.

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

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

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).

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

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

$$= 5.5\ \%$$

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 2.2: 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

3 Set up a detailed farm or garden plan

3.1 Applying the elements of layout to the home garden

3.1.1 Stepwise process for garden layout planning

This is a stepwise process: Step 1 to 3. Work from the big picture to the detail.

Step 1: Where does your homestead lie in the landscape, and how will this affect what you can do in your garden?

Think of altitude, aspect, ridges/valleys, slope and natural drainage routes. Include sun, wind, frost and water. Keep these factors in mind when you choose your garden site, when you think about how to compensate for ‘not-ideal aspects, and when you decide what crops to plant.

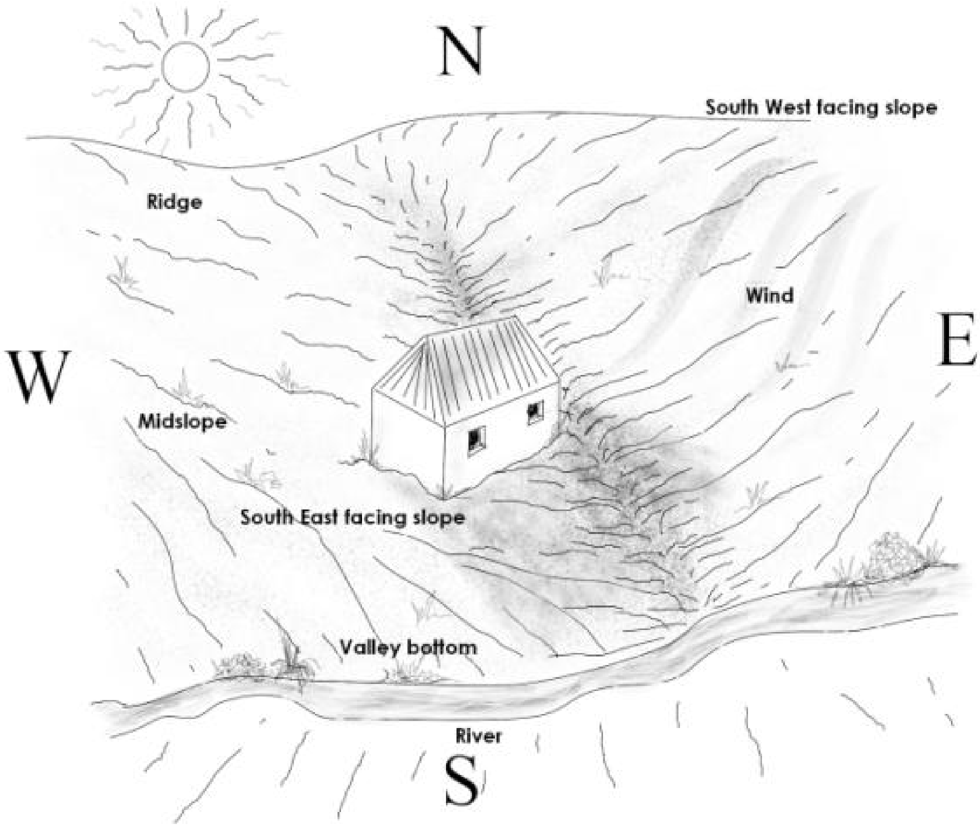


Figure 3.1: Step 1 – Considering the location of the homestead in the landscape

In Figure 3.1 the homestead is situated on the mid-slope, which is better than on the ridge (exposed to wind) or in the valley bottom (tendency for frost). However, it is on a South-facing slope, which tends to be colder as the sunshine cannot warm it as effectively as slopes that face North[1]. This gardener would have to take care to make the most of the available sunshine.
A natural drainage route passes by the Eastern side of the house. Rainfall runoff would run towards and down this shallow area during rainstorms, down to the river. The prevailing wind direction is East.

[1] *True for the Southern hemisphere. North of the equator, South-facing slopes get more sun.*

Step 2: Where would you like to have your garden?

Choose an area to make your garden, then test your choice: is it the best place for you? No site is ever perfect, but the ideal would be: Fertile soil. Easy to get water to it. North side of the house or buildings. North-facing slope. Protected (or can be protected) against wind, and against animals. Close to your house so that you can easily spend lots of time there. Others in the family are satisfied that you use this area.

Weigh the positive and negative points of your choice, and make a final decision on where to make the garden.

Plan how you will compensate for the 'not-ideal' aspects of your garden site, such as exposure to wind, etc.

The most important thing is to MAKE A DECISION and to MAKE A START!

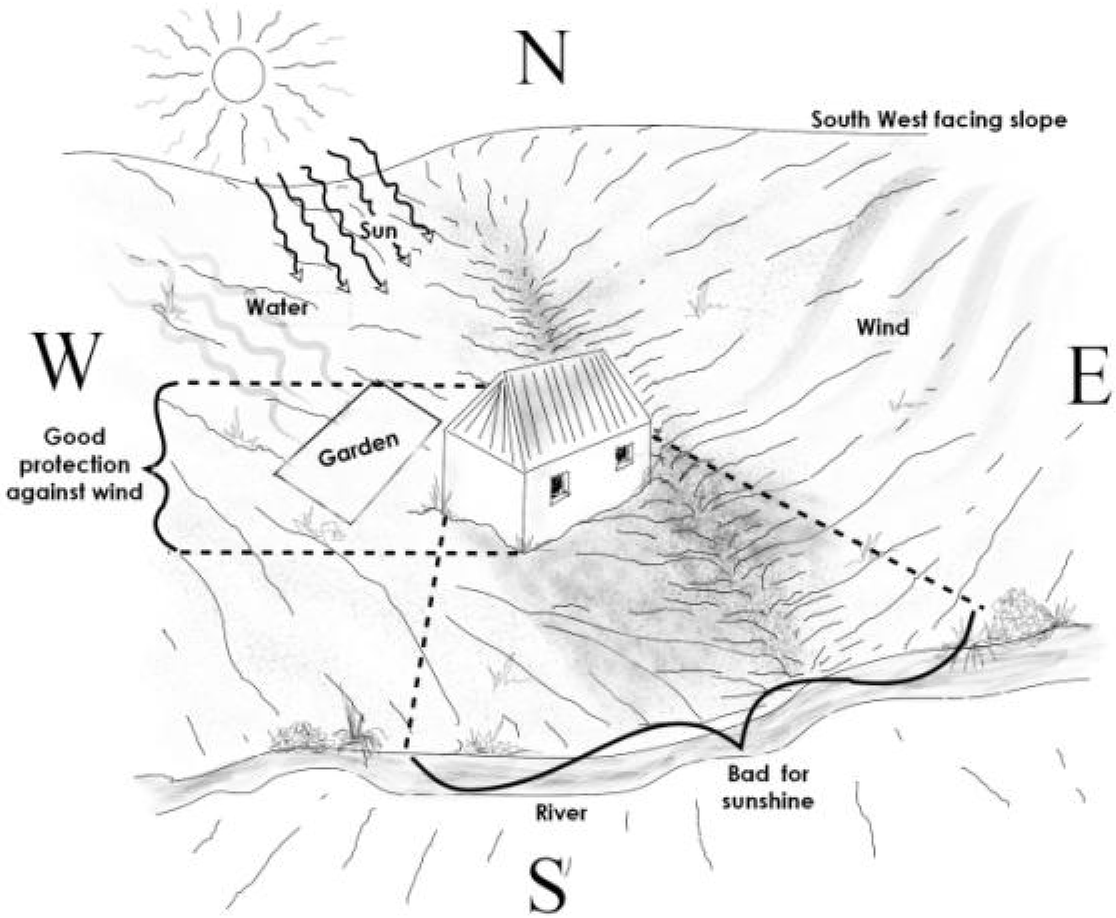


Figure 3.2: Step 2 – Selecting a suitable area for the garden

This gardener has selected a garden area on the North-Western side of the house. It makes the best use of sunshine by avoiding the areas South of the house which would be in the shade for parts of the day. The chosen area is half-hidden from the regular Easterly winds, although further protective hedges would be advantageous. Water running down the SE-facing slope towards the drainage route could be intercepted and spread through the garden. It should also be possible to make some low earth ridges (berms) to divert extra water from higher up in the drainage route towards the garden. The selected garden area is also nice and close to the house, making it easier to keep stray animals away and to spend lots of time there. The Northern wall of the house warms up during the day and will add further heat to the garden. Grey water can easily be taken from the kitchen to the garden.

Step 3: How will you lay out the planting beds in your garden?

Usually, one would start by thinking about water when you decide how to lay out your garden beds. You will first decide where to place your long narrow planting beds across the slope, and then how to shape the earth into rainwater flow paths and ditches so that runoff will flow to your plants during every rain event (see next section: 'Turning runoff into run-on').

Water factors affecting garden layout

We all know that water always flows downhill, and that the steeper the slope, the faster the water will run. Fast-running water has lots of energy, and drags everything in its path along with it – this is why soil erosion happens.

Runoff running through our garden must be slowed down to prevent soil erosion.

Fast-running water also has very little time to infiltrate into the ground, so despite lots of rain, the soil underneath can remain dry (in the root zone of the plants).

Runoff must be slowed down and even dammed up to have lots of time to seep into the soil – into the root zone of our plants.

We also know that water in a plate will all collect at the lower end if we hold the plate at an angle, but if we put it on a level table, the whole surface of the plate will be covered equally with water.

Our planting beds and ditches must be as level as possible, so that the water can reach everywhere equally. In that way we'll make best use of the water we have.

Other layout factors

In Step 2 you have already considered sunshine, wind and frost protection when you selected your garden area. Now, as soon as you have decided the basic positioning of the beds to maximise the use of rainwater in your garden, you can make further adjustments to create the best possible conditions for your plants, for instance:

- In which beds will you plant fruit trees to create some shade for your vegetables during the worst heat of the day?
- What barriers will you plant/erect on the windward side of your beds to protect the garden soil and plants against drying out from wind exposure?
- How will you prevent animals and birds from eating all your hard work?

These strategies are some of the most interesting aspects of gardening, and gardeners can spend hours in happy conversation sharing their latest creative ideas with each other!

3.2 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.

Figure 3.3: Photo of MaTshepo Khumbane's garden. (Compare this photo to the diagram overleaf).

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.

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

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

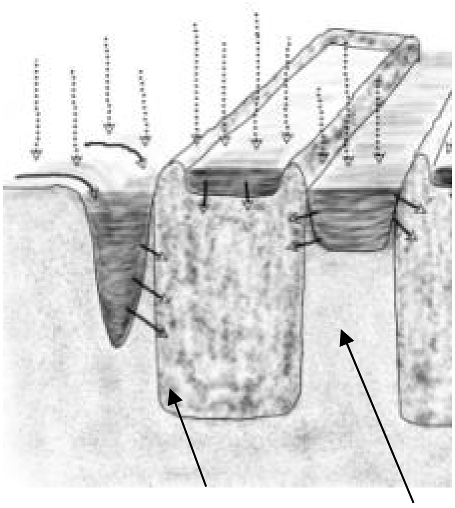
'We call this system "double-double" – now we can grow double as much food (higher yields), and we can grow food double the time (summer and winter)!"

Andile, Upper Nqumeya, Eastern Cape.

The challenge with run-on systems is to explain them in the simplest possible way, so that people will be encouraged to start experimenting with them. Further learning can then be built on their own experience. For this reason we will take you through the run-on system in steps – starting with 'baby steps' and taking you right through to 'mature steps'; slowly progressing from little secrets to deeper secrets.

1] Baby' steps – preparing deep-trenched beds to soak up the water:

Let us first have a look at how the water moves from being pooled around your trenched planting bed into the root zone of your plants.



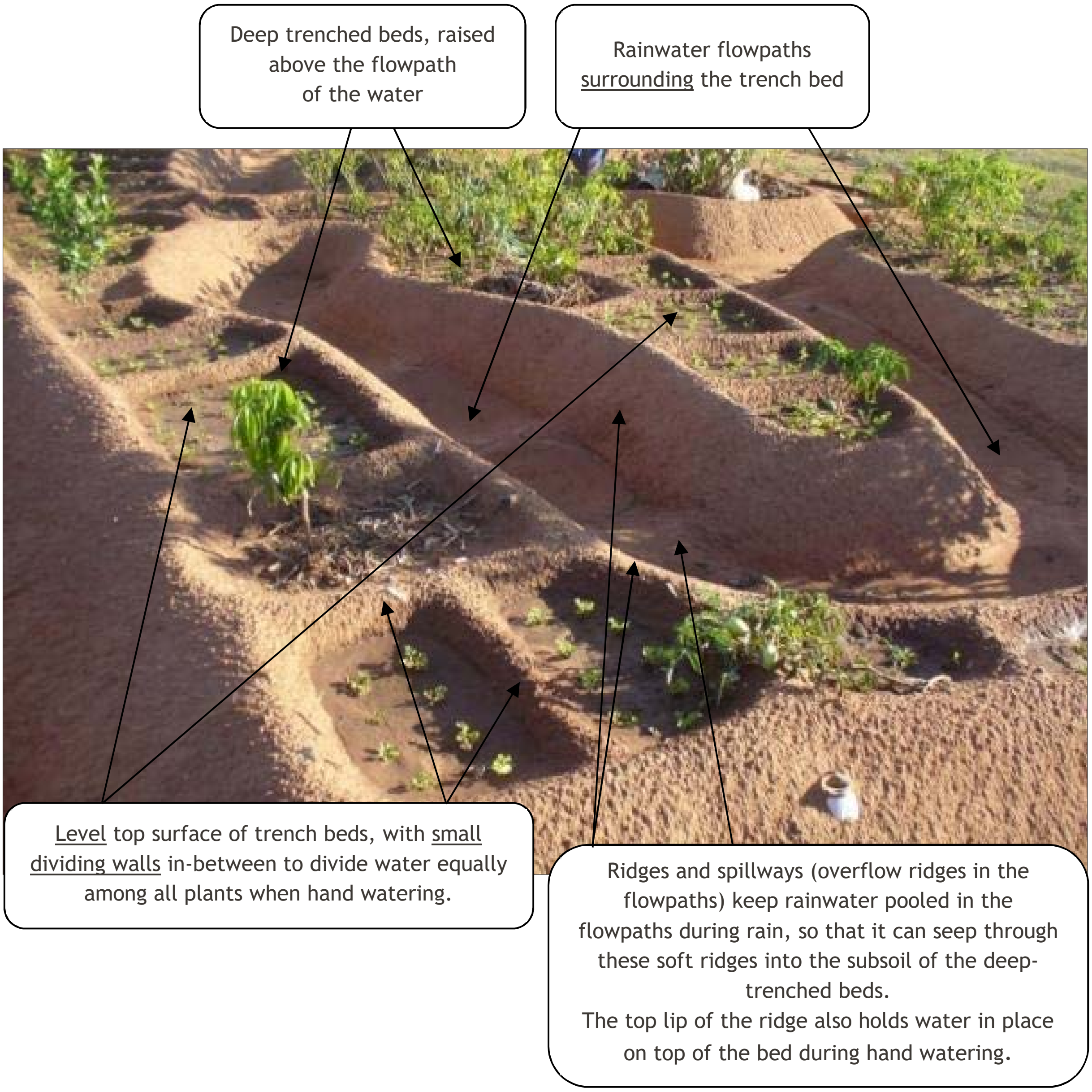
During a rainstorm, water pooling in the top ditch (left on this drawing) and in the rainwater flow paths (right on this drawing) infiltrates (soaks) sideways into the deep soft soil of the trench bed. This all happens underground, so you cannot see it unless you dig and look! Very little water soaks into the soil beneath the footpath/rainwater flow path, because this soil is very hard, while the ridges and deep soil in the trench beds are very soft and absorbent from all the organic matter that has been mixed into it.

Deep soft soil of trench bed

Hard soil beneath footpath

Note that each bed is trenched, raised, ridged and surrounded by footpaths which double as rainwater flow paths during rain:

- TRENCHED to create a deep fertile root zone;
- RAISED to elevate it above the flow path of the water and make the soil even deeper;
- RIDGED to keep the water on the bed when you irrigate. The ridges also absorb lots of extra warmth for the roots, and creates ideal space to grow sweet potatoes and other crops that need ridging ; and
- SURROUNDED by rainwater flowpaths so that water can pool all around the trench bed during a rainstorm to give maximum time for water to infiltrate into subsoil of the trench beds through the soft porous ridges. The footpaths are on hard, undisturbed soil; therefore the pooled water absorbs mostly sideways into the ridges, and then soaks down into the deep trench.



Note that **all hand watering or irrigation is applied on top of the trench bed** – NOT in the rainwater flowpaths between the trench beds! Evaporation losses are tremendous if one tries to apply irrigation water via the rainwater flowpaths!!

2] **'Toddler' steps** – making a furrow for runoff to flow to the garden:

Look at where water runs across (and adjacent to) the yard during a rainstorm.

Often, you can see evidence of where water has flowed, even when it isn't raining, for instance, low-lying flow areas with small pebbles where the fine soil had been washed out; or fine soil that had been deposited in wavy patterns.

Think of how you can dig a furrow and make some soil berms (ridges) to direct this water to flow towards your garden every time it rains. This is your runoff supply furrow.

*In the words of Zanele Semane[2], your **runoff supply furrow** is: "a furrow that your planting beds can drink from".*

This simple <u>runoff supply furrow</u> brings water to the planted trench bed in MaTonisi's new garden.

Photo: J Denison, Upper Nqumeya, Eastern Cape.

3] 'Child' steps – making escape routes for excess surface flows:

One of the first challenges you may experience once you have created a runoff supply furrow to your garden, is what may happen in a heavy rainstorm – the water could be too much, and wash out your planting beds!

Therefore, before we discuss how to lay out the rainwater flowpaths inside the garden, we will first learn how to take control of how water flows into and out of the garden:

- The best way to prevent flooding and erosion damage, is to create an escape route for excess water at the bottom of your garden.
- Another way is to block the water in the runoff supply furrow from entering your garden once it is wet enough. The disadvantage of this is: what happens if you are not at home at the time? This WILL happen sooner or later!

[2] *Zanele Semane, facilitator working with Border Rural Committee, East London, South Africa*

Water always flows down-slope, therefore it will start overflowing out of your garden at the lowest point it can find (think again of the plateful of water you are holding at an angle). Therefore, you should build a safe escape route at the lowest point in your garden – this is like a 'dam spillway' or overflow section, made of earth across the exit point of your last rainwater flowpath (see drawing below).

Here are some tips on how to make an **escape spillway** that would achieve its purpose without itself breaking up against the flow of the water:

- Make the top edge of your spillway **low enough** (lower than the ridges around your trench beds) so that the water can get out of the garden before it overtops your ridges and washes into the soft soil of the planting beds. Make it slightly higher than the bottom of the flowpath, so that water can dam up behind it to soak through the ridges.
- **Widen the rainwater flowpath** (i.e. where the water flows) before it reaches your spillway, so that the water can slow down even further. Your spillway could be **600mm to 1m wide**, but you can adjust this until you are satisfied, depending on how it holds up over time. The wider it is, the slower will be the flow of water over the spillway, and the better protected it is against eroding away.
- Make the **top** of your spillway at least **300mm from the back to the front** (i.e. like a normal 30cm school ruler), so that it won't wash away easily. It is 2m in this photo!
- You can pack stones on the escape spillway to help slow down the flow of the water.
- Water from this escape spillway can flow into the bottom ditch at the lower edge of your garden.
- The **bottom ditch** acts like a long overflow section. Look at the watermark on the photo below to understand how this works. Water spilled sideways out of the bottom ditch before the ridge could be overtopped.

Figure 3.4: Escape routes for excess rainwater flows: (1) escape spillway and (2) the long bottom ditch.

Figure 3.5: Water mark against the ridge above the long bottom ditch. Water overflowed safely out of the ditch (downhill, to the right on the photo) once the water reached this level.

4] 'Young adult' steps – spreading runoff through the garden:

Your **runoff supply furrow** brings water to your garden, and your **escape spillway** and **bottom ditch** ensures that excess water will flow out of the garden before it starts eroding your planting beds. But how can you spread the water from the runoff supply furrow throughout the garden so that it reaches all your plants?

To achieve this, you will continue to apply the same principles:

- Water always flows downhill and must be slowed down;
- Water is distributed evenly when the soil surface is level, i.e. **Flat** (not sloping/at an angle); and
- With an **even** surface (without hollows and bumps).

In this section we will go step-by-step through the process of marking out and constructing the network of ditches and rainwater flowpaths in your run-on garden.

How does one lay out the run-on system in practice?

This is the easiest to do if it is a new garden which can be laid out on the contour. If it is an existing garden in which none of its edges follow the contour, or other restrictions prevent you from following the contour, it can still be done, but your long beds may get shorter!

Follow these steps to lay out a new garden:

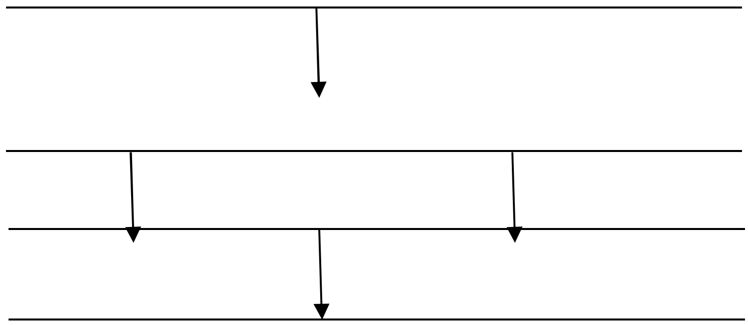
Step 1: Bring the water to the garden – make a runoff supply furrow

i. Find the highest point along the garden perimeter.
ii. Make berms and a runoff supply furrow so that runoff from higher areas will collect at (be channeled to) the garden's highest point or edge.
iii. You can also make a stone 'check dam' to slow the water down and to remove excess silt before it enters the garden.

At the end of this runoff supply furrow from a nearby road, the small stone 'check dam' slows down the water and removes silt before the water enters the garden. (Photo: Prof. B. Mati, Kenya.)

Step 2: Mark out the top and bottom cut-off ditches and rainwater flowpaths in the garden

i. Draw a line on the ground along the contour (i.e. level) where the top edge of the garden will be (this is where you will dig your top cut-off ditch).
ii. Draw further lines parallel to the top edge, not more than 1.5m apart, where the long flowpaths will be. Continue until you reach the bottom edge of the garden, where you will mark the bottom ditch.
iii. Now draw the position of the connecting pathways, staggering them to prevent long uninterrupted downhill pathways.
iv. If you have already made your first trench bed earlier, incorporate it into your overall design. Your layout could look something like this:



Step 3: Dig the top ditch

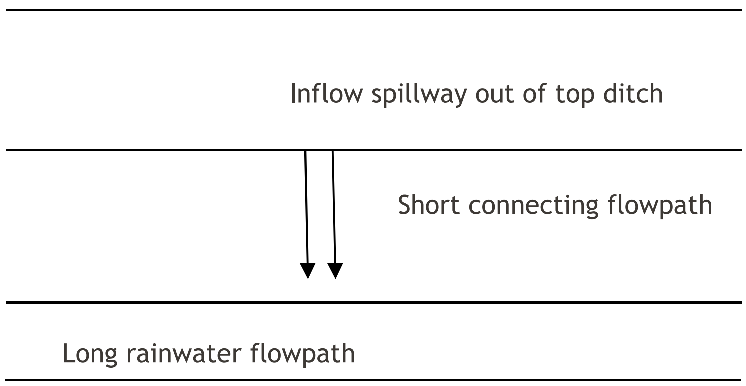
i. Dig out the **top cut-off ditch**. Dig this deep enough to contain the amount of runoff you would expect to run into the garden via the runoff furrow.
ii. Heap the topsoil all along the lower edge of the cut-off ditch, thereby creating a **sidewall** for the ditch.
iii. If you have too much, place the excess topsoil all along the lower edges of the long flowpaths.
iv. Do not use 'dead' subsoil for the planting beds or ridges, but you can use it in the bottom of your hard rainwater flowpaths/footpaths.
v. Make sure that the bottom of the top ditch is **level**, so that water will spread and stand evenly along its full length during a rainstorm.
vi. Create an **inflow spillway** out of the top ditch (i.e. a section where the sidewall is slightly lower than the rest of the sidewall of the top ditch) to lead water into the network of rainwater flowpaths in the garden.

Remember that because you are just shaping the soil, you can always reshape it later once you have observed how your system responds during a rainstorm.

- Your priority now is to create the water flows to your existing beds, and to expand the water distribution system to reach your beds as you add them later.
- If you have already made your first trench bed earlier, you would now want to create the flowpaths and spillways to pool water around the trench bed – always ensuring that excess water can overflow and escape down-slope without damaging your garden.
- You may want to lay out the run-on system for the whole garden, and deep trench your planting beds one-by-one over time.

Step 4: Make rainwater flowpaths that will pool the runoff between the trench beds

i. Make sure that your first **long rainwater flowpath** (which runs parallel to the top ditch above it) is level and even, and wide enough to walk in (not less than 300mm). Form **ridges of topsoil** along the edges of the flowpath/footpath to hold the water.
ii. Find the point where the **connecting flowpath** from the **inflow spillway** out of the top ditch joins the **first long flowpath**.



iii. From this point, dig out the connecting flowpath, working back upslope towards the inflow spillway. Make sure the flowpath comes out level and even!
iv. If the garden slopes very steeply, in other words the connecting flowpath will become very deep when you try to dig it out until it is level, you can construct another spillway at its connecting point with the long flowpath, and level out the connecting flowpath at a slightly higher elevation.
v. You can now continue this process of digging out long flowpaths and level connecting flowpaths with spillways in-between, until you reach the bottom edge of the garden.

Step 5: Dig the bottom ditch

i. Dig out the **bottom cut-off ditch** along the lower edge of your garden. Make sure that its bottom is level.
ii. This is a deeper ditch, but not a pathway, because no-one will need to walk in it.
iii. Plant grass or pack stones along the down-slope edge of the ditch, or wherever water will overflow out of the ditch, to protect the area against soil erosion.

Step 6: Secure the escape spillway

i. Make sure that the top of your escape spillway is lower than any other spillway in the garden, so that all excess water will find its way out of the garden via the escape spillway.
ii. You can pack flat stones wherever you want to protect the soil against flushing out and eroding.
iii. Channel the water that overflows the escape spillway and the bottom ditch to where you need it: this could be an open pond, an underground tank, or another garden further down.

5. 'Mature' steps – working with subsurface flows:

We have mentioned before that a lot of the action with run-on systems and trench beds happen underground, which makes it harder to understand what is happening.

Research supervised by Professor Leon van Rensburg of the University of the Free State at MaTshepo's garden, revealed that there is a waxy layer about 50-60cm underground, which helps water to flow underground, all the way to the river. This means that by helping more water to infiltrate into the soil, MaTshepo is actually also helping to reduce flood peaks and improve the baseflow of the river.

MaTshepo's soils are also sandy, meaning that deep percolation happens more easily. She has come up with a plan to reduce deep percolation without waterlogging her beds (drowning them from below). By placing a layer of plastic sheeting or green cow dung in the bottom of her trench bed and about 10cm up the sides before filling it, she creates an underground pool of water which can spill over the edges of the plastic once it gets any deeper than 10cm. Ingenious!

3.3 Designing a garden plan

A plan of action needs to be developed for each site. To do this, you first need to help the farmer/s conduct a detailed site assessment. Assist farmers with this by doing and/or asking the following:

a] Assess the **soil** types (for this you can do a bottle or sausage test).

b] Measure the **slope**.

c] Identify WHC methods that are suited to that specific site (taking into account the slope, soils, and rainfall, and the reason/s for harvesting water).

d] Ask: What are you doing already? Is there a small intervention that you can add to this?

e] Ask: Where does the **water** run when there is hard rainfall? (Answers are likely to include: compacted areas in front of houses, roads, drains, paved areas, steeper slopes, rocky slopes, rock domes, netball courts, parking areas, school grounds, etc.)

f] Look at the **roofs**. Ask: Is there excess runoff from existing tanks (if any)? How can excess roofwater be channelled into a new or existing growing area?

g] Ask: Can you bring water into the garden/fields using diversion furrows? (Farmers will need to think about things such as land ownership, future land use, competition for runoff water when more than one person wants to use it, etc.).

h] Discuss the WHC methods that could be tried. Give the farmers relevant information and let them think about the implications, make suggestions, and arrive at their own decisions about what they want to try.

i] Work through each method that could be used so that farmers have enough information as to how much work each method will take, what it will look like, and how it should be done. You can do this by going through the farmer handouts with them.

j] Mark out some contour lines in the garden for swales, trenches or tied-ridges, or mark out contour lines for cut-off furrows outside the garden if farmers want to try this.

k] Be involved and share ideas, make sure that the farmers make their own decisions and modifications.

3.4 Record the Action Plan

You can end the planning process by helping farmers mark out the methods they are going to implement (using, for example, stakes and string). Alternatively, you can suggest that farmers draw a plan of their house and garden or field, and show on the plan the methods they are going to implement.

As the facilitator, it would be a really good idea for you to draw up a plan of each site (i.e. garden or field).

This will remind you :

WHO each person is,
WHAT methods they have chosen to implement, and
WHEN they started.

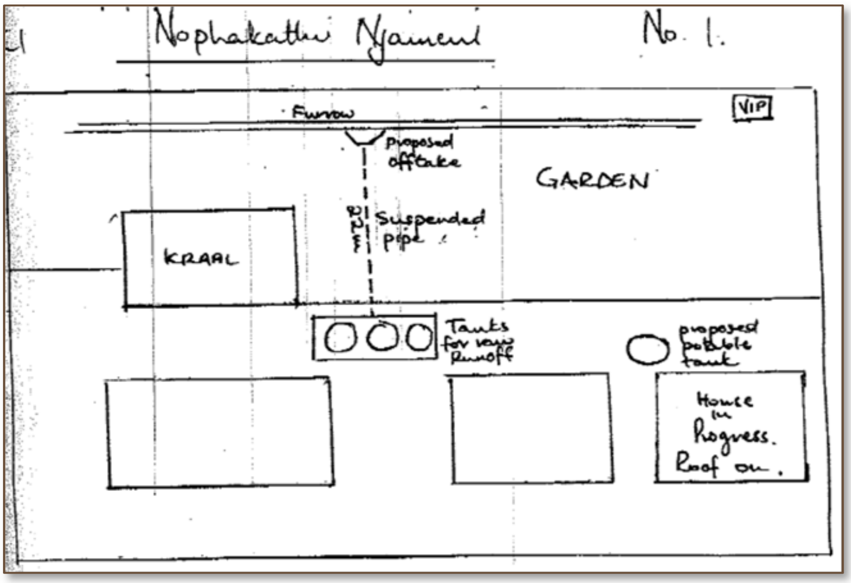


Figure 3.6 *A facilitator's sketch plan of WHC at a homestead.*

Develop a WHC Plan for a Garden

Complete this activity with a partner.

1. Select a site which you can use for this activity. The site must have a vegetable garden, but the gardener (who could be a friend, family member or farmer) must not be using more than one or two water harvesting and conservation methods.

2. With your partner, conduct a thorough site assessment. Make sure that you follow all of the guidelines that are provided in this chapter (see Sections 2.3 and 2.4).

3. Select at least two WHC methods that are appropriate for the site and that are not already being used by the gardener.

4. Draw a clear and detailed plan of the site that shows exactly how the methods you have selected can be incorporated into the system.

5. Compile a report which includes the following:
   - 5.1 Your names, the date, and the title of this activity.
   - 5.1 A brief description of the site, the name of the person it belongs to, why you selected it for this activity, and a description of any WHC methods currently used on it.
   - 5.2 A *detailed description* of your site assessment. List everything that you assessed and describe how you did so and what the results were.
   - 5.3 Your site plan.
   - 5.4 Your specific reasons for selecting each of the WHC methods you have included in the plan.

Make sure that you follow any additional instructions given by your lecturer.

Time: 3 hours

4 WHC methods in more detail

4.1 Diversion Furrows

Also called:	Used in:	
- Feeder channels	Gardens	✓
- Trenches	Fields	✓
- Run-on ditches	Grazing land	
- Ex-field RWH		

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. If a diversion furrow is in an area of heavy foot traffic, it can be filled with a porous material such as gravel so that it does not become a tripping hazard.[2]

Figure 4.1 *Diversion furrow leading to a catchpit*

Figure 4.2 *Diversion furrows leading to trench beds*

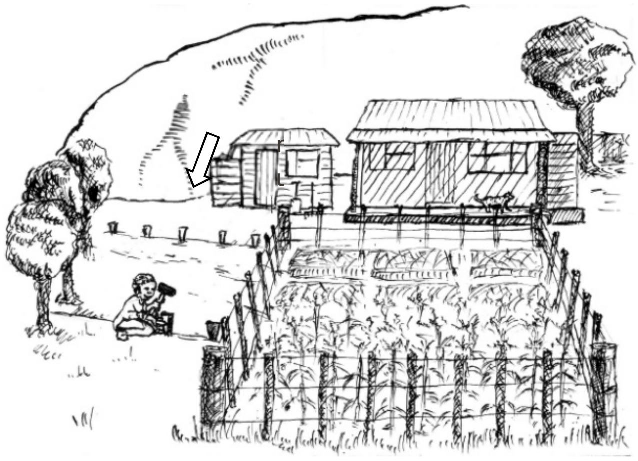
Figure 4.3 *Diversion furrow leading to a trench bed*

4.1.1 Planning

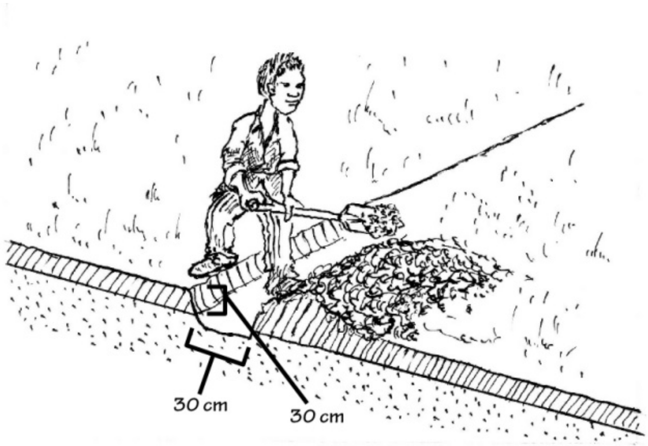
Soil	Slope	Rainfall	Tools & Equipment
Any soil. Where soils are easily erodible or hillside slopes are steep, the diversion furrow should slope gently downwards so as to avoid erosion.	**Any slope.** On steeper slopes, care must be taken to prevent erosion.	**Any rainfall.** In higher rainfall areas, measures to prevent erosion may be needed.	**Spade*** pegs and string A-frame. **essential*

4.1.2 Method

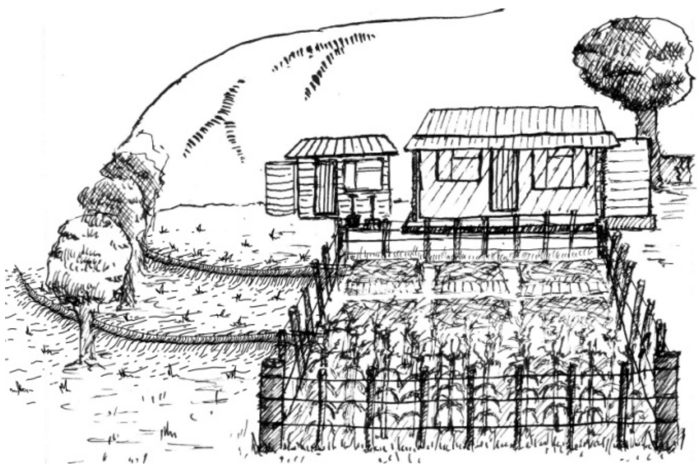
i. Look at the ground when it rains to see where the storm water runs, and decide which of this water you want to divert. Mark out a route for your furrow which will intercept this water and carry it to the garden, field or storage tank.



ii. Dig a trench approximately 30 cm wide and 30 cm deep. Place the soil on the downslope side of the trench.



iii. Ensure that the furrow leads into the rainwater harvesting method being used in the field or garden. In the case of a tank, the furrow will typically lead into a small catch pit which traps sediment and debris so that it does not enter the tank.



4.2 Stone Bunds

Also called:	Used in:	
- Stone lines - Stone banks - Contour stone bunds	Gardens	✓
	Fields	✓
	Grazing land	✓

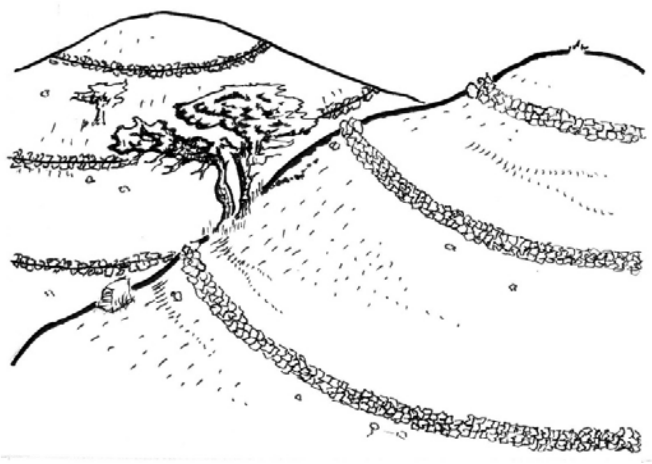


Figure 4.4: Stone bunds on a hillside

Stone bunds are used along contour lines to slow down, filter and spread out runoff water, thus increasing infiltration and reducing soil erosion. Over time sediment, which is captured on the higher side of the bunds, accumulates to form natural terraces.

Figure 4.5: *Natural terraces which have formed from an accumulation of sediment*

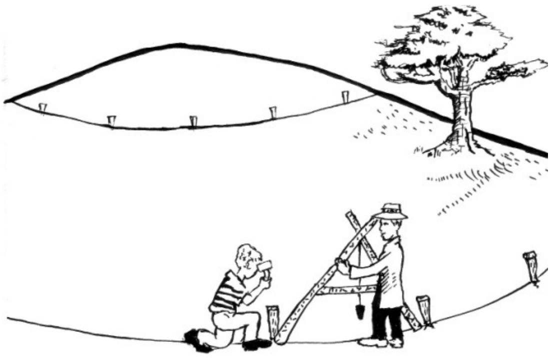
Figure 4.6: *Stone bunds being maintained*

4.2.1 Planning

Soil	Slope	Rainfall	Tools & Equipment
Any soil.	0.5 to 3%, preferably below 2%	200-750 mm (arid to semi-arid areas)	- Stones of various sizes* - Wheelbarrow* - Spade - A-frame or line level **essential*

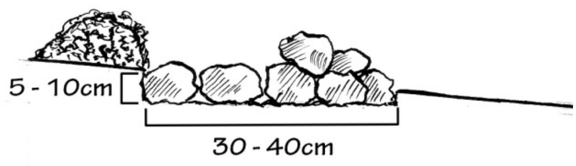
4.2.2 Method

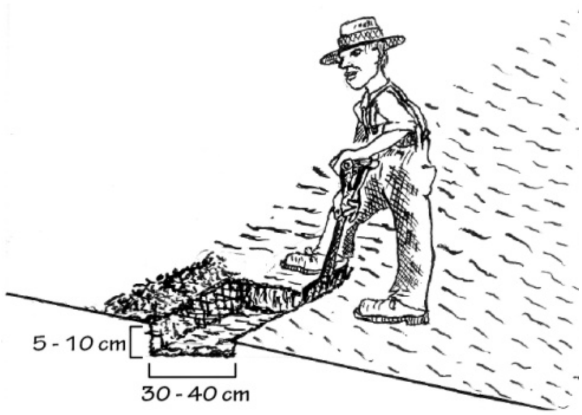
Slope	Spacing of bunds
<1%	20 m
1-2%	15 m
2-5%	10 m



i. Calculate the slope of the land to determine how far apart the bunds should be and decide how many bunds you plan to construct.

ii. Mark out each contour line using an A-frame or line level. If necessary, make slight adjustments to the position of the pegs so that the lines form a smooth curve.





iii. Dig a shallow trench along the contour line (5 - 10 cm deep, and 30 – 40 cm wide). Place the excavated soil upslope of the trench.

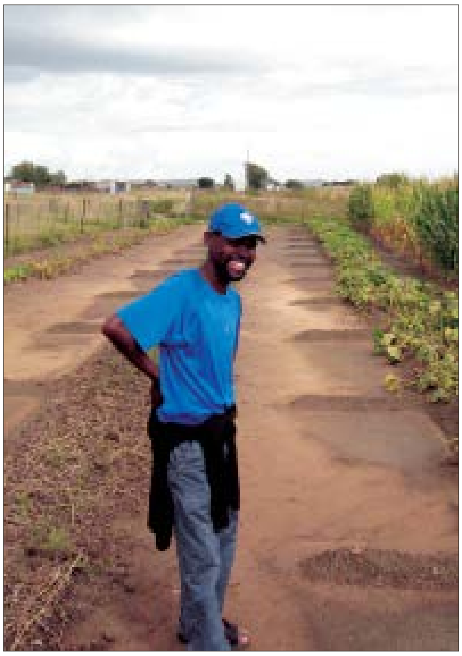
iv. Place large stones along the base of the trench and on the down-slope side to create an “anchor line.”

v. Place smaller stones on the up-slope side, and use them to fill any gaps between the larger stones. Leave the excavated soil on the upside of the stone bund.

vi. Maintain the bunds by replacing any stones which become dislodged after heavy rainfall.

4.3 Tied Ridges

Also called:	Used in:	
- In-field RWH - Partitioned furrows - Cross-ridges - Furrow dikes	Gardens	✓
	Fields	✓
	Grazing land	



This method increases the water that is available to plants by collecting rainfall from an unplanted sloping basin and catching it with a furrow and ridge. Planting takes place on either side of the furrow where the water has infiltrated.

Basins are created by digging out shallow furrows along the contour lines of the slope and constructing ridges on the downside of the furrows. These are "tied" together by slightly lower ridges which are constructed at regular intervals along the furrows (these ridges are also called *crossties*). The loss of water through evaporation can also be minimised by placing mulch in the furrows.

Figure 4.7: *Mulch placed in furrows to minimise evaporation*

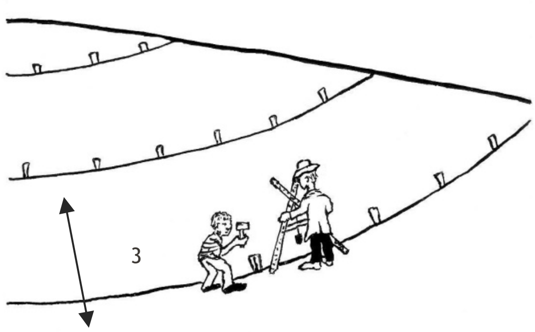
Figure 4.8: *Water is captured in furrows*

4.3.1 Planning

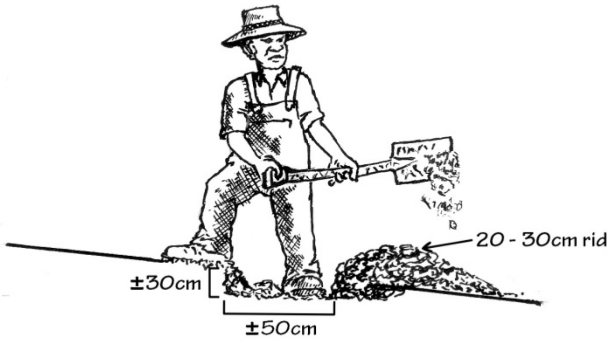
Soil	Slope	Rainfall	Tools & Equipment
- Soil depth of 700mm - 1000mm. - Soils should be relatively stable. The best soils are clay or soils with a relatively permeable topsoil over a less permeable subsoil.[18]	Can be up to 7% on non-erodible soils.	Annual rainfall of 400-700 mm.	- spade* - fork - tape measure - string, sticks - mulch - wheelbarrow - A-frame or line level *essential*

4.3.2 Method

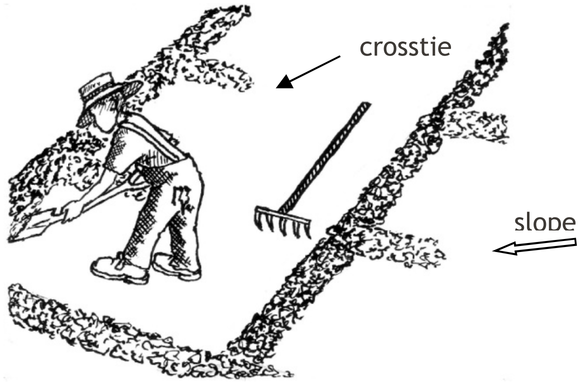
i. Select a site and clear the ground of rocks, bushes, grass and weeds.



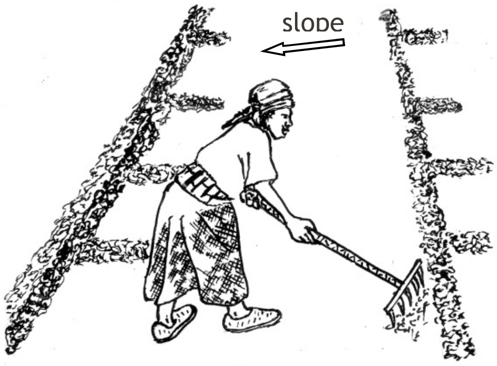
ii. Mark out the contour lines on the slope, three meters apart.



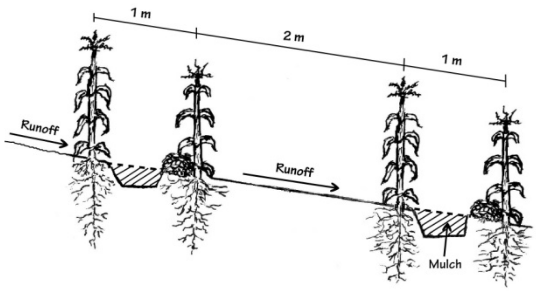
iii. Dig out a shallow furrow (about 50 cm wide and 30 cm deep) along each contour and place the soil on the down-slope side of the furrow to create a ridge (about 20–30 cm high).



iv. Create crossties (ridges which are 15-20 cm high) every 3 meters. Ties must be lower than the main ridges so that water never flows over the ridges.



v. Use a rake or plank to level out each basin, as this is the water catchment area. Place mulch in the furrows if possible.



vi. Plant in two rows , one on either side of the ridge and furrow.

4.4 Swales

Also called:	Used in:	
- Bunds - Contour ridges - Berm 'n basin - Contour ditches	Gardens	✓
	Fields	✓
	Grazing land	

A ***swale*** is an earth bank constructed along the contour with a furrow on the up-slope side. 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. The method as described here is used mainly for crop production and not pastures. Typically, permanent crops (e.g. fruit trees) are planted just below the ridge of the swale, while seasonal crops (e.g. vegetables) are planted between the swales. Over time, seeds and organic matter accumulate on the ridge of the swale, causing vegetation to grow, which stabilizes the ridge. Alternatively, the ridges can be planted with long-living plants such as comfrey, marigolds, nasturtiums or grasses. The ridge of a swale can also double as a raised accessway such as a footpath.

Figure 4.9: *Swales prepared for planting*

Figure 4.10: *Vegetables growing on the swales*

4.4.1 Planning

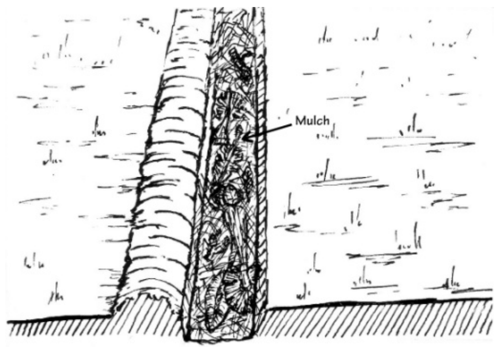
Soil	Slope	Rainfall	Tools & Equipment
Any soil. The sandier the soil, the thicker the swale should be. In clayey soil, swales can be a bit higher and narrower because the clay holds together well.	5 - 25%[22]	Swales should be used with caution in areas with high rainfall (1200 mm or more) as waterlogging can occur.	- Spade* - A-frame or line level* - Pegs/stakes **essential*

4.4.2 Method

i. Decide where you want to grow your crops and mark out contour lines which are 5 meters apart. If the slope is steeper the lines can be made closer (up to 3m apart).

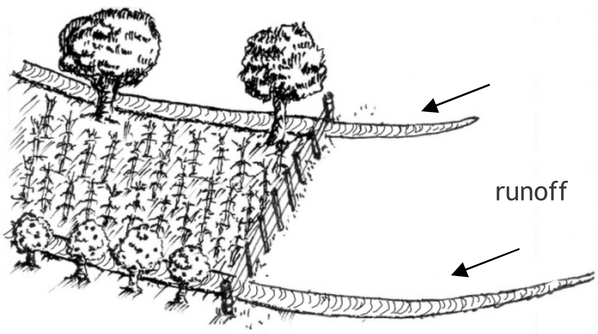
ii. Dig a shallow furrow along each contour line (30 – 40 cm deep and 50 cm wide) and place the soil on the down-slope side of the furrow.

iii. Use the soil you have excavated to create a ridge (30 – 40 cm high and 50 cm wide) on the downslope side of the furrow. Use an A-frame to make the top of the ridge level. Walk along the ridge and



v. Fill the furrow with mulch (place the coarsest mulch at the base).

iv. Plant permanent crops (e.g. fruit trees and shrubs) immediately below the ridge of the swale and seasonal crops between the swales. If necessary, dig diversion furrows or extend swales to bring additional surface runoff into the planting area stamp on the soil to compact it.



4.5 Terraces

Also called:	Used in:	
Benches	Gardens	✓
	Fields	✓
	Grazing land	

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. Terraces create flat planting areas and stabilize slopes which would otherwise be too steep for crop production. A series of terraces creates a step-like effect which slows down runoff, increases the infiltration of water into the soil, and helps control soil erosion. Terraces are built on steeper slopes, so there is a high risk of erosion taking place if they are not constructed correctly. To avoid erosion, each terrace must overflow sideways into a drain that is protected with rocks, branches or gabions.

Figure 4.11*: A terrace built easily and cost-effectively using old tyres packed with soil.*

Figure 4.12*: A farmer standing at her stone terrace wall*

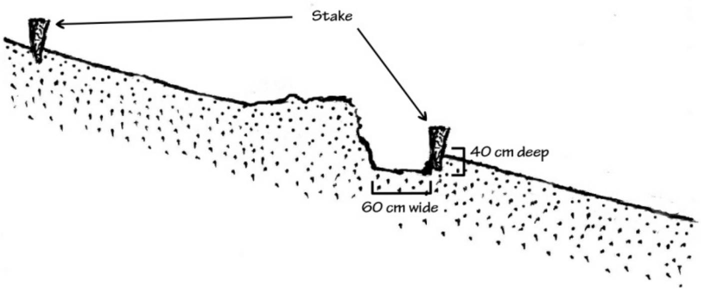
4.5.1 Planning

Soil	Slope	Rainfall	Tools & Equipment
Any soils, although there is need for caution in clay soils which are prone to waterlogging, and highly erodible soils.	10% - 40%[24]	Sufficient rainfall for crop production required.	- Stones of various sizes (flat or angular stones are preferable)* - Wheelbarrow* - Spade* - A-frame or line level* - Stakes/pegs and string* - Hammer and chisel - Pick-axe **essential*

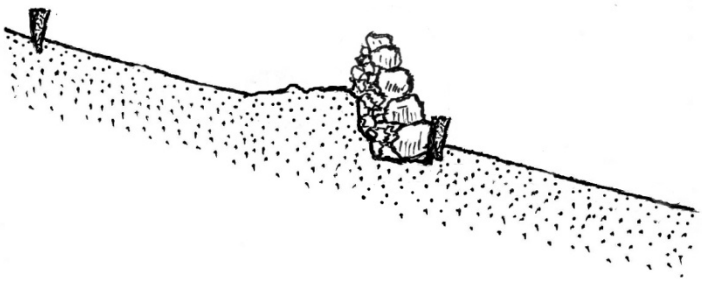
4.5.2 Method

i. Calculate the slope to determine the spacing between terraces (see Table 1). Starting at the bottom of the slope, mark out the contour lines for each terrace you plan to build. If necessary, adjust the position of the pegs so that each line forms a smooth curve.

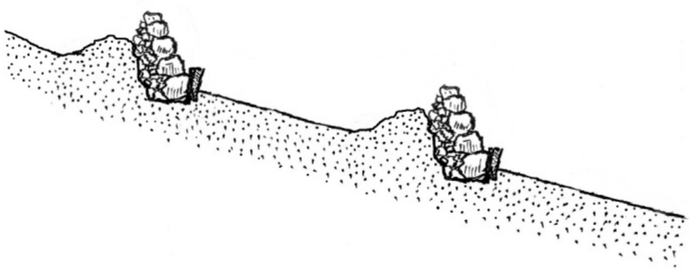
ii. Dig a trench about 40cm deep and 60cm wide along the first contour line (see Table 4.1). Place the excavated soil upslope of the trench.



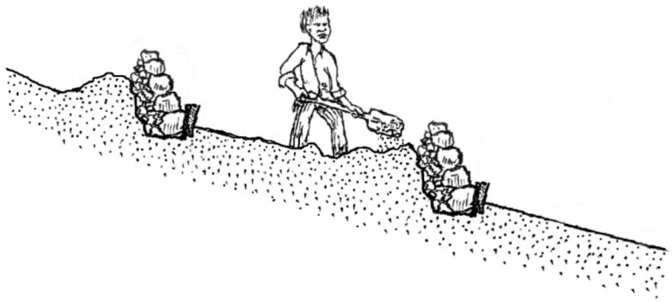
iii. Start building the terrace wall by placing large stones along the base of the trench. Place the biggest stones on the down-slope side to create an "anchor line"25 and place smaller stones on the up-slope side. Use small stones to fill any gaps between the larger stones. Pack the stones so that they lean back against the soil to ensure that the wall remains stable.



iv. Move to the next marked contour line and build the next terrace wall by repeating steps 2 and 3.



iv. Level the soil excavated from the terrace foundation up against the back of the constructed wall. If you need more soil dig away the upper part of the terrace and spread it across. Make sure you do not dig more than 30cm near to the upper wall, so that you do not undermine the foundation.



v. Use an A-frame and a rake to get the soil level. You will now have two terrace walls and a level terrace of soil between the walls. The final soil surface must be at least 10 cm lower than the terrace wall so that erosion does not take place.

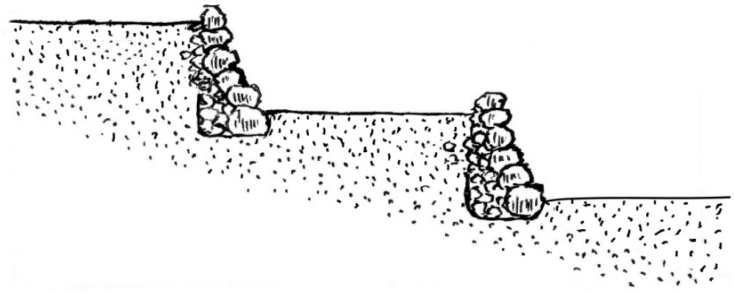


TABLE 4.1: TERRACE SPACING AND DIMENSIONS

Slope		Distance between terraces (meters)	Terrace height above ground level (meters)	Terrace height above bottom of trench (meters)
Percent	Ratio			
10%	1:10	8.0	0.8	1.2
15%	1:6.7	5.3	0.8	1.2
20%	1:5	4.0	0.8	1.2
25%	1:4	3.2	0.8	1.2
30%	1:3.3	2.7	0.8	1.2
35%	1:2.8	2.3	0.8	1.2
40%	1:2.5	2.0	0.8	1.2

Erosion protection

During high rainfall events, excess water from the terrace must be allowed to overflow at the side of the terrace. Because there is a high risk of erosion at this overflow point, it is necessary to protect the overflow with small rocks and/or grass. The water which overflows will move down a natural drainage line which, due to the steep slopes, may also need erosion protection, for example using rock packs, or brushwood walls, to avoid gullies forming.

4.6 Fertility pits

Also called:	Used in:	
- Banana circles - Circular swale	Gardens	✓
	Fields	
	Grazing land	

Fertility pits enable runoff water to be captured and conserved in 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. Plants, particularly those which require a lot of water (such as bananas, paw-paws and tree tomatoes), are grown in or around the pits, where they benefit from the moist and fertile soil.

Figure 4.13: Fertility pit filled with organic material

Figure 4.14: A fertility pit being prepared

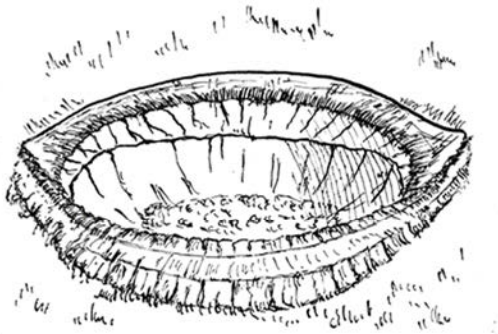
4.6.1 Planning

Soil	Slope	Rainfall	Tools & Equipment
Any soil type (the organic material will improve any soil).	Up to 25%.	Any rainfall.	- Spade* - Organic materials (mulch, compost, manure)* - Trees * (e.g. Banana suckers, paw-paw seedlings) - Plants (e.g. Sweet potato, beans, ginger, lemon grass, yams, comfrey) **essential*

4.6.2 Method

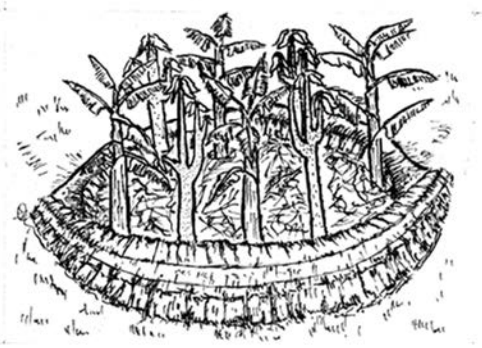
i. Decide where the pit should be. Mark out a circle about two metres in diameter and dig down about 1 metre. The pit should be fairly concave (shaped like a bowl). Place the soil you have dug out around the edge of the pit.

ii. Shape the soil around the edge of the pit to form a ridge or mound. If the pit is on a slope you can dig diversion furrows to direct runoff into the pit (see step 5 below).

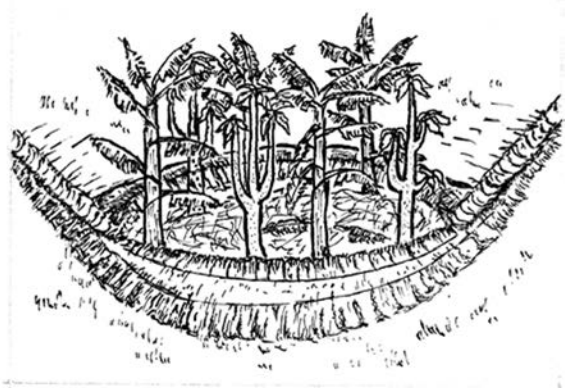


iii. Fill the pit with organic material, placing the most coarse materials at the bottom. You can overfill the pit because the materials will sink over time.

iv. Use the fertility pit as a compost heap, and construct a diversion furrow to direct any excess runoff into the pit.



v. Plant trees and plants around the rim of the mound. Space the trees so that they have enough room for growth and place plants between the trees.



4.7 Roofwater Harvesting

Also called:	Used in:	
No other names	Gardens	✓
	Fields	
	Grazing and Degraded land	

Collecting water from roofs for household and garden use is widely practiced across South Africa, and tanks and containers of all types – from large brick reservoirs to makeshift drums and buckets – are a common sight in rural areas. There are, however, many ways of improving both the quality and the quantity of water that can be harvested from the roofs of houses, schools, clinics and outbuildings.

Collecting water from roofs has the following advantages over any other surface:

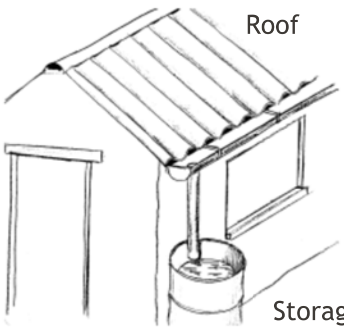
- Roofs are physically in place and runoff is immediately accessible;
- Water collected from roofs is much cleaner than from ground runoff; and
- Most of the rainwater falling on a roof can be collected, as there is little absorption or infiltration on the roof surface (with thatch being an exception).

There are three main components to roofwater harvesting; the **roof**, the **gutter** and the **storage tank**. What follows is a summary of each of these components, and practical suggestions as to how each can best be utilised.

4.7.1 Roofs

- **Roof type and water quality**

Most roofs are suitable for rainwater collection. However, roof water can be contaminated to varying degrees by the roof material itself, by bird and animal faeces, and by leaves and dust. For this reason, even on roof materials which are considered safe for harvesting drinking water, a set of basic measures to limit contamination is strongly recommended (see the recommendations at the end of this section).



- **Safe roofs**

Corrugated iron, slate, fibre cement, asbestos cement, tiles, concrete are all sufficiently safe surfaces and provide reasonably clean water. There is no evidence to suggest that asbestos roofs, which present a health hazard during construction due to potential breathing of fibres, should not be used for harvesting drinking water.

- **Unsafe roof materials**

Roofs with metallic or lead paint, or with lead flashing, must not be used because the metals are toxic and can enter the water.

4.7.2 Guttering

Guttering is a potential weak link between the roof and the storage container,[35] so this is an area where losses can be prevented with little effort. The following types of gutters are widely used in South Africa:

- **uPVC gutters**

These are well-suited to houses which are constructed more formally, where rafters and rooflines provide a straight line for the gutters to be attached. PVC gutters are difficult to attach to informal housing such as huts and shacks, where rafters or beams are often not aligned with each other and where roof structures are often made with rough, untreated poles which are weakened by insect attack, making firm fixture difficult. PVC gutters typically require the installation of a facia, which adds cost to the overall gutter installation. PVC gutters cannot be used on thatch roofs.

- **Sheet metal gutters**

These gutters are made from flat galvanised sheets, or from corrugated sheets which have been flattened with a hammer. Home-made gutters can accommodate the challenges presented by informal or traditional housing, and can be hung from roof sheets which are skew by fixing them to the roof sheets with 3mm fencing wire.

Figure 4.15: Sheet metal gutter fixed to roof sheets with 3mm fencing wire

There is also an innovative and more formalised sheet metal gutter design, whereby the gutter is riveted directly to the upper surface of corrugated iron roof sheets and curves underneath the roof to catch the water.[37] This design has much potential for addressing the challenges of fixing gutters to informal housing, as it circumvents the need for roof timber to be aligned and in good condition. These gutters are more adaptable than PVC guttering as they can be bent or twisted to ensure that sufficient slope is achieved in situations where rooflines do not slope consistently. However, sheet metal gutters cannot easily be used on rondavels or thatched roofs.

- **U-Round HDPE guttering**

This patented system is specifically designed for collecting water from thatched roofs. It is a highly flexible system which is well suited to the widely varying construction situations found in rural buildings. The gutters can bend around corners and can easily accommodate changes in level. The fixings of U-Round gutters need careful attention where rafter spacings exceed 0.5 meters, in which case the gutter can be fixed to the roof sheeting with 3mm wire to provide additional support.

Figure 4.16: U-Round guttering used in Cata Village, Eastern Cape

4.7.3 Storage Tanks

Many different types of storage tanks can be used. Tanks are typically made of plastic, plastered block, corrugated iron, ferrocement, natural stone or bitumen-geofabric. Recent studies have shown that plastic tanks are approximately half the cost of any other tank type for a typical household application; they are also quicker and easier to install and have fewer quality (leakage) issues. The only disadvantage of plastic tanks is that they have an expected life span of 10 to 15 years, whereas well-constructed ferrocement or plastered block tanks can last for up to 30 years with ongoing minor repairs.[39] Plastic tanks must always be positioned properly on level and stable bases. Plastic tanks typically come in sizes of 1000 litres, 2000 litres, 5000 litres and 10,000 litres.

4.7.4 Runoff and Storage Calculations

It is important to note that for any roof size there is a maximum amount of water that can be collected. It is common that tanks are installed without any water runoff and storage calculations being done. If the tanks are not sufficient for a household's needs and they overflow significantly during the wet months, additional tanks could be used to store the water which is overflowing. Observation and experience are thus a sensible way of building up storage in a step-by-step manner. As a rule of thumb, you can install 5000 litres of storage for every 40 square metres of roof – but this is a rough approximation and will vary substantially between households and in different parts of the country.

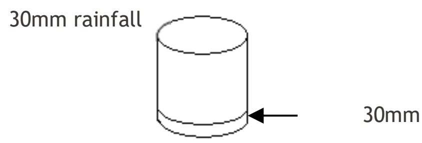
An accurate calculation can be done to arrive at the optimum tank size that is required. This optimum size is related to the monthly rainfall, the size of the roof, and the amount of water to be used each month. The calculations can be done scientifically using publicly available software such as SAPWAT, which can be obtained from the Water Research Commission via their website or by written request. SAPWAT requires computer skills and a level of technical competence to use. There are also more simple methods of estimating water demand, tank size and water runoff from roof areas. These calculations will give acceptably accurate results, and are described next.

4.7.4.1 Calculating roof runoff volumes

The runoff from a roof is calculated using the rainfall, the plan area of the roof (roof surface area in square meters) and the runoff coefficient.

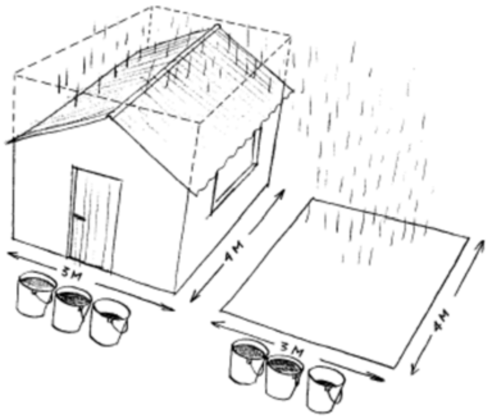
Runoff (litres) = roof surface area (square meters) x rainfall (mm) x runoff coefficient

i. **Rainfall**
   Rainfall is expressed in millimetres, which is the depth of water that has fallen during a rainfall event. For example, during a 30mm rainfall, 30mm of water will collect in a container which has a flat bottom and vertical sides



ii. Plan area of the roof

It is important to understand that the roof surface area used in the calculation is the *plan area of the roof*. The reason for this is because the amount of rain that is collected stays the same regardless of whether the roof is flat or pitched.



1mm of rain on 1ha - 10 000l.
1mm on 1m^2 is 1 litre

iii. Runoff coefficient

Not all of the rainwater which falls onto a roof will run off into the gutter, as certain amounts will be lost to absorption and evaporation. The amount of water that is lost will differ, depending on the kind of roof system that is in place. Each roof material has a *runoff co-efficient*. This is used to calculate the amount of rainfall that will run off and the amount which will be lost. A runoff co-efficient of 0.9, for example, means that 90% of the rainfall will run off, while 10% will be lost to evaporation and absorption (note that leakage and overflow can lead to further water losses). The higher the runoff co-efficient for the material, the more water can be collected from the roof.

TABLE 4.2: RUNOFF COEFFICIENTS FOR DIFFERENT ROOF MATERIALS (WITH EFFECTIVE GUTTERING IN PLACE).

Type	Runoff coefficient	Percentage Runoff
Galvanised iron sheets	0.9	90%
Tiles (glazed)	0.8 - 0.9	80 - 90%
Flat cement roof	0.6 - 0.7	60 - 70%
Thatch	0.2 - 0.5	20 - 50%

Thatch has a wide runoff coefficient range because runoff varies considerably for different types of thatch. Rietgrass, for example, has a higher runoff value than the more widely-available turpentine grass. Other factors which impact on thatch runoff are: the slope of the roof; the age of the thatch; and the sensitivity of all thatch to the type of rainfall that takes place (e.g. a gentle rain of short duration has lower runoff, while thunderstorms have higher runoff).

4.7.4.2 Example of monthly roof runoff calculation:

A rectangular rural homestead has two houses which feed the *same tank*:

- House A: a 'flat' which is 4 m x 6 m, with a corrugated iron roof and gutter system
- House B: a rondavel, which is 5 m in diameter, with a corrugated iron roof and gutter system

The January rainfall is **115 mm**.

Step 1: **Calculate the total roof surface area**

House A roof area (rectangle) = 4 m x 6 m = 24 m^2

House B roof area (circle) = $\frac{\pi \times d^2}{4}$ = $\frac{\pi \times 25}{4}$ = 19.6m^2

TOTAL roof surface area = 24 + 19.6 = **43.6 m^2**

> The symbol π is "pi". The value 3.14159 can be used in the calculation.
>
> d = diameter

Step 2: **Calculate the January runoff from the roof**

Runoff (litres) = roof surface area (square meters) x rainfall (mm) x runoff coefficient

January runoff from both houses (litres) = 43.6 m^2 x 115 mm x 0.9

= 4512.6 litres

= **4513 litres** (rounded off)

This calculation can be done for each month (January to December) to get an estimate of the total annual roof runoff from both houses into the tank (see Table 4.3).

TABLE 4.3: MONTHLY RUNOFF FROM 43.6 M^2 OF CORRUGATED IRON ROOF

Month	Average Monthly rainfall (mm)	Roof area (m^2)	Runoff coefficient	Runoff volume (litres)	Cumulative volume (litres)
Jan	115	43.6	0.9	4513	4513
Feb	123	43.6	0.9	4827	9340
Mar	109	43.6	0.9	4277	13617
Apr	78	43.6	0.9	3061	16678
May	61	43.6	0.9	2394	19072
Jun	35	43.6	0.9	1373	20445
Jul	30	43.6	0.9	1177	21622
Aug	35	43.6	0.9	1373	22995
Sep	55	43.6	0.9	2158	25153
Oct	60	43.6	0.9	2354	27507
Nov	80	43.6	0.9	3139	30646
Dec	95	43.6	0.9	3728	34374
TOTAL	876			34374	34374

In this example, the total average annual runoff is 34374 litres. It is not necessary to have storage space for this total volume, because every month some water will run into the tank while some will be taken out for domestic and garden use. To calculate the amount of storage space that is actually needed (i.e. the tank size and/or the number of tanks required), one must first calculate the water requirements for both the garden and the household.

4.7.5 Garden Water Requirements

SAPWAT can be used to calculate water requirements for gardens. However, even with this programme there are many assumptions which have to be made about the WHC approaches that are used and how the garden will be planted. These include estimates of garden size, the mix of plants from month to month, water-use efficiencies, and planting densities, none of which are fixed and all of which impact directly on water-use estimates.

The table which follows provides estimates which can be used for approximate tank sizing, given the wide range of garden uncertainties which must be assessed in any single situation.

TABLE 4.4: APPROXIMATE WATER REQUIREMENTS FOR VEGETABLE CROPS WHERE INTENSIVE WHC METHODS ARE USED (LITRES/MONTH/M^2)

Crop water demand	Typical crops	Summer rainfall area demand (litres/month/m^2)		Winter rainfall area demand (litres/month/m^2)	
		Summer	Winter	Summer	Winter
High demand	Spinach, chinese cabbage, rice,	70	98	165	23
Medium demand	Potatoes, mealies, wheat, mixed crops	63	73	135	25
Low demand	Tree crops, beans, cabbage	25	48	65	50

Water requirements for a garden of 50 m^2 in a summer rainfall area would thus be calculated as follows:

TABLE 4.5: GARDEN WATER REQUIREMENTS ACROSS THE YEAR FOR A GARDEN OF 50 M^2

Month	Season	Crop water demand (see Table 4.4)	Monthly garden requirement / m^2	Monthly WHC garden requirement for 50 m^2	Cumulative WHC garden requirement (litres)
Jan	summer	Medium	63	3150	3150
Feb	summer	Medium	63	3150	6300
Mar	summer	Medium	63	3150	9450
Apr	winter	Low	48	2400	11850
May	winter	Low	48	2400	14250
Jun	winter	Low	48	2400	16650
Jul	winter	Low	48	2400	19050
Aug	winter	Low	48	2400	21450
Sep	winter	Low	48	2400	23850
Oct	summer	High	70	3500	27350
Nov	summer	High	70	3500	30850
Dec	summer	High	70	3500	34350
TOTAL					34350

4.7.6 Domestic Water Use Estimates

It is common sense that water consumption is linked to availability and quality – the more people have access to, the more they will use, within reasonable limits of supply or cost. Where people must carry water on foot, consumption can be as low as 7 litres / person / day. Where yard connections are available, this can easily increase to 5 times that amount.

When assessing how much water a roof-harvesting system can yield for a household, the particular household situation must be considered. It is recommended that the value of 25 litres per person per day (as set by the DWA) is used in the supply-demand balancing calculation if no other information is available.

- Typical *daily* demand for 5 people (litres): 5 x 25 litres = 125 litres / day
- Typical *monthly* demand for 5 people (litres): 125 x 30.5 days = 3812.5 litres / month
- Typical *annual* demand for 5 people (litres): 12 months x 3812.5 litres = 45750 litres / year

OR

TABLE 4.6: TYPICAL VALUES FOR RURAL HOUSEHOLD WATER NEEDS, SOURCES AND RECYCLING

Water use/water need	Typical quantities needed	Quality required	Suitable water sources	Recyclable portion and quality
Domestic water – safe for drinking				
Potable (drinking, cooking, dishwashing)	7 liter per person per day	Drinking standard	Treated municipal water; uncontaminated local springs, wells & boreholes; roof-harvested rainwater.	60% (mainly from dishwashing)
Domestic water – good for cleaning purposes				
Domestic non-potable (washing self, cleaning house, laundry)	65 liter per person per day	Clear water	All the above, plus surface-harvested rainwater (e.g. underground rainwater tank); local streams, rivers, dams.	70% (good for raw water uses)
Water for production				
Vegetable gardening	Maximum 20 liter per m^2 per week (summer)	Raw water, but without toxins	All the above plus recycled water from above uses plus run-on and infield rainwater harvesting.	0%
Fruit trees	Minimum 20 liter per tree per week			
Poultry (Smith, 2006)	0.200 liter per adult chicken per day			
Small livestock	10 liter per adult goat per day (10% of bodyweight)			
	50 liter per adult cow per day (double for lactating animals)			
Cement-block making	20 liter per 20 large blocks or 40 maxi-blocks	Raw water (free from chemicals and silt)		

4.7.7 Assessing Annual Supply and Demand

Supply and demand is assessed by looking at the **total supply** versus the **total demand** for the year. In the example we have been using:

- The **supply** is the runoff from the roof, which is 34374 litres/year (average);
- The WHC **garden demand** for crops on a 50 m^2 garden is 34350 litres/year;
- The **household demand** for 5 people is 45,750 litres/year.

The annual supply and demand is summarised in Table 4.7, along with the equivalent number of 5000 litre plastic tanks that these volumes would fill (these are the tanks that are widely used in rural areas in South Africa).

TABLE 4.7: SUMMARY OF EXAMPLE – ROOF RUNOFF AND DEMAND

Description	Annual Volume (litres)	Approximate number of 5000 litre plastic tanks per year
Roof water supply (roof area = 43.6 m^2)	34374	Just fewer than 7 tanks (total roof runoff each year)
Garden demand (planted area = 50 m^2)	34350	Just fewer than 7 tanks (total water used in garden each year)
Household demand (5 people)	45750	Just more than 9 tanks (used in household)

In this example, the total yearly roofwater supply (of 34374 litres in an average year) is just enough to meet the total yearly needs of the 50m^2 garden (34350 litres/year), but the roof runoff is not enough to meet the domestic demand.

4.7.8 Calculating Storage Requirements

Because the rain does not fall equally on every day in the year, there is a need for storage to balance the supply and the demand over the wetter and drier months of the year. The storage requirement is calculated for each specific demand situation.

In the example we have been using, because the roof runoff is not sufficient for domestic use, the balancing calculation can by simplified by looking only at the roof runoff supply and the garden requirement (which would be the case where people have access to a reliable municipal water supply).

The balancing calculation is done for each month from January to December. The calculation is done on a cumulative basis, which means that the total for each month is added to the previous total. Similarly, each month of demand is added to the next. These can be presented in tables or plotted on a graph.

The storage space that is needed is the largest difference between the two sets of values (i.e. the cumulative roof runoff volume minus the cumulative garden demand.

TABLE 4.8: MONTHLY CUMULATIVE ROOF RUNOFF, GARDEN DEMANDS & STORAGE REQUIREMENTS PER L

Month	Cumulative roof runoff volume (litres)	Cumulative garden demand (litres)	Monthly storage required (litres)
Jan	4513	3150	1363
Feb	9339	6300	3039
Mar	13616	9450	4166
Apr	16677	11850	4827
May	19071	14250	4821
Jun	20444	16650	3794
Jul	21621	19050	2571
Aug	22995	21450	1545
Sep	25153	23850	1303
Oct	27507	27350	157
Nov	30646	30850	-204
Dec	34374	34350	24

The largest difference is in **April**. The storage needed is 4827 litres, which is approximately equal to one 5000 litre plastic tank.

If the calculation is to be done for both domestic and garden demand (in another situation, for example), then these must be added together to arrive at a total demand. The storage is calculated in the same manner, but using the combined garden and household demand figures.

4.7.9 Uncertainties and Approximations

The calculation for roof runoff is done using average monthly rainfall figures. Using average rainfall data will tend to *overestimate* the tank size that can be supplied by a given roof because low rainfall years are more common than high rainfall years. This means that in most years, there will be less runoff than the average, but in a few years there will be a lot more than the average. In practice this will leave the tanks less than full for most years, although they will overflow every 5 years or so.

4.8 Greywater use

It is recommended that specific structures are built for use of greywater on a regular basis. Suggestions are bag and tower gardens nod keyhole beds. These structures assist with the management of the greywater in the soil

4.8.1 Bag Gardens and Tower Gardens

Introduction

'**Bag gardening**' is a specific gardening technique that provides a small intensive food garden at the kitchen door, which can use grey water, and is easy to maintain once constructed. It became known in South Africa through contact with Kenyan examples.

In its simplest form, it is an upright 'gunny bag' filled with a fertile soil mixture, with a porous core made down the centre to ensure even water distribution throughout the soil mass. Vegetables are planted through holes made in the sides of the bag, and on the top surface.

In mountainous Lesotho, which has an effective growing season of only about three months, women carry their 'gunny bag' gardens indoors at night and during cold spells. This provides them with vegetables when crops planted outside cannot survive the severe climate.

Two further variations of bag gardening are found in South Africa, namely:

- The larger upright bag garden, in South Africa this is called a '**Tower Garden**'. Instead of a single bag, several bags are sewn together, or other suitable cloth like shade-netting is used, if available. The porous core is constructed of flat rocks. Tower gardens can increase the planting space fourfold compared to conventional ground level gardens;
- The horizontal or '**Flat Bag' Garden**, which is filled like the gunny bag, but placed down flat on its side. This obviates the need for a porous core; instead, it is watered by inverting a two-litre plastic cooldrink bottle in the centre of the bag. The bottle is left in place for up to a week to supply a slow trickle of water to the bag garden. Up to fifteen spinach plants can be grown in each Flat Bag, which shows the intensive nature of production in these bag gardens.

Figure 4.17: *Mrs Mahangu, Ndonga, with her **Tower Garden** in its third year of production.*

Figure 4.18: *This **Flat Bag** garden belongs to Mrs Linda Ngatsane, Female Farmer of the Year 2007, and Shoprite/Checkers Woman of the Year. Note the upturned bottle for slow, continuous irrigation of up to a week!*

Bag gardens and Tower Gardens can be made anywhere conveniently close to a home, for instance outside the kitchen door. This makes it easy to water them with grey water from the kitchen, and makes it possible to pick vegetables even during the cooking process! Anyone can make these gardens, but they are particularly useful for older or vulnerable people, as one does not need to walk far, nor bend down a lot. A well-maintained tower garden could yield vegetables winter and summer for at least three years. However, one must ensure that goats and chickens cannot get to the tower garden and destroy it.

4.8.2 Making the most of grey water

Grey water refers to water that had already been used for domestic purposes; such as washing of dishes and clothes. In many cases, water has to be carried from the nearest stand-pipe in plastic containers, not for the purpose of gardening, but for cooking and washing. This water can successfully be re-used for growing vegetables. This is a way of saving water, especially as water is very scarce in most areas.

Although gardeners were initially very sceptical that vegetables could be grown successfully with soapy water. However, the results speak for themselves and once they mastered the management of the system, the results were good:

- Gardeners were convinced: Vegetables can grow successfully with soapy water!
- Everyday, the available grey water is poured into the Tower or Bag Garden. The soapy water is cleared out of the system by pouring two buckets of clean water into the column, once a week.
- One can also reduce the soap in grey water by spreading some wood-ash on the water surface and leaving it in a container overnight to settle before using it for the plants.

4.8.3 This is lazy gardening

One of the main attractions of the method is that little labour or attention is required and this appeals to all busy gardeners. Once people have become familiar with the Tower Gardens, they prefer to position them right at the back door so that it is easy to pour the wastewater into the tower.

It is difficult to predict how much water is required: in full production, two to three 20 liter buckets will be needed, while one bucket should suffice in winter. If water forms a puddle around the bottom of the tower or bag, it is an indication that too much water is being applied and the obvious answer is to make a second tower!

Figure 4.19: Participants in Potshini are planting spinach into the sides of the newly prepared tower garden. Tomatoes and onions will be planted on the top surface.

4.8.4 What vegetables can be grown?

Figure 4.20: Note how taller-growing crops have been planted on the top surface of this Tower Garden (i.e. at about waist height).

Bag and Tower Gardens are ideal for leafy crops, typically the various varieties of **spinach**, which are planted through holes made in the sides of the bag or cloth. Ideally, the holes should not be directly above one another, but should be staggered diagonally for more sunlight and space for root development.

Tomatoes and **onions** can be planted in the top layer and, if crops require trellising, this can be provided by extending the vertical uprights and joining them with wire or string.

Where possible, companion crops should be grown for biological control of disease and pests. **Garlic** and **onions** are particularly useful.

An unexpected benefit is the way in which the vegetables have **thrived in severe heat wave conditions** that have proved too much for conventionally planted gardens. The reason for this is not quite clear. Possible factors are the free air circulation, lower soil temperature and the better moisture status of the soil.

It is not claimed that towers would be able to provide all the food a family needs, but the contribution made to nutrition and eating pleasure is very considerable.

4.8.5 How to make a Tower Garden

A Tower Garden can be constructed from shade-netting (or other available cloth), four poles, soil, kraal manure and wood ash.

The poles are planted upright to hold the cloth 'skin' in place while the tower is being filled with soil, and are used for trellising, if necessary. A porous centre of flat stones controls the flow of water so that the soil in the tower is kept at the right water content for growth. The soil mix provides fertility, while the wood ash in the mixture helps neutralise the effects of soapy water.

Figure 4.21: A picture of a tower garden being constructed. Poles here are made from branches, and the tower is made from shade cloth

Ground surface:

The ground needs very little preparation; all that is needed is to level and compact a circular area of at least 1m in diameter. It should also be noted that the tower would need enough sunlight for vegetables to thrive. In very hot areas it can be beneficial to cover the tower garden with a simple shade cloth structure, or place it next to a tree for partial shade during the day.

Poles:

The upright poles can be made from trimmed branches, fencing standards or any other available thin poles. Where crops such as tomatoes are planted on the top surface of the Tower, extensions can be wired onto these poles to provide trellising.

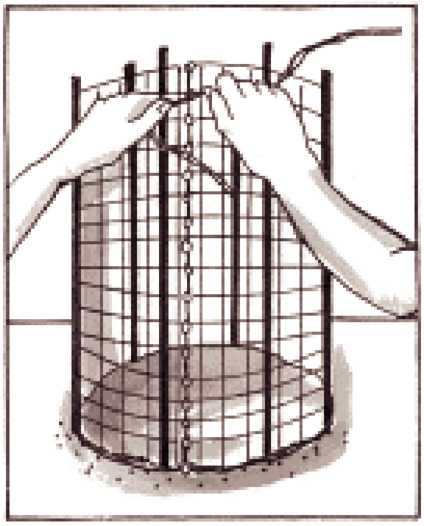


Figure 4.22: It is important to use nylon string or fishing line to join up the ends of the shade netting to form a cylinder, as shown in the diagram. The recommendation is to use 80% knotted shade cloth, available at most farmer co-ops. The string and the shade cloth will last best if they are UV protected.

Cloth:

The selection of the cloth that forms the sides of the tower is critical. In Kenya, nylon gunny bags were used, but were found to only last for about two years.

All sorts of materials were tried initially in South Africa:

- Sacking, as shown in some of the photographs, did not last the season;
- Black plastic sheets deteriorated rapidly in the sunlight;
- Shade netting proved to be far more durable.

Soil:

The soil must be fertile and must retain moisture well.
People should be able to develop appropriate soil mixtures utilising locally available material, but some experimentation would be required.

The following recipe gives a good soil mixture of the right quantity for one Tower Garden:

- Six wheelbarrows of soil;
- Four wheelbarrows of cow manure; and
- Two wheelbarrows of wood ash.

Building the tower with the soil mixture is something of an art. The three parts should be mixed well and must be slightly damp, to be cohesive without compacting during placing. When water is applied when the tower is in use it must be distributed evenly throughout the soil mass and thus to the plant roots.

Porous core:

The stone filling that forms the porous core must be built correctly to ensure that water poured into the top of the stone column can flow evenly throughout the soil mass. When the first attempts were made in South Africa , round stones were used and the water simply ran down the center of the tower, leaving most of the soil mass dry. Carefully packed flat stones, or building rubble, solved the problem. Smallish round stones may be used, provided they are so arranged and packed that satisfactory water distribution is achieved.

Figure 4.23: Participants in Potshini are busy filling up the porous stone column in the middle.

- Note the small white bucket (bottomless) that provides a rigid sliding structure for the placing of the stones.
- Use flat stones or flat pieces of building rubble to build the porous core. Lay them horizontally to help push water outwards towards the soil.
- Avoid any compacted areas in the soil, as this will hinder even water distribution.

4.8.6 Conclusion

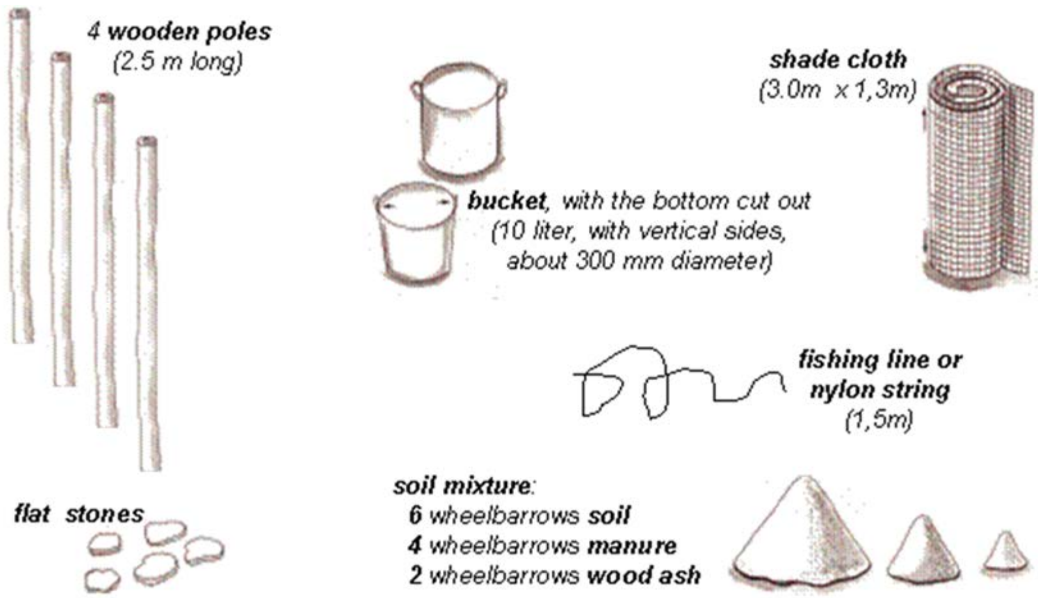
Tower Gardens and Bag Gardens are in their infancy in South Africa, but have the potential to make a real difference in areas where extreme climate and adverse circumstances have led to household vegetable gardening being considered out of the question. Tower Gardens have been implemented in the Lady Frere and Cala areas near Queenstown in the Eastern Cape, in Potshini in KwaZulu-Natal, and in Limpopo Province in the Nzhelele valley, North of the Soutpansberg and Makuleke in the North Eastern part of the province.

In all of these places the system worked very well, but many households kept it going for more than a year. The main reasons for abandoning the garden seem to have been the following:

- It was not well fenced and was sooner or later destroyed by goats and/or chickens;
- It was too far from the kitchen to easily make use of the grey water; and/or
- The household received water supply on site, which enabled them to start a larger, conventional garden.

Figure 4.24: Flourishing Tower Gardens

4.8.7 What material does one need to make a Tower Garden?



4.8.8 How does one make a Tower Garden?

Step 1:
Choose a flat piece of ground (1m x 1m), as close to the kitchen as possible, but make sure that goats and chickens won't be able to get to your Tower Garden.

Step 2:
Plant the 4 wooden poles to form the four corners of the Tower.

Step 3:
Wrap the cloth around the poles and sew the ends together with fishing line or nylon string (something that won't rot away, letting the Tower collapse).

Step 4:
Roll the top edge of the cloth down and out of the way before filling the Tower.

Step 5:
Using a spade, mix the soil, manure and ash very well, then mix in some water to make it slightly damp (not too wet!), so that you can place the soil mixture without compacting it.

Step 6:
Fill the first 30cm (one ruler height) of the Tower with the soil mixture.

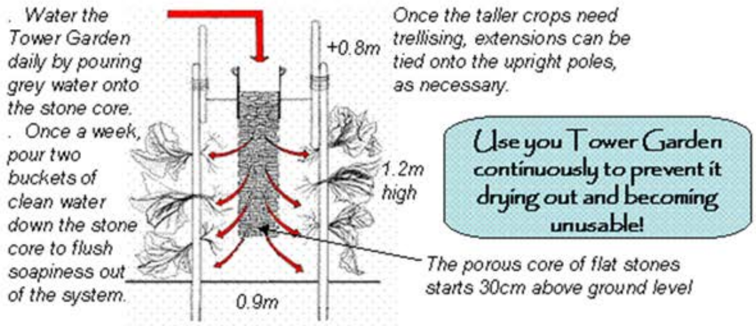
Step 7:
Place the bottomless bucket in the centre of the Tower, on top of the first layer of soil.

Step 8:
Pack flat stones carefully in the bucket, in such a way that water poured into the top would run through nice and slowly. This gives water time to seep sideways into the soil to the plant roots.

Step 9:
Fill the next layer of soil in the Tower around the bucket and up to its rim. Take care not to compact the soil while placing it.

Step 10:
-Pull the bucket out partially, leaving the stones in position.
-Pack the next layer of stones into the bucket and then the next layer of soil, again to the rim of the bucket.

Repeat until the Tower is at waist height (about 1.2m high). Plant seedlings into small holes made in the cloth, staggered around the sides of the Tower; and taller-growing crops on the top surface of the Tower.



5 Soil fertility and soil conservation

5.1 Living Soils

Soil, which covers much of the earth's surface, consists of unconsolidated mineral and organic matter (rock, and decayed organic material and living organisms).[1] Air and water are also components of soil.

Most life on earth depends upon the soil for food. Soil serves as a medium for plant growth and is the primary nutrient base for plants, providing them with water and minerals. Humans and animals, in turn, get nutrients from eating the plants. The soil is also home to many organisms such as seeds, spores, insects, worms, snails, mites, millipedes, bacteria, fungi, algae and other micro-organisms.

Soil is a medium which stores and moves water, and thus plays an essential role in the water cycle. When it rains, a large proportion of water falls directly or indirectly onto the soil, where, depending on factors such as the structure and texture of the soil, it:

- Infiltrates and is stored in the soil for plant use;
- ***Percolates*** down through the soil and recharges groundwater aquifers; and/or
- Runs over the soil surface as surface runoff.

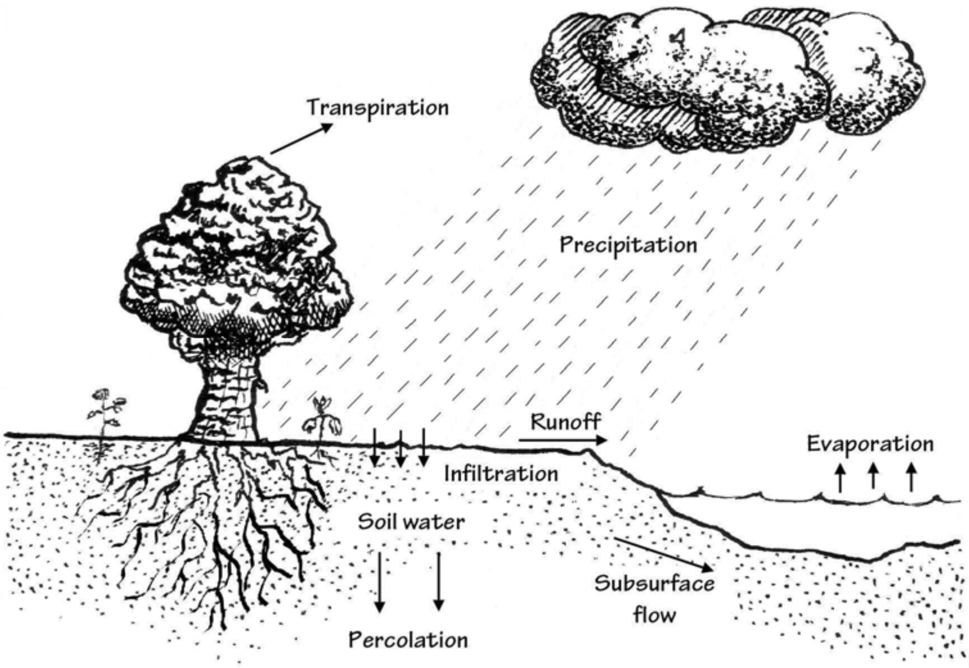


Figure 5.1: Water movement through the soil

Soil consists of **solid matter** (mineral particles and organic material), **water** and **air**. Water and air is held in the spaces that exist between the soil particles and organic matter. These spaces, which are called *pores*, enable water, air and nutrients to move around within the soil system. Water infiltrates the soil through the pore spaces when there is precipitation (such as rain) and the pores become filled. As the soil begins to drain or dry, the water in the pores is replaced by air.

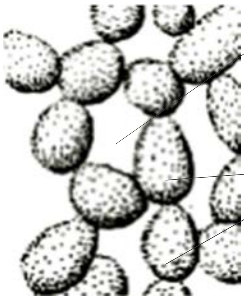


Figure 5.2: Soil composition

Soil is a medium which absorbs, stores and moves water, as illustrated in Figure 5.4.

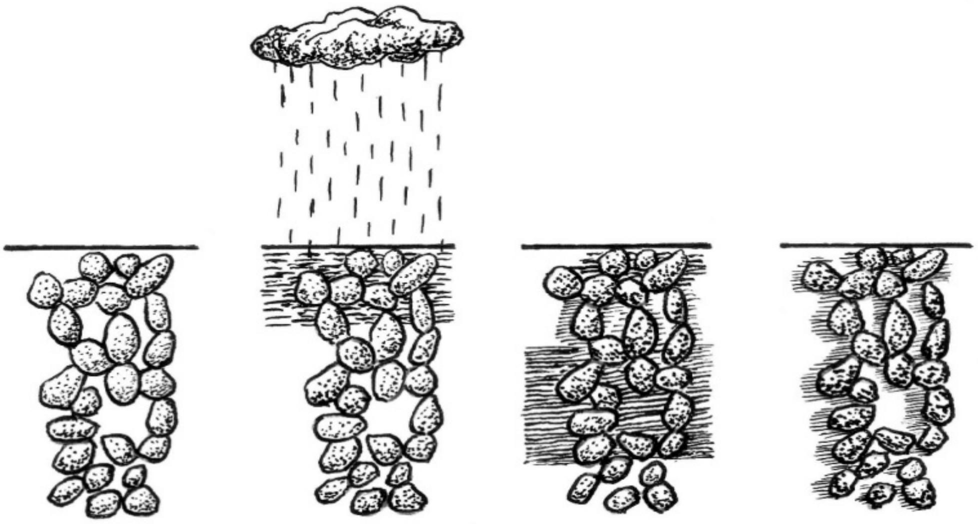


Figure 5.3: Water in the soil

The following terminology is used in relation to the penetration and movement of water through the soil:

Infiltration:

The rate at which water enters the soil surface (measured in mm/hour). Infiltration rates can be very low for clayey or compacted soils, and very high for sandy soils.

Drainage:

The ability of the soil as a whole to drain excess water. Drainage problems can arise when there is an impermeable layer (e.g. a layer of clay, rock or compacted ***subsoil***) at a shallow depth which prevents water from draining away.

Permeability:

The rate at which water (and air) can penetrate or pass through a layer of soil. Some soils are more permeable than others (i.e. water moves through certain types of soil – such as sandy soil – more quickly).

Water Content:

Water held in the soil.

Water-Holding Capacity:

The ability of a soil to hold water, measured as the amount of water held between ***field capacity*** and ***wilting point***. Water-holding capacity is linked to soil texture: coarse soils such as sand have the lowest water-holding capacity, while medium-textured soils have the highest. *Saturation* (or ***saturated soil***) is the soil water content when all of the pores are filled with water.

Field capacity (or *moist soil*) is the soil water content after the soil has been saturated and then allowed to drain freely for 24-48 hours. *Permanent **wilting point*** (or *dry soil*) is the soil water content once plants have extracted all the water they can from the soil.

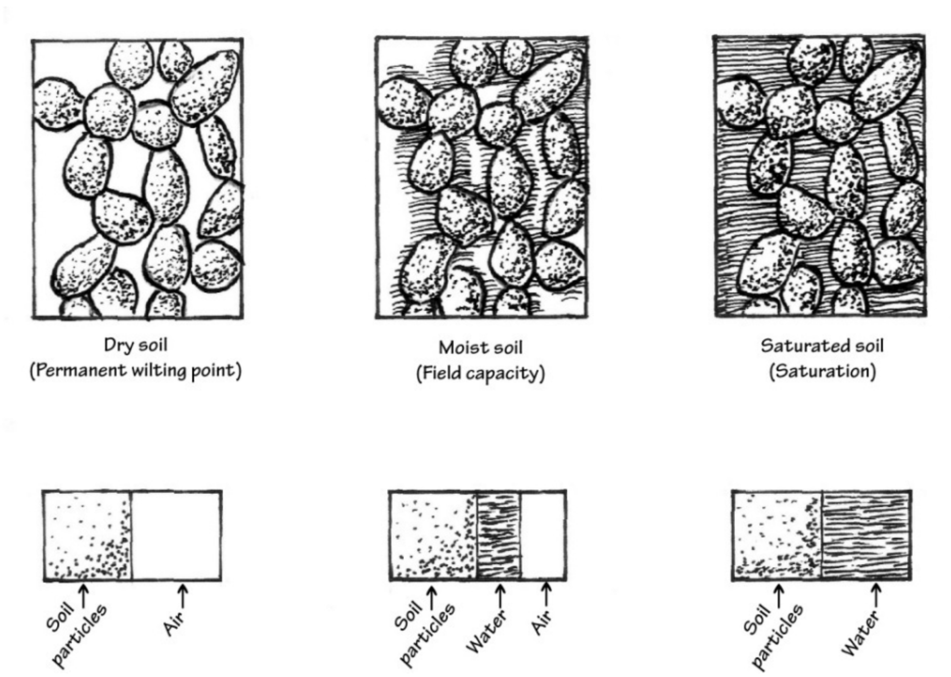
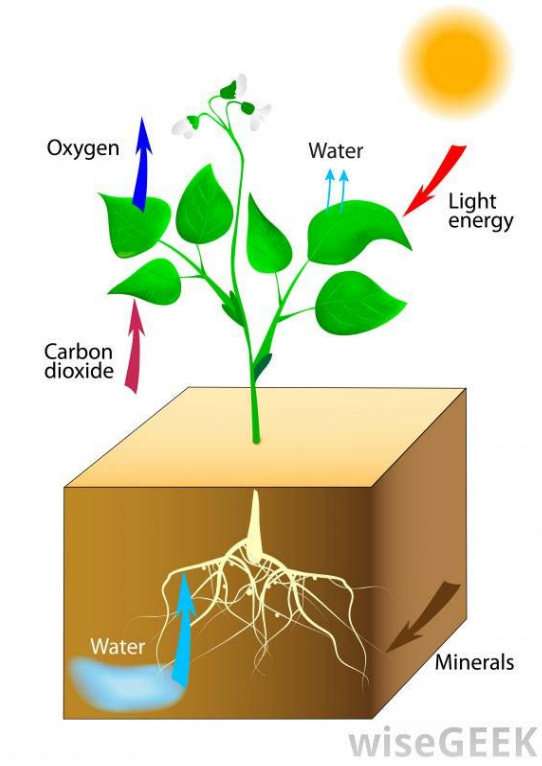


Figure 5.4*: Amount of water and air in dry soil, moist soil and saturated soil*

Plants that are growing in the soil link the water that is present in the soil to the atmosphere. The shoots of plants, which consist of the stems and leaves, are exposed to the atmosphere. The leaves of plants contain many small openings, called ***stomata***. During daylight, these stomata open to take up carbon dioxide from the atmosphere. This carbon dioxide is transformed into sugar during a process called photosynthesis. It is this sugar that forms the elementary building block of all the different types of tissues found in plants. When the stomata open, water inside the leaves is exposed to the atmosphere and evaporates. This means that when plants take up carbon dioxide from the atmosphere in order to grow, they lose water to the atmosphere. The water that is lost from the leaves has to be replaced. This is where the roots of the plant play their role. The loss of water from the leaves creates a suction in the leaf cells because the walls of the cells are elastic.

The suction created in the leaves from the loss of water is transmitted through the stems to the roots, causing the roots to suck water from the soil.

As plant roots take up water from the soil, the soil dries out. It becomes increasingly difficult for plant roots to take up the water that remains, so unless the soil water reserve is replenished, a situation will develop where the roots can no longer supply the leaves with enough water to make up for the losses to the atmosphere. When this situation develops, the plant responds by wilting, a sign that the cells in the leaves do not have enough water. The stomata close to prevent the plant from drying out and dying, and when the stomata are closed, carbon dioxide is no longer taken up so plant growth comes to a halt.



Simply put, the optimum growth of plants is dependent on the leaves of the plant being supplied with sufficient water at all times. Whether this actually happens depends on many factors. One important factor is the weather, as a lot more water is lost from the leaves during dry, hot, windy conditions than in cool, humid, windless conditions.

The ability of plants to maintain an adequate supply of water to the leaves, even under extreme conditions, is dependent on the water content of the soil and on the distribution of the root system of the plant. The closer the water content of the soil is to ***field capacity*** (the soil water content after the soil has been saturated and then allowed to drain freely for 24-48 hours), the easier it is for the plants to suck water from the soil. Therefore, keeping the soil water content close to field capacity is a management practice that promotes high plant growth rate.

5.2 Soil types

Soil is made through the breaking up of the basic elements or minerals of the earth. These are initially found in the form of rocks. Over a very long time, these rocks are broken down into small particles through rain, wind and sun 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.

- 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 are called loams and they are an equal mixture of sand, silt and clay.

5.2.1 Characteristics of soils

TABLE 5.1 CHARACTERISTICS OF SOILS

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

5.2.2 How to tell your soil type

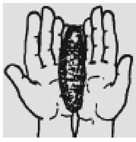
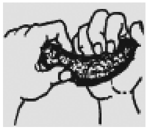
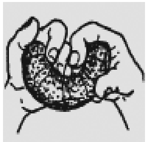
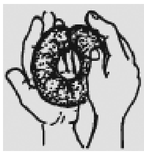
You can tell how much sand, silt or clay is in your soil by how it feels. Wet some soil and roll it into a ball between your hands. Then roll this little ball into a sausage. You can tell what kind of soil it is by looking at the table below.

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.

Sandy soil needs to be given organic matter to increase its ability to hold water and plant food. 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.

All types of soil need organic matter to increase their fertility, or plant food.

TABLE 5.2: SOIL 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
Quite sandy	Rough	Can be rolled into a sausage but it cannot bend		Sandy
Half sandy & half smooth	Rough	Sausage can bend a little		Sandy loam
Mostly smooth	A little sandy, quite smooth but not sticky	Sausage can bend about half way around		Loam or silt loam
Mostly smooth	A little sand quite smooth and sticky	Sausage can be bent more than half way round		Clay loam or sandy clay
Smooth	Smooth and sticky	Sausage can bend into a ring		Clay

Another method of identifying the proportion of soil separates 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.

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.

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.

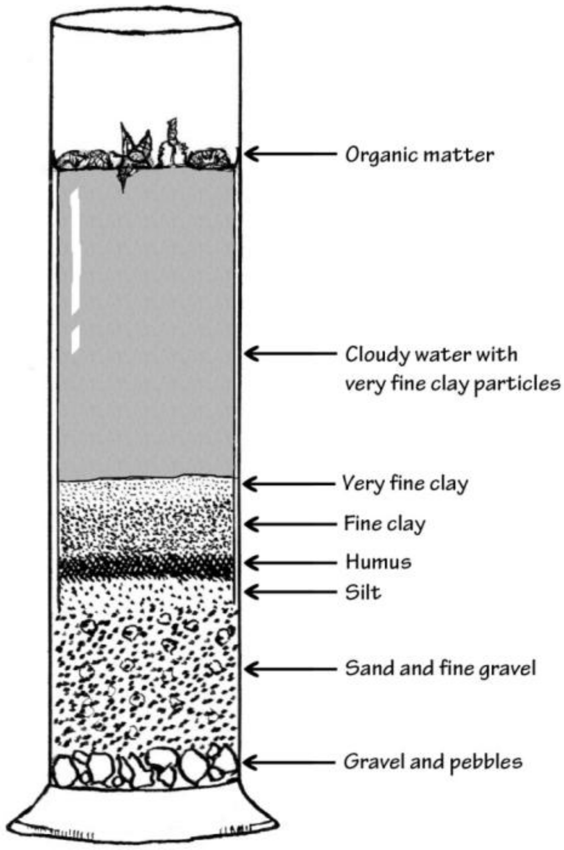


Figure 5.5: Bottle test showing proportion of soil separates (From: WHC Manual, WRC, 2010).

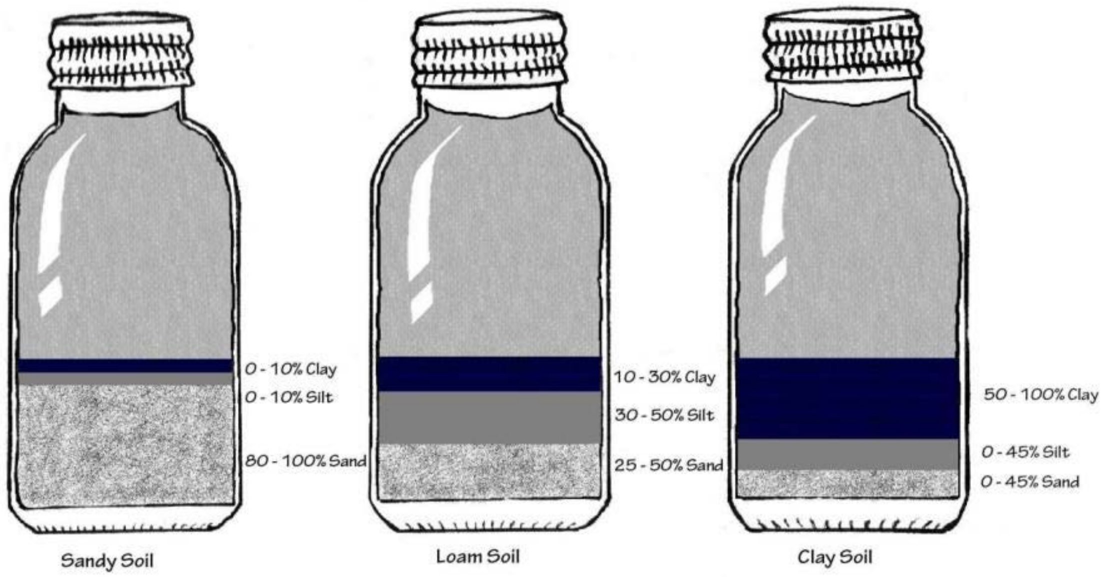


Figure 5.6: Using the bottle test to estimate the proportion of soil separates in a sample

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5.2.3 Why are nutrients and soil so important?

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 intern benefit from the variety of nutrients available. Soil is important to human survival, health and vitality.

5.3 Soil structure

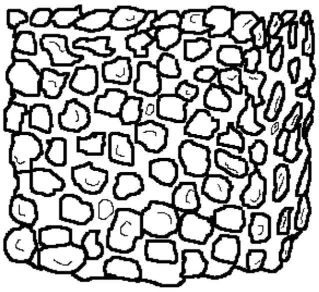
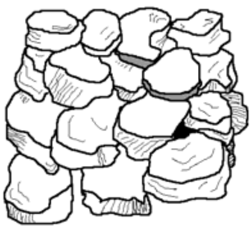
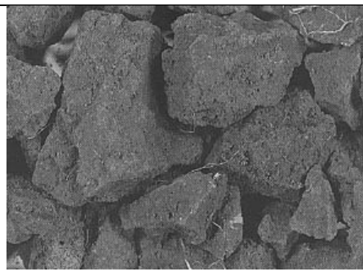
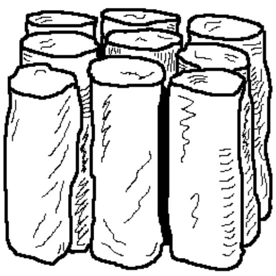
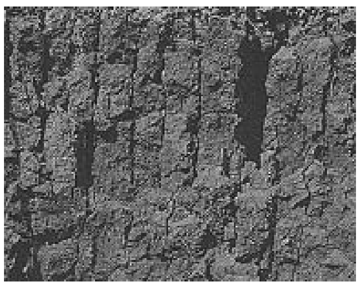
Soil structure describes the grouping or arrangement of primary particles (sand, silt, clay and organic matter) into larger, secondary particles called aggregates or peds. In other words, soil structure is the shape that soil takes, determined by the way in which individual soil particles clump or bind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

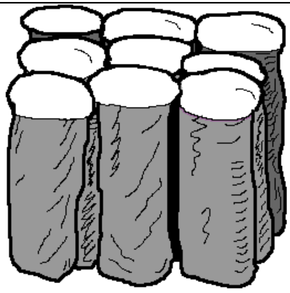
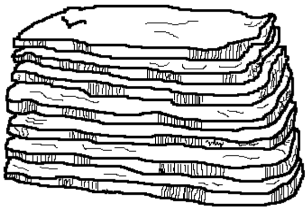
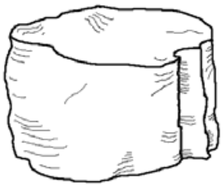
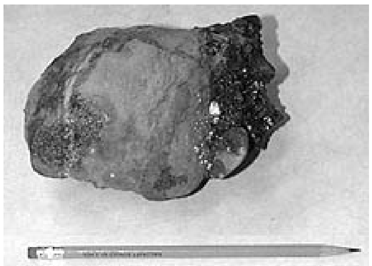
Soil structure affects the movement of water and air in the soil, as well as root penetration and biological activity. For example, a dense structure greatly reduces the amount of air and water that can move freely through the soil, and it is difficult for roots to penetrate such soil.

There are five major classes of soil structure: granular, blocky, prismatic, columnar, platy. There are also soils which lack structure, such as sandy soils, and these are referred to as “structureless”.

TABLE 5.3 : SOIL STRUCTURE

(From: Wikipedia. Soil. [Online]. Available from: http:// en. wikipedia. org/wiki/Soil [Accessed 16 September 2009].

Granular: Resembles cookie crumbs and is usually less than 0.5 cm in diameter. Commonly found in surface horizons where roots have been growing.		
Blocky: Irregular blocks that are usually 1.5 - 5.0 cm in diameter.		
Prismatic: Vertical columns of soil that might be a number of cm long. Usually found in lower horizons.		

Columnar: Vertical columns of soil that have a salt "cap" at the top. Found in soils of arid climates.		
Platy: Thin, flat plates of soil that lie horizontally. Usually found in compacted soil.		
Single Grained: Soil is broken into individual particles that do not stick together. Always has a loose consistency. Commonly found in sandy soils.		
Massive: Soil has no visible structure, is hard to break apart and appears in very large clods		

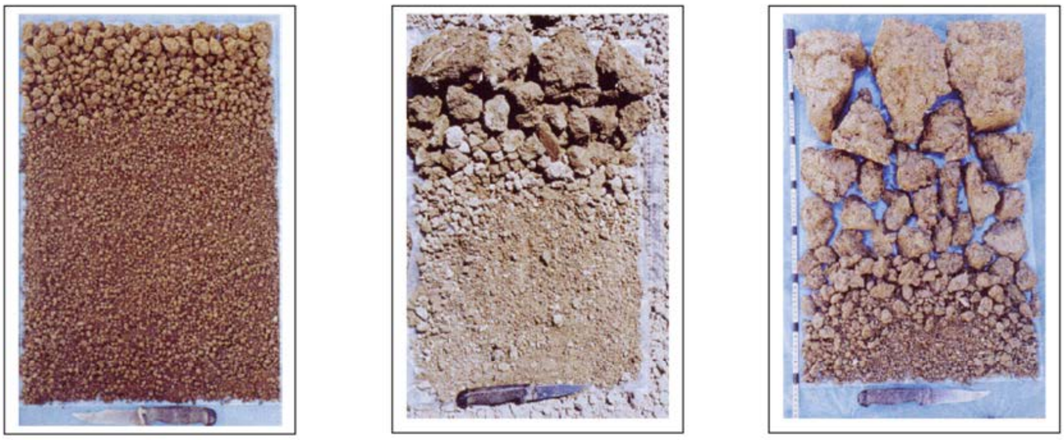
**Soil structure photographs courtesy of Dr. Elissa Levine, NASA/Goddard Space Flight Center*

The structure of the soil is influenced by how it is managed – some practices are harmful, while others are beneficial. Harmful practices break down the structure of the soil, making it a lot harder to work with and for plants to grow well in. Beneficial practices build up the structure as well as the quality of the soil, making it easier to work with and for plants to grow in well.

5.3.1 Soil structure test 1: Shatter test

Here a 20cm square block of soil is dropped a maximum of 3 times from a height of 1m onto or into a basin or square wooden frame or sheet of plastic. If large clods break away, drop them again individually once or twice. If a clod shatters into small pieces after the first drop leave it like that.

Arrange the clods on the bag from coarsest to finest. This provides a measure of the aggregate size distribution. Compare the results with the 3 photographs to provide a score.



GOOD CONDITION VS: 2	MODERATE CONDITION VS: 1	POOR CONDITION VS: 0
Good distribution of friable finer aggregates with no significant clodding	Soil contains significant proportions of both coarse firm clods and friable, fine aggregates	Soil dominated by extremely coarse, very firm clods with very few finer aggregates

Figure 5.7: Soil structure

Some examples of harmful practices:

- Watering too much and too often.

  Result: The soil organisms and plants get choked because they lack air.
- Adding chemical products such as pesticides and fertilizers.

  Result: Causes unnecessary poisoning of the soil.
- Heating of the soil surface through fire or prolonged sunlight.
- **Result:** The ground dries up and micro-organisms are killed.
- Compaction of the soil through tillage and walking.

  Result: The soil crusts or caps.

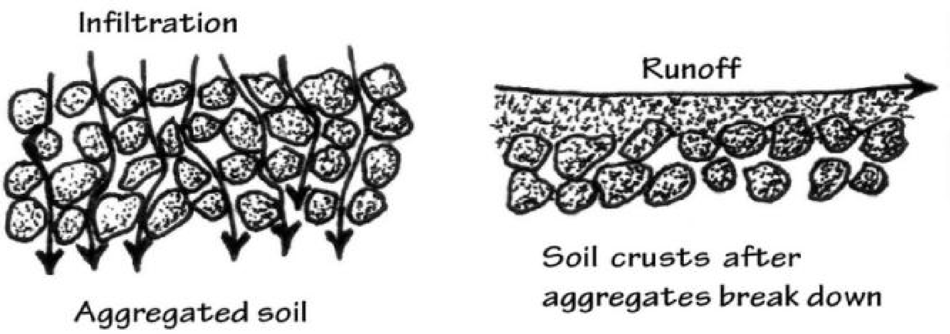


Figure 5.8: Infiltration vs Runoff (From: WHC Manual, WRC, 2010)

Some examples of beneficial practices:

- Controlling soil erosion and rainwater run-off.
  Result: Minimises damage to soil and crops (eg. valuable ***topsoil*** does not get blown or washed away).
- Allowing fallow intervals (periods where fields/plots are rested and not used for production).
  Result: The soil has time to recover its structure and fertility before planting takes place.
- Cultivating soil-enriching crops – species high in ***biomass*** or green manures.
  Result: Species high in biomass add a lot of organic matter to the environment and soil, while those high in green manures add nutrients such as nitrogen to the soil.
- Incorporating animal manure or compost into the soil.
  Result: Improves the soil structure and increases the soil life; helps create a well-balanced soil that is alive and can support plant growth.
- Mixed cropping; The soil structure benefits when the soil is occupied by the roots of many different plants, because:
- the roots move the soil;
- The roots create a network of living matter which dies and rots to create humus;
- When the roots die they leave tunnels which improve the porosity and drainage; and
- The roots are a living store of plant nutrients.

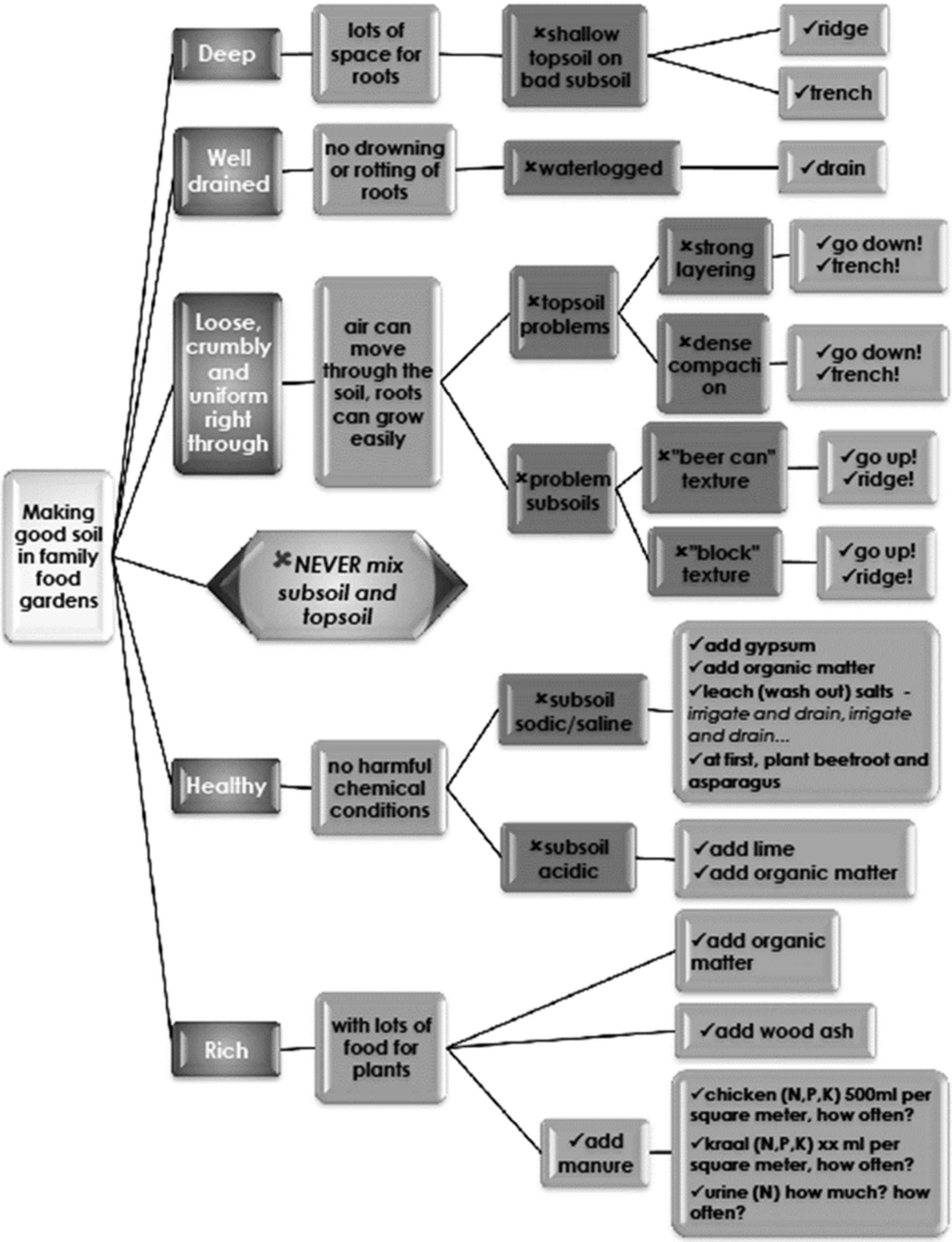


Figure 5.9: Making good soil in family food gardens.

5.4 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.

5.4.1 Nitrogen

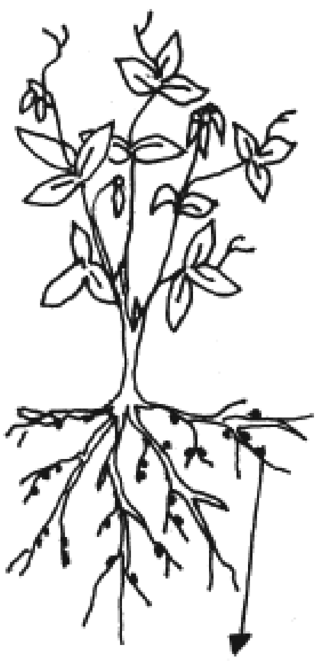


Figure 5.10: Nodules on the roots that fix nitrogen

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.

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.

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.

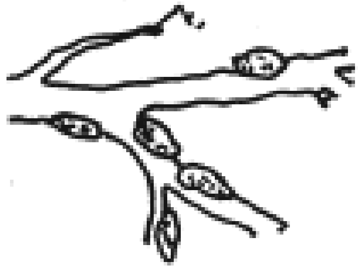


Figure 5.11: The bacteria in the root knots binds free nitrogen from air in the soil and release nitrogen after the plant dies

Examples of legumes that we often grow:

- Ground nuts
- Cow-peas
- Beans (including soya beans)
- Peas

Figure 5.12: 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.

5.4.2 Phosphorous

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.

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.

Figure 5.13: Preparing bone meal

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.

5.4.3 Potassium

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.

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).

Figure 5.14: 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.

5.4.4 Other important nutrients:

Calcium (Ca) - Promotes plant lifer 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.

5.4.5 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.

5.5 Soil acidity

5.5.1 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.

5.5.2 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.

5.5.3 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.

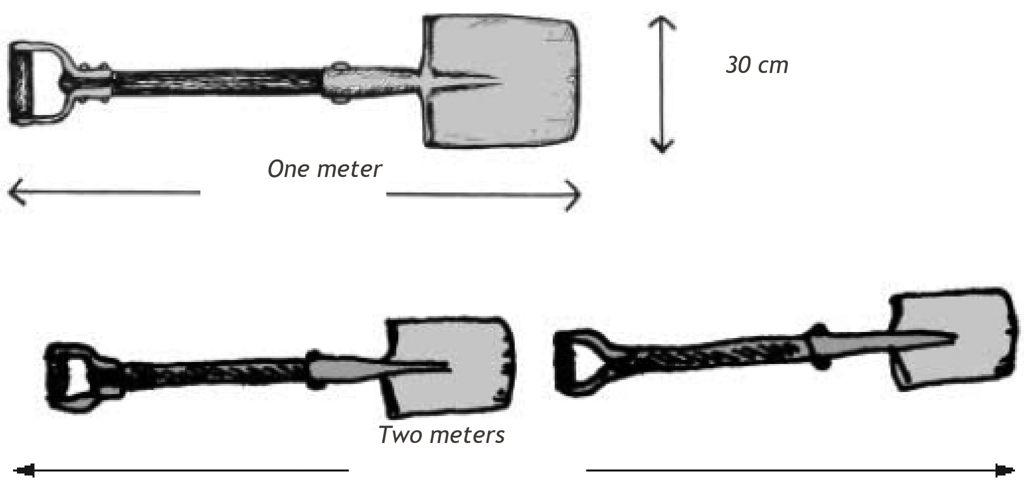


Figure 5.15: Easy measurements using a spade

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.

5.5.4 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

5.6 Photosynthesis

Plants and animals need nutrients to keep alive and healthy. Plants also have a special green colour (given to them by a substance called chlorophyll). They use energy from the sun, carbon dioxide from the air, 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.

The type of food made by photosynthesis is starch. This starch is used by the plant to grow and stay alive. Plants also store food to be able to grow after the cold seasons or for when their seeds need to grow.

Besides the starch, the plants also produce oxygen. Oxygen is a gas that all living things need to live.

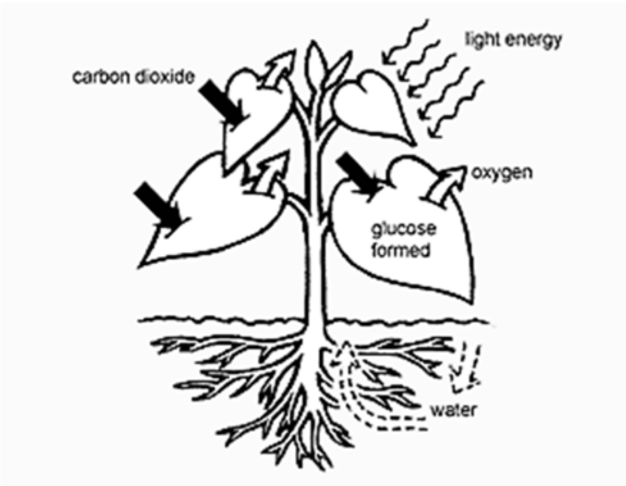


Figure 5.16: Photosynthesis
(from Agriseta NQF 3, LG:Plant anatomy and hysiology,2008)

5.7 Nutrient cycling

In nature nutrients are always being recycled. Plants take up nutrients from the soil to grow big, strong and healthy. When they grow they produce flowers that attract beneficial insects. These insects like bees and butterflies help with pollination (fertilization of the flower). The flower then turns into a fruit which is food for insects, birds, animals and or humans. These animals take the fruit (with seed inside) and spread the seed where ever they go. This ensures that the plants will grow in other places. Manure is returned to the soil.

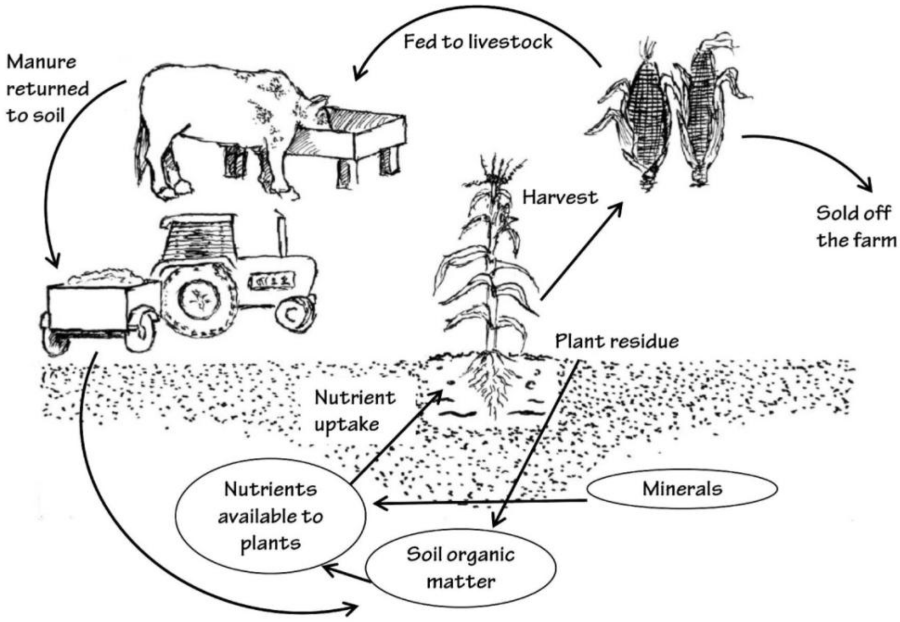


Figure 5.17: Nutrient cycle.
From: WHC Manual, WRC, 2010)

During the autumn and winter months plants may drop their leaves. These leaves and other organic matter are broken down by micro-organisms, earth worms and other insects so that it can dissolve into the soil and become humus. Humus gives the soil a dark colour, it holds a lot of nutrients and improves soil fertility. That is why soil life is so important.

To summarize this - all the goodness (nutrients) from fruits, leaves, branches, whole plants, animal dung and dead animals decompose and go back into the soil. The nutrients are taken up by plants in the soil and in this way are recycled (used again and again). The life of a plant is therefore a cycle and nothing is ever wasted. Nutrients are cycled through the soil and plants. Below is an example of the nitrogen cycle.

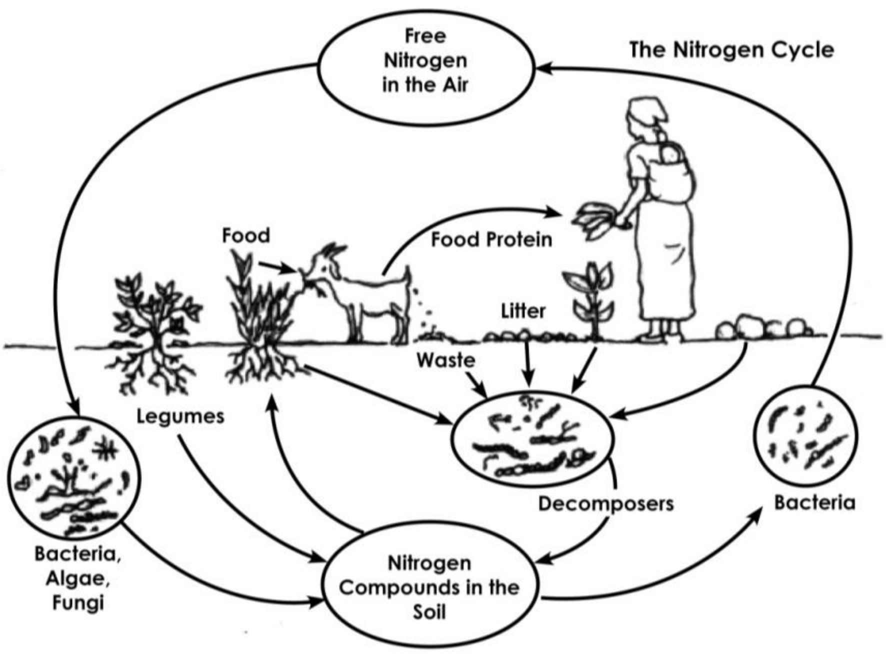


Figure 5.18: Nutrient cycle.
(From: WRC; Homestead Water Management Manual, 2009)

5.8 Improving soil health

Chemical fertilizers can restore soil fertility quickly because the nutrients are available to the plants as soon as they dissolve in the soil. However they do not improve soil structure and there are other disadvantages to using them.

There are many natural ways of improving soil health and fertility. Composting and manuring are common examples. This is where manure (dung) from animals and compost (humus) is ploughed or worked back into the soil. Other examples include the use of liquid manures and brews, green manuring, nitrogen fixing trees, crop rotation, mixed cropping and worm farming.

5.8.1 A comparison between chemical fertilizers and natural compost methods

Chemical Fertilizers: Disadvantages	Natural soil fertility methods: Advantages
- Chemical fertilizers are quick-acting, short- term plant boosters. - They can negatively impact on soil structure and organic matters - Beneficial life in soil including earthworms are negatively impacted - Chemical fertilizers alter vitamin and protein content of certain crops making them more vulnerable to diseases. - Growing plants often take up a lot of nitrates which makes growth soft and sappy and this is what pests love - Over time essential elements can be "locked up" and are therefore not available to plants. This reduces the fertility of the soil and plants can be more susceptible to disease and pest attack. - The activity of many soil organisms is inhibited. - The soil tends to become acidic - Fertilizers meet the basic nutrient needs of soil NPK but what about all the other elements? - Fertilizers are inorganic. They are manufactured in factories and this is not sustainable - Fertilizers are expensive to produce and buy - Chemical fertilizers are easily leached out. This can lead to pollution of water sources	- We are working with nature and natural laws - Natural methods of improving soil fertility endeavor to address the issue as a whole - by increasing a variety of nutrient levels, improving soil structure, water holding capacity and microbial activity (improving and encouraging life in the soil) - When we make our own compost we are in charge, we don't have to rely on anybody - It is sustainable because we can keep making compost/use natural methods - Nothing goes to waste - We use what we have - We don't have to pay money. Why pay for fertilizers when you can make your own? - It takes a while for organic matter to decompose into humus and before the nutrients are released but on the other hand it continues to improve soil fertility and soil structure for a long time. - Nutrients are not as easily lost or leached out - Crops produced in healthy soils are naturally healthy and show more resistance to disease and pests - An increase in organic matter reduces the likelihood of erosion

6 Composting

6.1 Compost Piles

Compost is decayed organic matter (plant and or animal), used as a fertilizer. It is the decomposed organic material called humus. Composting is therefore the art of making and using compost.

Nature maintains soil fertility by cycling and re using all dead animal and plant matter. Compost provides most the nutritional needs of a plant. It encourages beneficial microbial activity, improves water holding capacity and soil structure. It feeds and replenishes soil which in turn assists healthy, disease free plants to grow.

6.1.1 Building a compost pile

You will need: Air and water, nitrogen rich materials (animal manure, green plant material, vegetable waste, green weeds), carbon rich material such as (thin branches, leaves, dried grass, dried maize, ground nut shells).

Not essential but helpful: lime, bone meal (reduces acidity), seaweed (full of nutrients), mushroom compost, urine (diluted in water)

6.1.2 Creating your compost heap

Chose a suitable site (near water, in your garden, preferably under a bit of shade – to prevent moisture loss).

Collect all the materials you will need. Mark the area where you are making the pile. 1m by 1.5m is advisable or 2 spades by 2 spades. The size depends on the amount of organic matter available. Hoe the area you have marked out, removing all grass and plants.

Arrange the branches and sticks on the area you hoed. Lay the coarse material like dried maize, twigs etc. on top (about 30cm thick) and water.

Figure 6.1: Starting a compost heap.

The second layer will be of dry materials such of leaves and grass. About 20cm thick. Again moisten with a fine spray of water.

The third layer, of green materials is laid on top, about 1cm thick. Repeat the process (keeping the flat rectangular shape of the heap) until about 1.5m high. Cover the pile with a 5cm layer of manure.

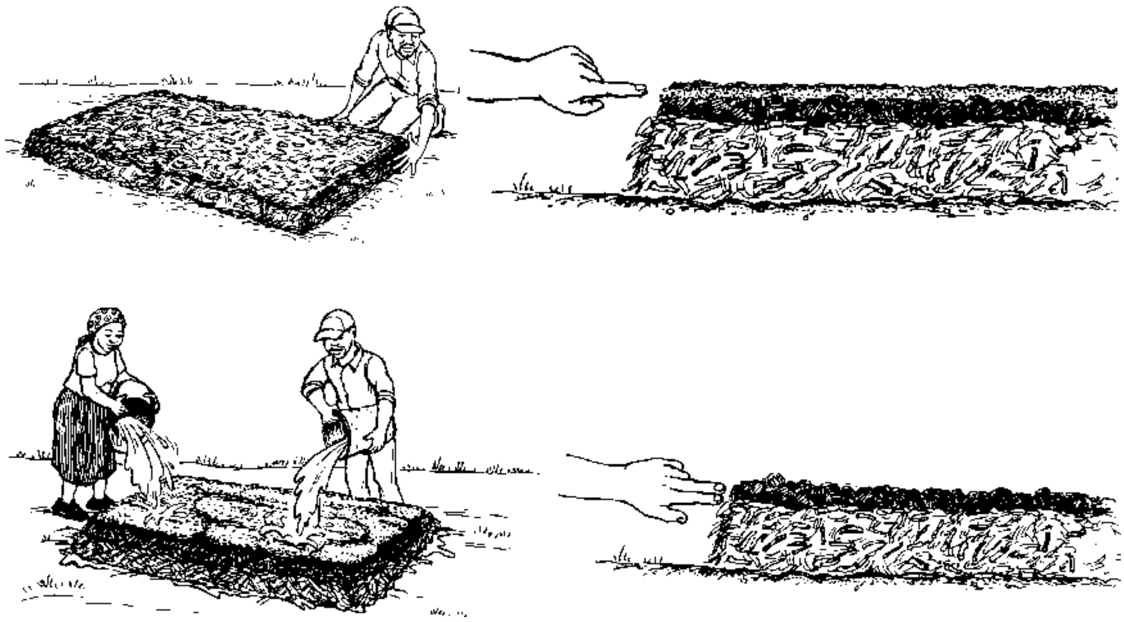


Figure 6.2: Adding second and third layer to compost heap.

Cover the heap with big banana leaves, old sacks or plastic to conserve the moisture and to keep nutrients from leaching out if you are experiencing a lot of rain.

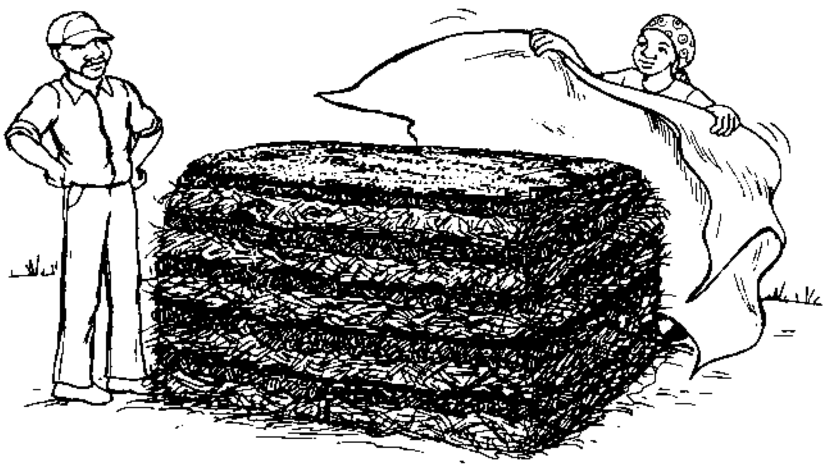


Figure 6.3: Cover the compost heat

Optional: Before you cover the pile, take a long sharp pointed stick and drive it into the middle of the compost pile at an angle. Within 2 or 3 days decomposition will have started and the pile should be hot inside. The stick helps you check the condition of the pile by showing you if it is wet or dry or warm. It should be checked regularly. If the pile is too wet it will rot and if to dry the pile will not decompose properly.

After a week or two the pile will cool, this is the time to mix the layers together. Turn the pile once a week from here on. Turning is done by putting top layers at the bottom and side material inward towards the center. This mixes materials and air which is essential for good decomposition. Spray water as you turn the heap.

The compost should be ready after the fourth turning or 6-8 weeks. How will you know it's ready? It will be dark in colour, crumbly, soft, light, soil like and smell like rich soil.

6.1.3 Practical notes and tips:

A compost pile needs water and air for it to work properly. This is so that the micro- organisms can do their work. Moisture speeds up the decomposition process and oxygen ensures the pile does not smell. It should not smell.

Bacteria and fungi digest organic matter, they release organic acids which lowers the pH. The lower pH encourages the growth of fungi and the breakdown of lignin and cell walls. A certain amount of warmth is needed for quick effective decomposition and for the destruction of weed seeds. To get active heat generating compost piles you will need the correct proportion of carbon as to nitrogen in the starting material (30:1). If you do not have animal dung (especially in the dry season when grasses are very low in Nitrogen content) add green tree leaves. The green tree leaves keep their high nitrogen content throughout the year. Carbon provides both an energy source and the basic building block making up about 50 % of the mass of microbial cells.

6.1.4 Application of compost

Compost is applied directly onto the soil. There can never be too much compost. Apply at any time of the plants growth as it is a complete fertilizer, full of nutrients. The best time to apply compost is just before planting your seed and a few weeks after the seeds emerge. Vegetable gardens and nurseries need compost all year round. Well matured (well decomposed) compost can be dug in (never dig in immature compost) apply approximately 5-10tons /ha.

6.1.5 Advantages and disadvantages of making compost

Advantages	Disadvantages
Easy to make, easy to find all the plant matter, can be made at any time of the year	Uses a lot of water at first, takes a few months to mature, takes a bit of effort

6.2 Pit Compost

The pit composting method is similar to that of a trench bed or eco-circle. Organic material is layered in a pit and heaped up into a dome shape about 1m high and left to decompose.

6.2.1 Resources required

Composting materials; organic matter (nitrogen rich greens and carbon rich browns), soil, wood ash, water and farm tools (wheel barrow, watering can, spade, machete).

6.2.2 Making a compost pit

Step 1: Dig a pit 1-1.5mwide by a 1-1.5m (in semi shade and in an area that is not water logged).

Step 2: Put the dry materials in first (about 20-25cm thick), water (moist not wet), add greens (20-25cm thick), then add manure, soil and ash (10-15cm thick)

Step 3: Repeat step two until the pit is filled.

Step 4: Place a sharp stick or sticks into the material in the pit, vertically to allow air to circulate through the various layers.

Step 5: Cover with dried grass, banana leaves (whatever you have)

Step 6: Turn every 2 weeks. The compost will be ready in 3-4months

Figure 6.4: A pit being filled with compost materials - visible is a layer of manure.

Figure 6.5: An example of a compost pit that has been covered with an old feedbag.

6.2.3 Advantages and disadvantages of pit compost

Advantages	Disadvantages
- Easy, doesn't require much time - Cannot be destroyed by livestock - Remains moist for longer	Could smell if it's not done properly, need to dig the pit and look after the compost

7 Soil enriching methods

7.1 Trench beds

7.1.1 Introduction

Figure 7.1: 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).

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).

Figure 7.2: Layer of tins at bottom of trench

Figure 7.3: 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.

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

7.1.2 The method

Step 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.

Step 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.

Step 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.

Step 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).

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.

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

Step 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.

Figure 7.4: A trench bed in Phutaditjhaba being filled, mixed and stamped down. Notice the mixture of manure, grass and soil.

Figure 7.5: 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.

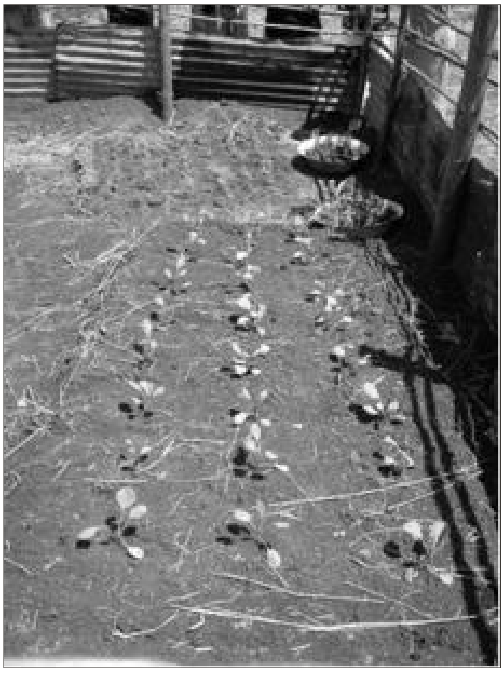


Figure 7.6: In this picture carrot seeds were planted in the smaller trench bed in the far corner. There are also two tubs of seedlings being produced. In the foreground is a recently completed trench bed into which bought cabbage seedlings have been planted. Again these grew well and did not show any negative effects from the decomposing material in the trench.

Step 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.

Step 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!

Figure 7.7: In this picture, drip irrigation is going to be used to water a trench bed.

Figure 7.8: 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.

7.1.3 Advantages and disadvantages of trench beds

TABLE 7.1: 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.

7.2 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.

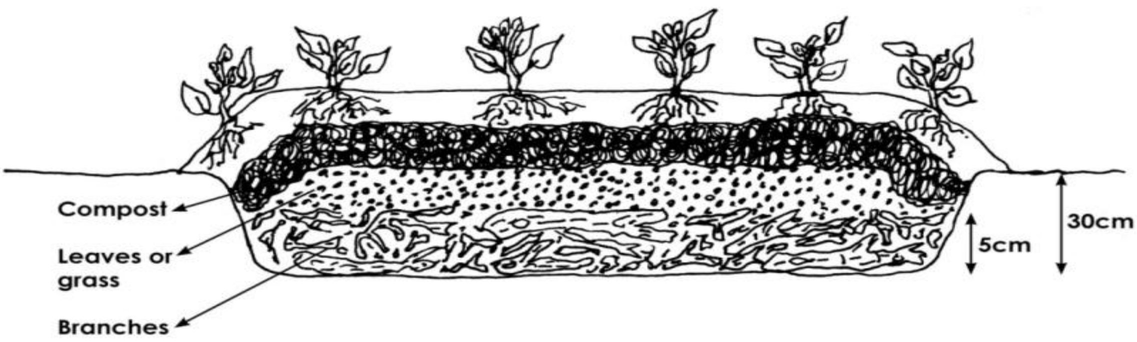


Figure 7.9: Shallow trench
(from WRC; Homestead water Management Manual, 2009)

7.2.1 Advantages and disadvantages of shallow trenches

TABLE 7.2 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

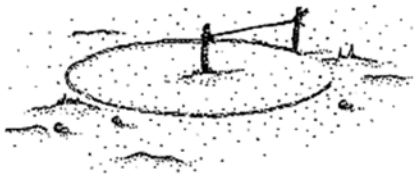
7.3 Eco-circles

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

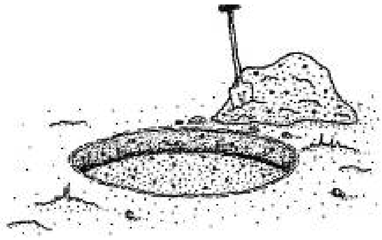
7.3.1 What you will need to make an eco-circle:

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.

7.3.2 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.

7.3.3 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

7.3.4 Advantages and disadvantages of eco-circles

TABLE 7.3: 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

8 Liquid manures

8.1 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.

8.2 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.

8.2.1 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.

8.2.2 Advantages and disadvantages of foliar sprays

TABLE 7.4: 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

8.2.3 Good plants for liquid manures

8.2.3.1 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.

Figure 8.1: 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.

8.2.3.2 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.

8.2.3.3 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.

8.2.3.4 Weeds

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

8.2.4 Advantages and disadvantages of plant brews

TABLE 7.5: 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

8.3 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.

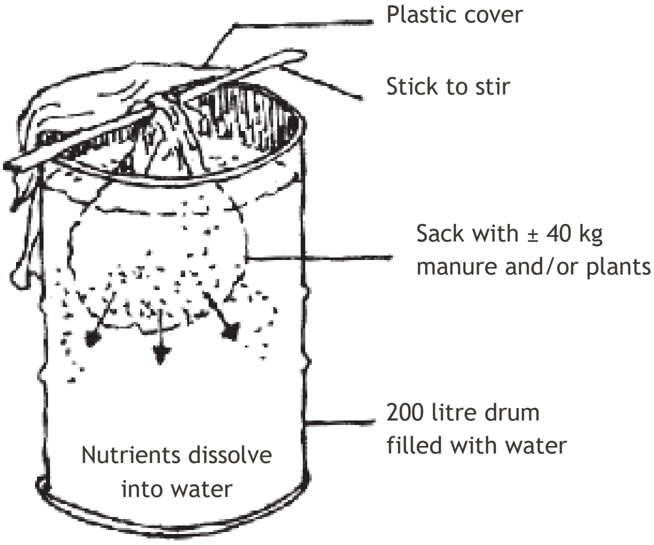


Figure 8.2: Liquid manure

- 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.

8.3.1 Good sources for animal liquid manures

8.3.1.1 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.

8.3.1.2 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.

Figure 8.3: Chickens

8.3.1.3 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.

8.3.1.4 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.

8.3.1.5 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.

8.3.2 Advantages and disadvantages of animal liquid manures

TABLE 7.6: 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.

8.3.3 A few more recipes for liquid manures

8.3.3.1 Fermented Plant Extract (FPE) Recipe from the PELUM Conservation Farming course in Zambia

This liquid manure is high in micro-organisms and is a good mixture for boosting immunity of plants (and people) and assisting against attack from fungal diseases.

You will need: 1kg brown sugar, chopped up green plant matter - bamboo shoots, banana leaves, comfrey leaves, weeds (use only vigorous growing, nutrient rich healthy plants. No flower heads).

Instructions: Cut up the plants (small), add the sugar, mix well, put in bucket (push it all to the bottom, tightly) and put a rock on top of it to keep the air out. Cover the bucket with newspaper (tie the newspaper on with string).

The newspaper will let air in and keep fruit flies out. Keep at a stable temperature for 14-21 days. This is when the juice will be drawn out and the microbes active. The juice is ready to use on plants, in the soil, in toilets and is also suitable for human consumption.

8.3.3.2 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.

8.4 Earthworms

Figure 8.4: Earthworms.

Normal digging of the soil can help with the drainage and aeration of the soil. There are natural diggers in the soil-earthworms. They can dig just as well or even better than humans can dig with tools. Ploughing with tractors and hoes can kill many of these natural diggers and will compact the soil.

A way of increasing the fertility of the soil is to add earthworms to it. Earthworms serve several vital functions, including:

- Breaking down dead organic matter in the soil.
- Burrowing and moving under the soil, thus naturally aerating the soil.
- Providing a source of nutrients to other organisms when they die.

8.4.1 Making vermi-compost

To start, use any dark container with a drainage hole at the bottom. Place a layer of stones and paper at the bottom. Fill around half the container with grass, manure, kitchen scarps and other organic matter. Place the worms in the container and continue to fill. Make sure this mixture remains moist and continue to ‘feed’ the wormery on a weekly basis. In time everything will be reduced to thick crumbly humus. The worms move to the top of the bin/container and the humus can be removed from the bottom, with a few worms, and used in garden beds.

Figure 8.5 a & b: Making vermi compost.

9 Manure

The manure of animals grazing on natural veld (rangeland) on infertile acid soils and sandy soils will be particularly poor in plant nutrients. The older manure becomes the less plant nutrients it will have. Old manure always contains less nitrogen than fresh manure – due to the evaporation of some of the nitrogen. If manure is subject to leaching by rains, and/or if the liquid manure is allowed to flow or drain away, the manure will have much lower amounts of plant nutrients than the original fresh manure.

Straw, dry hay and dry grass are excellent bedding materials for kraals and sheds where animals are kept. Various types of shrubs can be used where these materials are not available. Manure should be well mixed with bedding material and stored in piles that remain wet, but are not open to being leached by rain. Some form of cover for the pile is a good idea.

For vegetable production, at least 20 tons farmyard manure should be applied per hectare. This means that at least 2 kilograms (one 5 litre bucket) of manure must be applied per square metre. In South Africa, farmyard manure is relatively poor in phosphorus (P). Natural South African soils are also very poor in phosphorus. Thus, additional phosphorus must be applied together with manure. This can be in the form of superphosphate or bone meal

In rural areas where chickens roam freely, their manure is often not available, or may be difficult to collect due to the small size of the droppings. However, chicken manure is an excellent source of plant food. Chicken manure contains high concentrations of nitrogen and phosphorus and is therefore a good source of these nutrients. It is a “sharp” fertilizer that will damage (“burn”) the crop if applied in too large quantities.

Application of chicken manure to a crop should never exceed 2 tons per hectare. Two tons chicken manure per hectare is the same as 200 g (about 500 ml) per square metre. Thus, for the application of chicken manure to small areas of land or to beds, the following measuring method can be used: Cut the neck off a 500 ml plastic soft drink bottle, at the “shoulder” of the bottle. Apply one such bottle full of chicken manure for every one square meter.

9.1 Manure as a natural fertilizer

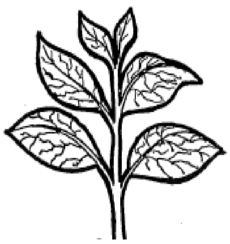
Nutrients in animal manures (average): Kg/ton

								Purchased	
	Cow	**Horse**	**Goat**	**Sheep**	**Pig**	**Chicken**	**Rabbit**	**Kraal**	**Compost**
N (Nitrogen)	5	6	14	7	5	13	18	7	5
P (Phosphorous)	2	3	2	3	4	11	13	1	2
K (Potassium)	3	6	6	4	6	20	6	7	8

Nitrogen

Promotes vegetative growth, i.e. stems and leaves

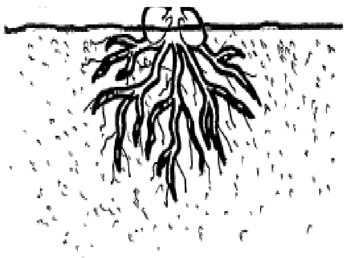
N



Phosphorous

Promotes root development, needed for flowers and seeds

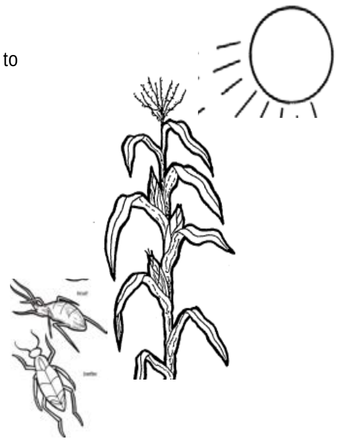
P



Potassium

Strengthens plant, gives resistance to heat, cold, disease and pests

K



Crop type	N	P	K
	kg/ha	kg/ha	kg/ha
Amadumbe	100	100	150
Beans	80	40	50
Beetroot	68	60	80
Brinjal (Egg fruit)	100	60	80
Cabbage	180	80	100
Chillies & Sweet Peppers	100	60	80
Carrot	75	75	100
Lettuce	100	75	100
Maize (green/sweetcorn)	100	20	80
Onion	100	75	100
Peas	40	40	50
Potatoes	160	100	130
Pumpkin & Hubbard squash	100	60	80
Spinach	100	75	100
Sweet potato	100	60	80
Tomatoes	160	75	100

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.

9.2 Nutrient availability and manure application

TABLE 9.1: 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

9.3 Rates of manure for nitrogen needs

Nitrogen compounds in manure eventually convert a nitrate form. Nitrate is soluble (dissolvable) and is moved into the root zone with water. It is then available to plants in same form as commercial nitrogen fertilizers.

The release of available nitrogen from the complete organic compounds during manure decomposition is very slow. This is important as it extends nitrogen availability and reduces leaching. This is especially important if your soils are sandy.

The idea is to first apply enough manure to meet the first year's need of available nitrogen. Decreasing amounts are then applied in following years because of the carry-over organic nitrogen that will be released from previous applications. If the same rate of manure is applied each year, it is possible for a field originally low in nitrogen to accumulate unnecessarily high levels in successive years.

The nitrogen in poultry manure is in released fastest, about 90% is released in the first year. Fresh manure which contains both the urine and solid portions and has a large amount of urea or uric acid provides a somewhat slower release rate, with approximately 75% of the total nitrogen released the first year. An even more gradual nitrogen release can be expected from dry feedlot steer manure, with only 35% of the total nitrogen released the first year.

Every so often, the garden needs a tonic to revitalize and revivify. Making liquid manure from "found" ingredients provides a cheap and effective way of increasing and maintaining garden fertility and capturing minerals from deep within your soil.

9.4 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.

10 Green manure

10.1 How does green manuring work?

Green manure crops are sown and allowed to grow, either until the land is needed again or until the plants have reached a certain growth stage – usually just before flowering. At this point, they are cut down, dug in to the soil and are left to decompose, releasing vital plant nutrients back into the soil which are then used by the next crop.

If you don't want to dig in the plants, then green manure crops can also be composted or used as a mulching material instead. This is how nutrients are recycled in nature so we are repeating nature's effective system.

10.2 Green manure plants

There are many plants suitable as a green manure crops. Some examples are given in the table below. Plants marked * are nitrogen fixers

TABLE9.2: EXAMPLES OF GOOD GREEN MANURE PLANTS

Name	Latin name	Sowing time	Characteristics	Growing time
Alfalfa/ Lucerne	Medicago sativa	Sept- Nov	Bee plant. Very deep rooting, long living -good animal fodder	1-2months or 5-10 years
*Winter Field Beans	Vicia faba	April- June	Bee plant, similar to broad beans.	overwinter
Buckwheat	Fagopyrum esculentum	Sept-Dec	Bee plant, deep rooting, very frost sensitive, but can resist cold. High protein grain	up to 2-3 mths
*Clover, red and white	Trifolium spp	Sept – Dec	Bee plant, adds nitrogen and boron to the soil	1-2 mths or a few yrs
*Fenugreek	Trigonella foenum graecum	Sept- Dec	Butterfly nectar, looks similar to clover	2-3 mths
*Lupin, bitter	Lupinus angustifolius	Sept-Nov	Bee plant, very deep rooting	2-3 mths
Mustard	Sinapis alba	March-Sept	Fast growing, good biomass	2-8 wks
Rye, grazing	Secale cereale	March-May	Bee/caterpillar food. Deep roots good for soil structure	autumn-spring
*Trefoil	Medicago lupulina	Sept-Dec	Bee/butterfly nectar. Tolerates some shade and drought	up to a few yrs
*Tares, winter (annual vetch)	Vicia sativa	March- May, Sept-Nov	Bee/butterfly nectar. For alkaline, heavy soils - not drought tolerant	2-3 mths or overwinter

10.3 Nitrogen Fixing examples

When using legumes as green manures it is important not to try and grow them to term and harvest seed. If this happens a lot of the useful nutrients that would have been incorporated into the soil is then used by the plant for producing seed and many of the benefits are reduced.

10.3.1 Lucerne

Figure 10.1: Close up view of a lucerne

Lucerne is a legume that helps to enrich your soil. Lucerne can be chopped up and cooked as spinach. Lucerne is also a good food for cattle, sheep, pig and chickens. You only have to plant lucerne once every 5-10 years. You can harvest it every summer.

Planting: Lucerne is planted during the summer months. Prepare the land well. Add compost/manure and ash. Work into the soil. Lucerne needs a lot of potassium (K) and phosphate (P). The seed is quite small. Seed can be scattered over the land and covered using a hoe or a rake. Seed can also be planted in little furrows like carrots.

Figure 10.2: A bed planted to lucerne.

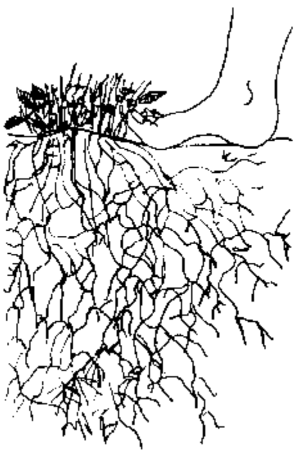


Figure 10.3: Cut down Lucerne when it is about ankle height.

It can also be planted as small patches or beds in the garden and left for 3-5 seasons before digging over the bed to plant vegetables again. Lucerne can also be planted as a ground cover and intercrop with vegetables.

Harvesting: Lucerne can be cut and used green. It is cut down to around 5-10cm above the ground – at about the height of one's ankle. Lucerne can also be dried to be stored as winter food for animals. Dry lucerne in flat piles in the sun. Keep on turning these piles over. Otherwise the hay at the bottom may rot. Drying takes about 3 days.

10.3.2 Clover (white and red)

Figure 10.4: Red clover.

Clover is most well known as a fodder crop grown in irrigated pastures for livestock. It is a cool season plant.

In the garden, the creeping growth habit means they can be planted on paths and between beds. It works very well when cut and used as a mulch and works well in compost heaps.

10.3.3 Field beans/ broad beans

Winter field beans are one of the few winter green manures, as it is a cool season crop. These beans can even be sown in between rows of vegetables in your raised bed system if you are short of space.

Figure 10.5: Winter field beans.

Mixtures of green manure plants can also be used. For example: field beans/mustard; or vetch/clover/rye.

Figure 10.6: Grazing rye.

10.3.4 Grains

Buckwheat

Buckwheat is used as a grain. It is high in protein, iron, calcium and magnesium. It is a hardy creeper that can be cut back and used repeatedly before being left to seed. It is a perfect green manure crop as it stores calcium, potassium and magnesium in its leaves and will immediately enrich and sweeten soil once dug in.

Buckwheat is a good companion to other grains such as oats and barley.

Figure 10.7: Buckwheat flowering. (Pics fromP. Pears. HDRA)

10.4 When is the crop ready?

It is better not to leave your green manure crop in the ground for too long, as land occupied in this way cannot be used for growing other crops. Also, if green manure plants get too old, then they can become tough and will take longer to decompose and be incorporated into the soil by soil organisms. For most green manure crops, it is usually recommended that they are cut and used just before they flower.

10.5 How to use green manure crops

1. Usually, green manure crops are cut down and dug into the top 15-20 cm of soil with a spade. The beds are left for several weeks to allow decomposition of the material in the soil, before planting.

2. Or, simply hoe off young plants (or chop down older ones) and leave them on the soil surface as a mulch. If plants are chopped down, then to prevent any re-growth of the stubble, cover the ground with a light-excluding mulch (e.g. black polythene/newspaper) until you are sure that the green manure crop is dead. If you are in a hurry to start replanting the ground, then you can of course simply plant through the mulch. You will need to allow several weeks before planting the next crop in the mulched area, in order to give the mulch some time to decompose and release its nutrients back into the soil.

> **Selecting green manures:**
>
> - Choose a quick or a slow-growing crop - to fit in with the time that the land will be left vacant and whether you will cut and use or dig in the crop.
> - The season of the year. (Not all varieties will survive the winter.)
> - Whether you want your crop to fix nitrogen or not.
> - Your soil type and how much drainage it offers

3. Cut the green manure and use the leaves for making compost. Composting is also a very good way of using any crops which have been allowed to get too old and tough to dig straight into the soil.

10.6 Advantages and disadvantages of green manuring

Advantages	Disadvantages
- Cheap and easy to grow, they can increase soil fertility, they improve soil structure and help prevent soil erosion, they encourage efficient use of land. - Most green manure crops are very attractive to wildlife. Green manures keep weeds in check (bare soil encourages weed growth). - By taking up nutrients from the soil, green manure crops prevent them from being washed away when it rains. - Some green manure plants (legumes) are nitrogen fixers. Green manuring increases the humus content of the soil.	- Might need a tractor if you plan to plant a large field. - It takes time and effort. Green manure crops mostly cannot be used as food crops.

11 Food security and nutrition

If we want to know whether a family, or a country, enjoys **food security**, we need to know whether:

- There is enough food around, in a household or in a country (**availability**);
- People can get hold of it when they need it, e.g. can grow it, or afford to buy it (**access**); and
- People are using the food well (**utilisation**), meaning the food does not go to waste due to contamination or loss of nutrients from the food.

The third point shows us that just having lots of food, does not necessarily mean there is **nutrition security** – in other words, that a person gets enough **nutritious** ingredients to be healthy. This is one of the reasons why even non-poor families in South Africa suffer from malnutrition.

Food safety is also important, because if we handle food incorrectly, like not washing it properly or allowing it stand in hot conditions for too long, the food can become unhealthy or even dangerous.

Adequate care is necessary to ensure that especially children, sick people and other vulnerable groupings get access to food (point 2 above). Therefore the skills and motivation of the mother or household caregiver is also an important matter for food security and healthy eating.

Recommendations for increasing food security include the following:

- Linking nutritional and agricultural interventions;
- Strengthening nutritional and agricultural research;
- Promoting mother and infant nutrition;
- Reducing malnutrition in children < 5yrs;
- Improving and expanding small scale water management;
- Improving access to better seeds and other planting material;
- Diversifying on-farm enterprises with high value products; and
- Establishing effective agricultural extension services.

Increasing agricultural productivity of food insecure farmers is a central theme within the poverty and nutrition security debate. The promotion and production of indigenous crops falls within this broader aim.

11.1 Good nutrition

Individual foods are not healthy or unhealthy, but a diet as a whole is healthy or unhealthy.

Some general rules of healthy eating are:

- People need to eat from **all the food groups every day**, (See Figure v: Go, Grow and Glow Foods) and they need to get enough - but not too much - from each food group. This is a **balanced diet**.

- The greater the variety of foods they can eat every day, the better. This is called **dietary diversity**.
- Also, there are certain foods we need to be especially careful that we don’t eat.

People find it very hard to change their behaviour, and particular food behaviour. Most of us stay with the food habits we learned as children, including food tastes and preferences, food preparation methods, composition of meals, regularity of eating and even the setting in which we normally take our meals.

11.1.1 Balanced diets

To eat well, means to eat **lots of different kinds of food** so that our bodies get all the good things that they need. This does not mean that people need to buy expensive food. By thinking carefully about what you eat, and what you prepare for your family, and choosing food well, your whole family can eat in a healthy and affordable way.

There are a number of ways of introducing healthy dieats at a community level. These are now mostly food based recommendations rather than a focus on specific nutrients.

11.1.2 Dietary Guidelines

These have been developed at a national level as the nutrition realted messages that need to be considered and are called the 10 food based dietary guidelines.

- Enjoy a variety of food for more nutrients;
- Balance food intake and energy used;
- Be active (exercising, walking, working in the garden and sweat);
- Eat regular meals (do not skip meals especially breakfast);
- Make starchy food the basis of most meals (white vs brown/wholewheat);
- Eat plenty of vegetables and fruit daily, they are very rich in many nutrients;
- Eat beans, peas, lentils and soya regularly;
- Meat, chicken, fish, milk or eggs can be eaten daily;
- Use fats sparingly- animal vs plant oil, hard vs soft;
- Use less salt, too much salt can lead to heart problems;
- Drink clean safe water. Water replaces water lost (i.e. sweat, urine) during exercise;
- If you drink alcohol, drink sensible- don't give children/don’t send children to buy alcohol.

These can be used as a way of introducing nutrition concepts at a community level.

11.2 The five food groups

Another way of introducing the concepts of the Five Food Groups in nutrition at a community level is to use the idea of "Go, Grow and Glow" foods. Foods are grouped according to their functions in human health and wellbeing.

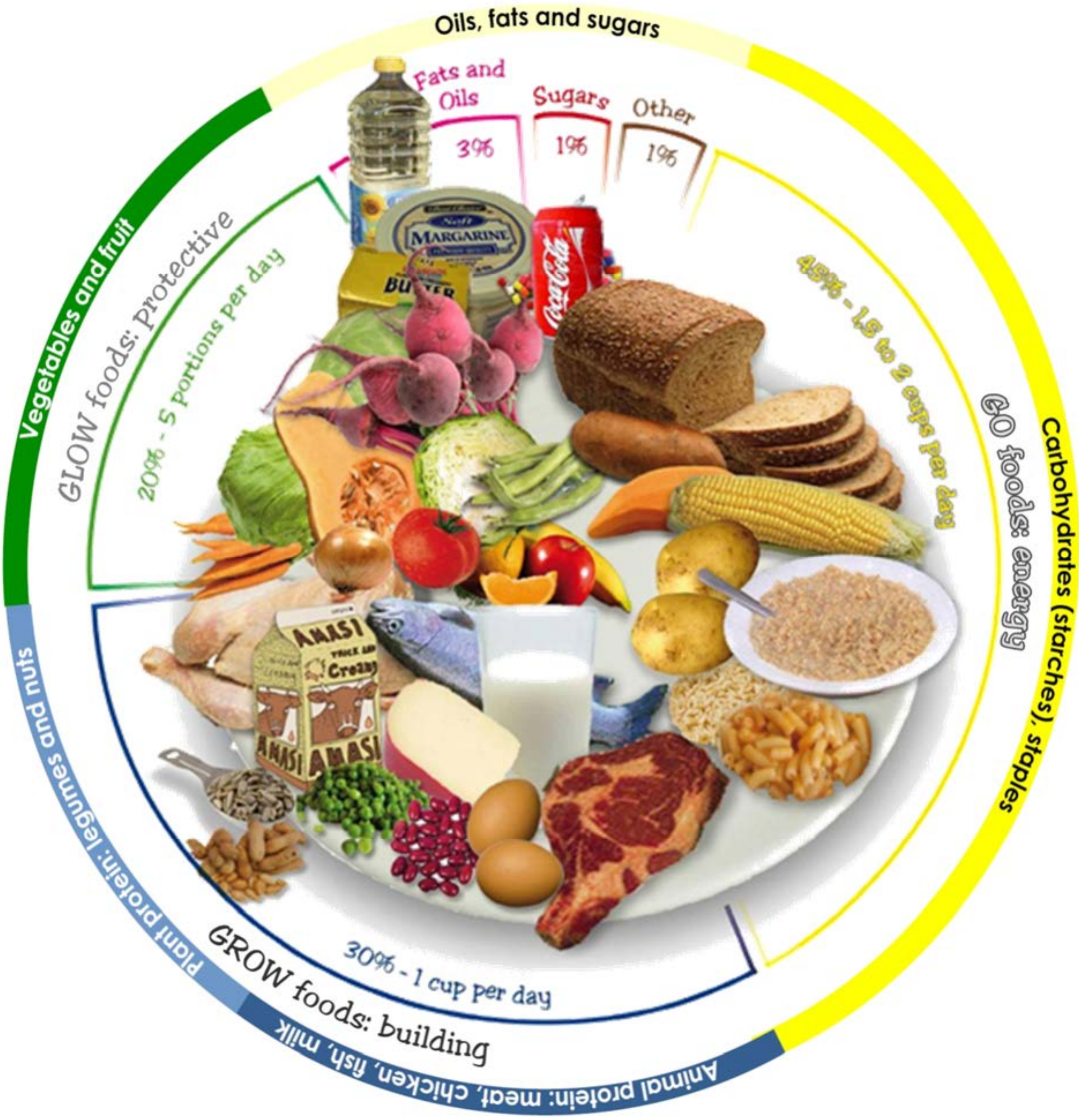


Figure 11.1: The Five Food Groups: choices and proportions needed daily.

11.2.1 Malnutrition

Malnutrition can be either:

- Over-nutrition;
- Under-nutrition; or
- Micronutrient deficiencies

Over-nutrition occurs where people over consume energy rich foods such as starches, fats and sugar. Weight gain and related diseases such as high blood pressure and diabetes become chronic conditions.

Under-nutrition relates often to what is known as Protein-Energy Malnutrition where too little protein and energy producing foods are eaten on a regular basis. In the chronic form this leads to growth impairment, immune deficiencies and difficulty with cognitive skill development.

Micronutrient deficiencies are often associated with under nutrition and relates to specific nutrients such as Vitamin A, iron, zinc and iodine. Under-nutrition and/or micro-nutrient deficiencies, especially among young children, can have long-lasting effects on their quality of life.

11.3 Some important nutrients

It is still a good idea ot also focus on a few of the critical nutrients and their functions. These include the following:

Vitamin A

Vitamin A is a micronutrient found in food. Vitamin A is very important to children under five years of age, malnourished children, pregnant and lactating women. Excess vitamin in the body is stored in the liver. Vitamin A is a fat soluble vitamin; therefore a small amount of fat should be added for vitamin A absorption. Spinach should be chopped and carrot grated for easy absorption. One of the best ways to prevent Vitamin A deficiency is to encourage families to grow and eat food all year round that are rich in Vitamin A .Mothers who are breastfeeding should eat plenty of food rich in Vitamin A.

Good Sources of Vitamin A:

- Orange-yellow vegetable (carrot, butternut, orange flesh sweet potato);
- Fruit (pawpaw, mango, peach) except citrus fruit;
- Dark green leafy vegetables (spinach and African leafy vegetables.

Functions:

- Ensures child growth and development;
- An anti-oxidant, it protects the body against infections;
- Eye vision.

Vitamin A deficiency (VAD):
Vitamin A deficiency may result in: poor growth and development in children; increased risk of infection, eye problems and death.

Vitamin C

Vitamin C is important for maintaining overall health and strengthening the immune system. Defieiencies can lead to many problems nad infactions, including scurvy in severe cases.

Functions:

- An antioxidant;
- Maintains healthy gums, skin and connective tissues;
- Strengthens the body against infections.

Good Sources of Vitamin C:

All fresh vegetables and fruit. Including for example citrus, guava, papayas, spinach, cabbage, broccoli and marrows. Prolonged boiling and other processing of vegetables will destroy most of the vitamin C – so they need to be eaten raw, lightly steamed or lightly fried.

Iron

Good sources of iron:

Iron rich foods include liver, meat and fish. Also legumes such as peas, beans, bambara, groundnut and cowpeas. These must be eaten with foods rich in Vitamin C. Both legumes and Vitamin C rich foods can be grown in the garden.

Anaemia is the **most widespread nutritional disorder in the world**. The most common cause is a lack, or deficiency, of iron in the diet. Other causes are parasitic infections (such as hookworm) and loss of blood during menstruation and child birth. People with anaemia usually have pale tongues and lips and the inside rims of their eyelids are white. Anaemia reduces people's ability to work, increases tiredness and slows children's learning.

Functions:

- Iron is an important mineral needed to produce red blood cells and transport oxygen/ air in the blood white.

Iodine

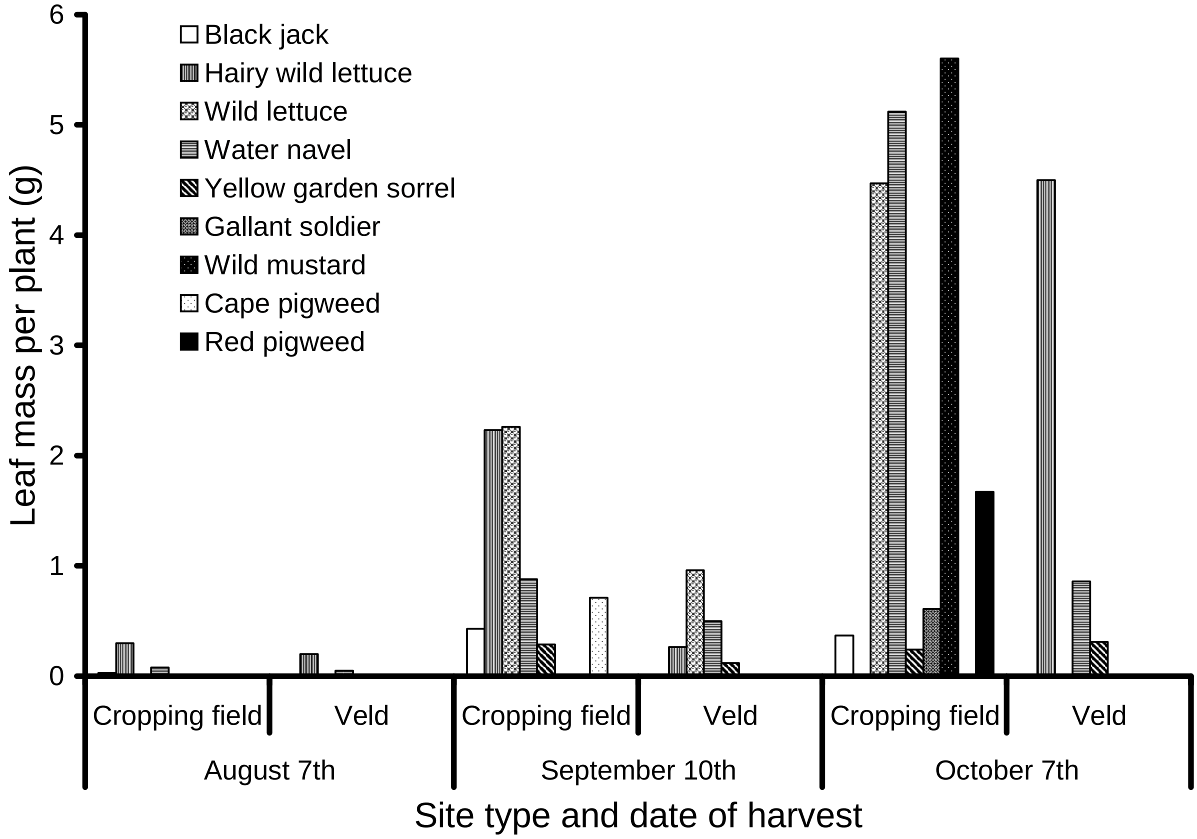
Iodine deficiency is caused by lack of iodine in food and in the soils in which food is grown. This is most common in areas where iodine in the soil has been washed away by rain, and inland areas that do not have easy access to seafood.

Iodine deficiency disorders include goitre, which is indicated by a swelling of the thyroid gland; low birth weight; inhibited growth in children; and impaired mental development. In severe cases, brain damage can be caused.

The use of iodized salt is the most effective way of preventing iodine deficiency and is highly recommended.

11.4 The contribution of African leafy vegetables (ALVS)

Common, wild, edible leafy vegetables grown in cultivated lands and in the veld. These are harvested during the rainy season and are plentiful during the summer months. Below is a graph giving an indication of typical occurrence of wild leafy vegetables in KZN.



(From: Water use, drought tolerance and nutritional value of indigenous crops: an overview. Modi A.T., Beletse Y. & Oelosfe A. WRC, August 2011)

The leaves of wild vegetables can be cooked and eaten fresh, sun or air-dried. When cultivated in home gardens, wild vegetables grow and produce in places where it is difficult for exotic vegetables to grow, because the former do not need many inputs. **They grow** easily, contain valuable nutrients, and are palatable at a young stage of plant development.

The table below gives a comprehensive analysis of the nutrients available in a cooked portion of the common ALVs.

TABLE 11.1: SELECTED LEAF NUTRITIONAL CONTENTS (PER 80G OF COOKED LEAVES*) OF SOME OF THE WILD VEGETABLES

Wild vegetable	Macronutrient		Minerals				Vitamins					
Recommended Dietary Allowance (adult female 25-50 years)	Energy	Protein	Calcium	Iron	Zinc	Selenium	A	C	E	Riboflavin	Niacin	B6
	(kJ)		(g)		(mg)		(µg)		(µg RE)		(mg)	
	9240	50	1000	15	12	55	800	60	8	1.3	15	1.6
Amaranthus spp	217	4.06	364	6.72	2.11	0.7	456.4	64.4	0.23	0.14	1.4	0.252
Black jack	310.8	4.76	245	8.4	1.27	2.5	1376	32.2	3.52	0.25	0.98	0.49
Gallant soldier	218.4	4.48	397.6	7.42	1.82	-	1058	9.38	-	0.29	1.69	-
Water navel	333.2	4.2	334.6	27.5	4.21	-	740.6	32.6	-	0.32	1.12	-
Wild lettuce	229.6	3.92	331.8	20.8	1.12	-	-	-	-	0.224	0.89	-
Wild mustard	198.8	5.18	399	13.3	1.90	-	476	15.4	0	0.196	0.86	-
Cabbage	190.4	2.1	43.4	0.42	0.21	1.26	9.8	42	0.35	0.028	0.42	0.112
Swiss chard	182	3.78	163.8	6.16	1.02	1.68	655.2	33.6	0.42	0.14	0.84	0.112

- *indicates no figures were available in literature.*

The graph below provides a more visual presentation of the vitamin A and C content of commonly eaten leafy vegetables.

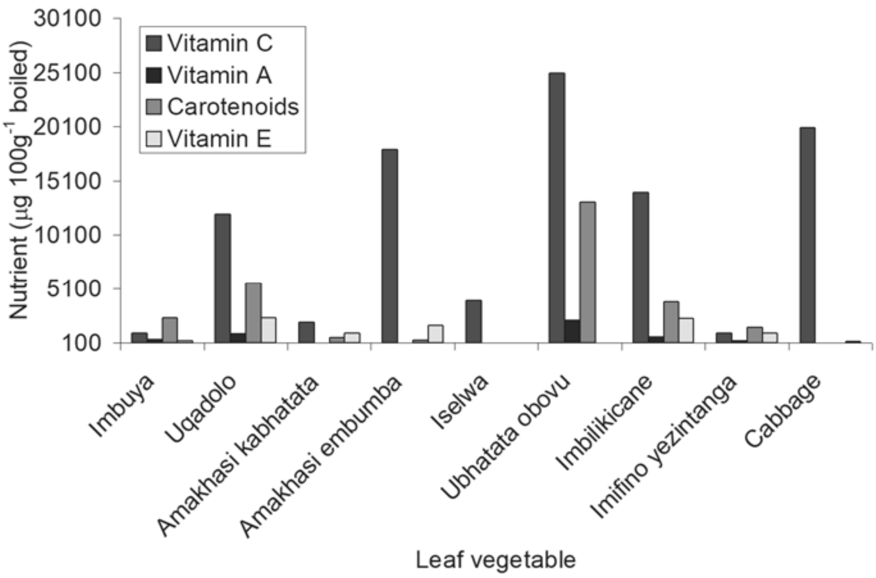


Figure 11.2: Amaranthus

Figure 11.3: Orange fleshed sweet potato (ubhatata bovu)

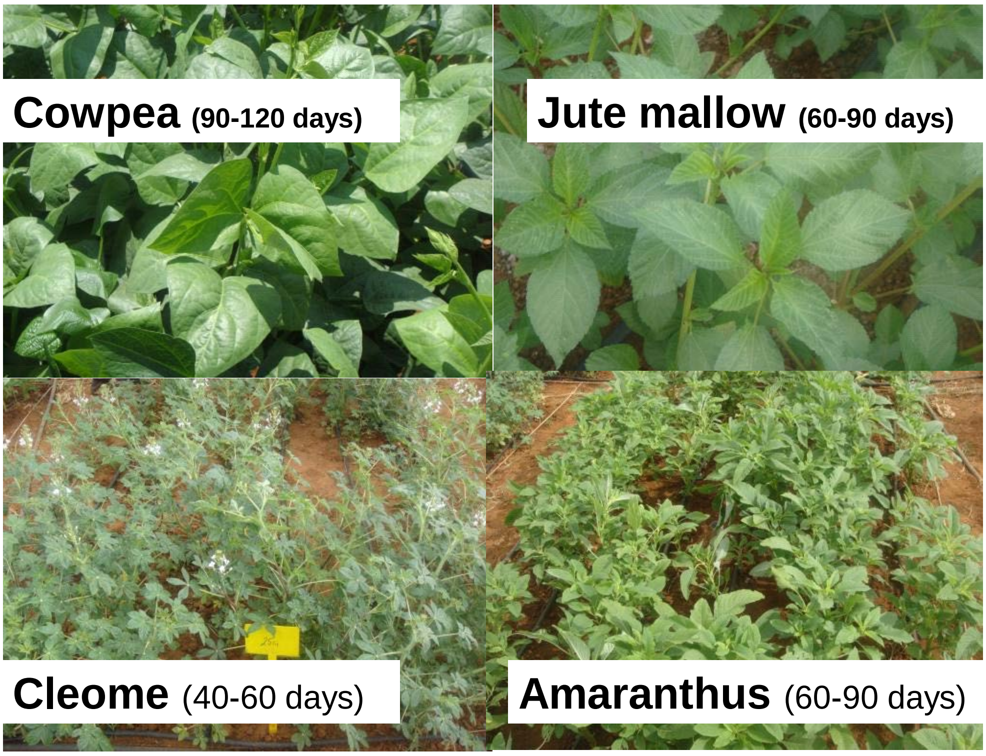
Figure 11.4: Gallant solider (ushukeyana)

Figure 11.5: Cowpea leaves (amakhasa embumba)

Figure 11.6: Lambsquarters/ goosefoot/ fat hen (imbilikicane)

Figure 11.7: Wild lettuce (Urhwaburhwabu/ihabe/habehabe

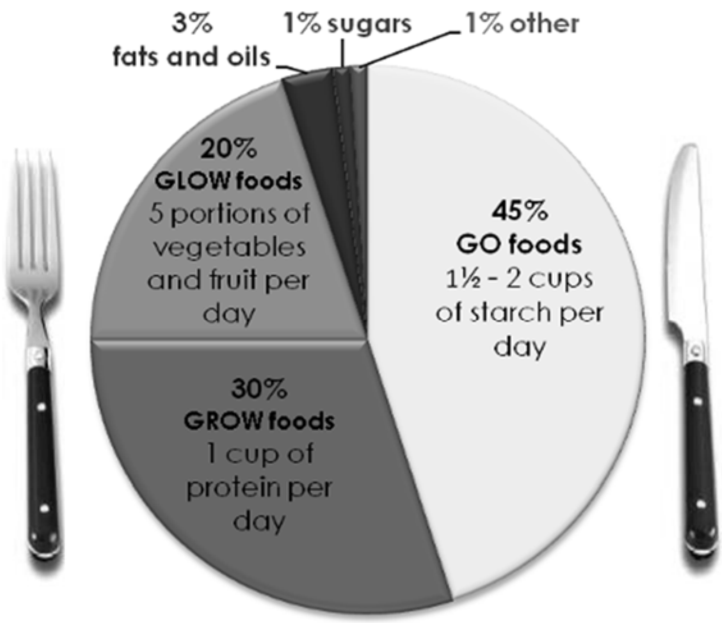
Figure 11.8: Wild mustard (umasilhlalisane)



11.5 Recommended daily amounts

Eating a balanced diet means that individual meals are also balanced, that is, each meal contains a proportion of the nutrients that a person needs every day. There are many ways of combining foods to make a nutritious meal. The basic nutrients of starch, protein, fats, vitamins and minerals need to be kept in mind.

On my plate – what I should eat each day:



12 Food preparation

Several traditional food-processing and preparation methods can be used at the household level to enhance the bioavailability of micronutrients in plant-based diets.

12.1 Important traditional food-processing and preparation methods

12.1.1 Soaking

Soaking involves immersing food (e.g. grains) in water for a period of time. Traditional method of soaking grains is healthier than the modern way of simply boiling.

Advantages of soaking:

- It improves digestion by breaking down proteins that are difficult to digest. Some enzymes that reduce nutrient absorption of iron and calcium for example may be reduced during soaking, making these elements more easy to absorb. (HealthBanquet, 2007);
- It enhances nutrition by reducing the effect of phytic acid (an anti-nutrient that prevents absorption of nutrients);
- It saves time and fuel.

How to soak grains:

- I cup grain (e.g. samp)
- 2 tablespoons of acid
- Warm water

For example, put samp, acid and water into a pot and leave to soak for about 7-12 hours (or overnight). Continue to cook as usual. Remove any foam that appears on top as it can contain released impurities.

12.1.2 Germination/malting

Malting is the process of germinating grains to release/create the enzymes needed to convert the starch to sugar and break down proteins. This makes these nutrients more available and also releases zinc and iron. It is an important process for creating traditional cereals for making porridge and fermented products. The malting creates a thinner cereal porridge without dilution with water while simultaneously enhancing their energy and nutrient densities.

This can only be done by "growing" the seed to the point where it has the maximum enzymes and halting that same growing process before the plant starts using those enzymes to continue growing the plant.

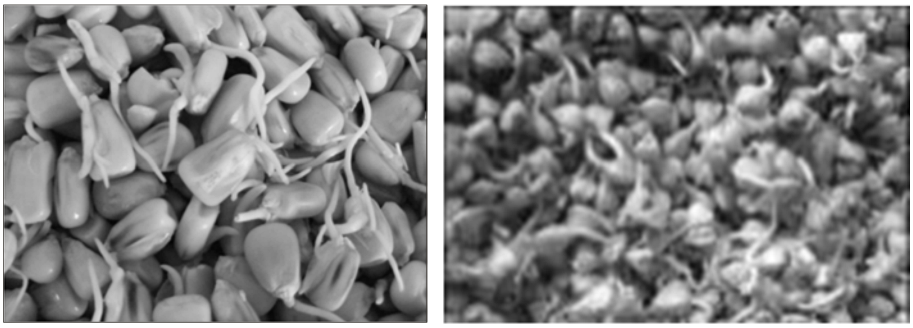


Figure 12.1 a & b: Germinated maize seeds (wwww.stillcoooker.com), and germinated amaranthus (www.homebrew.co)

How to do germination/malting:

The grain to be malted is soaked in water until they swell up. They are then places on racks or spread out in shallow containers and but kept moist and cool for 3-5 days until the seeds germinate and the roots start to grow out. At this point they are transferred to a hot, dry environment and the seeds are once again dried. They can be kept like this for a number of months. This malted grain can be used to make very nutritious porridge and are also used as an ingredient in fermented drinks. For the fermentation yeast is either added, or natural yeast is used, working with a starter culture.

12.1.3 Fermentation

Traditionally fermentation is carried out with mlated grains. Millet and sorghum work particularly well, but maize is also fermented to produce drinks like amahewu. A yeast starter culture is needed for the fermentation. Wild yeasts were used in the past (those linked to the ceareals themselves) and preserved in the starter culture traditional clay pots.

Figure 12.2: An image of a traditional wedding with the traditional clay pots and strainers used to make sorghum beer. (www. ezakwantu.com/Gallery African Beer Pots -Clay Pots)

Fermentation also improves protein quality and digestibility, vitamin B content, iron and zinc availability and microbiological safety and keeping quality.

Figure 12.3: Fermented sorghum beer (umqombothi) (From: Roger de la harpe/Gallo Images/ Corbis)

Examples of traditional fermented foods are:

- ujeqe (fermented maize bread);
- amahewu (fermented maize drink);
- umqombothi (fermented sorghum beer).

12.2 Preparation of vegetables and fruit

When preparing food, there are a few things to consider to make sure we do not lose the nutrients in the food. Below is a list with some suggestions:

- Buy or pick vegetables on the day you use them.
- Store vegetables and fruit in a cool, dry place.
- Clean and cut vegetables immediately before cooking. Most of the nutrients are in the outside parts of the vegetables and fruit. Try not to peel them. Cut the food into big pieces if possible – small pieces lose more vitamins.
- Cook vegetables in just a little water or in a stew, until just tender. Don't cook too long, or in a lot of water.
- Other ways to preserve nutrients are frying very quickly over high heat or in a little oil.
- Eat the food as soon after cooking as possible.

13 Some recipes for nutritious dishes

Here are a few fun ideas of nutritious dishes that can be tried out! [i]

Mashed Pumpkin with peanut butter

INGREDIENTS:

1 medium pumpkin or bitter melon, peeled, seeded and cut into cubes
3 cups maize meal
$\frac{1}{4}$ cup peanuts or 3 tablespoons of peanut butter
$\frac{1}{2}$ teaspoon of iodized salt
Sugar to taste (for bitter melon)

PREPARATION:

1. Boil pumpkin in salted water until soft
2. Mash until smooth
3. Add maize meal and cook for 30 minutes, stirring occasionally
4. Add peanuts or peanut butter.

Green Leaves with Peanut Sauce

INGREDIENTS:

750 g (3 cups) of leaves (amaranth, black jack, wild lettuce, kale, cow pea, taro, pumpkin, bean or any other) washed and cut

$\frac{1}{2}$ cups of peanuts or 2 tablespoons of peanut butter

Medium onion

Large tomato

Vegetable oil

Iodized salt to taste

PREPARATION:

1. Sort the leaves and steam them in a pot until tender
2. Roast peanuts and grind to a paste
3. Cook onion and tomato in vegetable oil
4. Add steamed leaves and more water. Add salt to taste
5. Serve with peanut paste.

Nutritious snacks

Small and school going children need to eat some snacks in between their main meals. It is good for them to eat little bits often, rather than large meals. Nutrient rich snacks should be preferred.

Peanut biscuits

INGREDIENTS:

12 tablespoons crushed raw peanuts

4 tablespoons sugar

1 egg

6 tablespoons maize meal

Water

1 tablespoon vegetable oil

PREPARATION:

1. Mix the ingredients together
2. Shape mixture into flat cakes
3. Cook cakes slowly on a greased hot plate or frying pan.

Peanut sweets

INGREDIENTS:

1 cup sugar

1 cup water

1 cup shelled and roasted peanuts

Vegetable oil

PREPARATION:

1. Dissolve the sugar in a pan of water
2. Heat the pan and stir until a syrup forms. When the syrup is golden brown, add the peanuts and mix well.
3. Pour the firm mixture on to a large oiled dish, spreading it into a 1-1.5 cm thick layer.
4. Let the mixture set, but before it gets hard, cut it into small squares.

Steamed bean flour cakes

INGREDIENTS:

Bean flour

Water

Pepper (ground)

Onion (ground)

Salt (optional)

Banana leaves

Dried fish or boiled eggs (optional)

PREPARATION

1. Mix the bean flour with water to form a paste (a little cassava or maize flour (maizena) can be added to bind the mixture).
2. Add pepper, onion and salt (and other ingredients, if desired) to the paste.
3. Wrap the paste in banana leaves and steam

14 Diversifying production in food gardening

14.1 Diversity for good nutrition

Generally, when we think about homestead food production, we think about vegetable gardens. And when we think of vegetable gardens, we may be thinking mainly of crops such as cabbage, spinach, onion, tomatoes and possibly a few others. Such gardens just provide a little extra food from time to time. Gardens like these cannot fulfil the purpose of providing food on a continuous basis, so that there is always something wholesome and nutritious to eat from the garden. In other words, there is enough, of enough different types of food to fulfil our dietary needs and preferences.

For this to be possible, we need to think of combining many different types of crops (vegetables, fruit, herbs) and plants (medicinal, protective, windbreaks, fodder for animals) in our gardening. We also need to think of including animals (small livestock could be easier – chickens, ducks, rabbits, pigs and goats). Then we need to combine all of this into a farming system that can manage itself to a certain extent and support us in the process.

14.1.1 Some changes we can make

- **For continuity:**

We want to be able to have something in the garden to pick and eat throughout the year. *(We need to wait a long time for cabbages and onions)* We can include crops such as:

- Amaranthus , other ALVs
- Spring onions/ bunching onions
- Leeks
- Coriander
- Lettuce
- Mustard spinach
- Rape, kale
- Brinjals
- Sweet potato (as well as orange fleshed for vitamin A)
- Garlic chives
- Parsley
- Fennel
- Broccoli, cauliflower (for leaves as well)
- Marrow (for leaves as well)

- **For protein:**

We want to grow crops that can add protein to our diets, especially for the young children (ages 1-5years). We can include crops such as:

- Turnip greens
- Cowpeas,
- Peas
- Sugar beans, jugo beans
- Peanuts

We also need to include small livestock such as chickens, ducks, rabbits, goats and pigs in our farming system.

■ **For vitamin C and vitamin A:**

We want to be able to eat fresh green and yellow fruit and vegetables every day. This is very important for children and sick people.

We can include crops such as:

- Tree tomatoes
- Granadilla, gooseberries
- Paw-paws, mango, banana, avocado
- Peaches, apricots, plums
- Oranges, naartjies, lemons
- Guavas
- Butternut, pumpkins of various types

We want to grow a range of fruit, so that there is fruit to eat throughout the year.

Figure 14.1: Tree tomatoes.

14.2 Drying of fruit and vegetables

Processing of food in this way helps to ensure continuity of food supply.
A system of drying racks made with and covered with shade cloth/ hale netting is suitable.

The vegetables and fruit are covered with a layer of netting for hygiene reasons. Dried vegetables can be stored for two years or more before being used.

Figure 14.2 a & b: Drying of tomatoes brinjal, peppers and naartjie. Drying of almost anything is possible!! (Pioneered at Dundee Agricultural Research Station) & Bottles of dried vegetables; including from left to right; Peppers, sweet potato, ground chillies and brinjals

Below is a table to help you think some more about different kinds of crops and foods that are rich in key nutrients, that can be grown and produced at a homestead level.

TABLE 14.1: HOME GARDEN CROPS THAT ARE RICH IN KEY NUTRIENTS

GO Foods (Energy)	GROW Foods (protein)	GLOW Foods		Iron	Fat
		Vitamin A	Vitamin C		
Avocado	Bambara groundnut or jugo beans	Amaranth or "imifino",	Cabbage	Beans/ peas*	Avocado
Bambara groundnut	Beans/peas	Other wild leafy vegetables	Citrus	Kidney	Bambara groundnut or jugo beans
Banana	Cow pea	Carrots	Guava	Liver	Butter
Cassava	Eggs	Cassava leaves	Mango, Papaya	Meat/ chicken/ fish	Groundnut
Coconut	Milk/ maas (soured milk) / yogurt/ cheese	Sweet potato leaves and tubers (also orange fleshed)	Peaches, plums, apples, pears	Some green leafy vegetables e.g. spinach or Swiss chard	Oil from plants; e.g. sunflower, sesame, groundnut etc
Groundnut	Groundnut	Liver	Passion fruit	Breast milk	Tree tomato
Maize	Meat/chicken/fish	Maize	Pineapple		Soybean
Millet, wheat, sorghum	Melon or pumpkin seeds	Mango	Tree tomato		
Rice	Pigeon Pea	Papaya	Sweet potato		
Sorghum	Soybean	Pumpkin	Tomato		
Sweet potato	Lentils, dahl	Rape or kale	Sweet pepper		
Taro/ amadumbe					

15 Natural pest and disease control

15.1 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.

15.1.1 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.

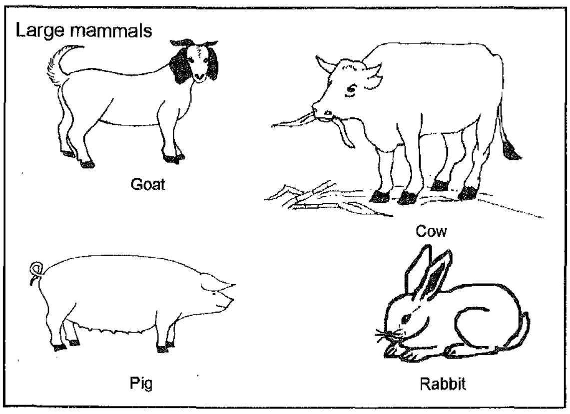
15.1.2 Animals

These include large mammals, rodents, birds, slugs and snails, insects and nematodes.

- **Large mammals**

Buck, pigs, goats, cattle, rabbits, dogs and cats are considered to be large mammals. If these are not kept out of the garden they could cause considerable damage.

Animal manure can be very useful in feeding the soil.

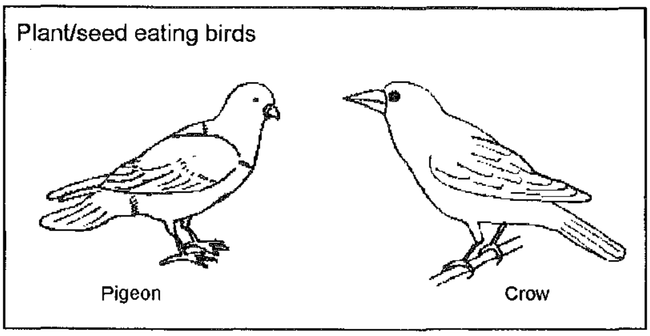


- **Rodents**

Rodents include mice, rats and mole rats and moles. These animals can cause damage to your crops and stored grain and should be controlled.

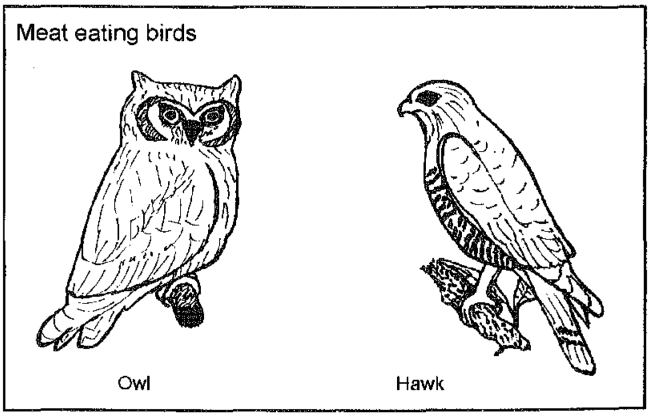
- Birds

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.



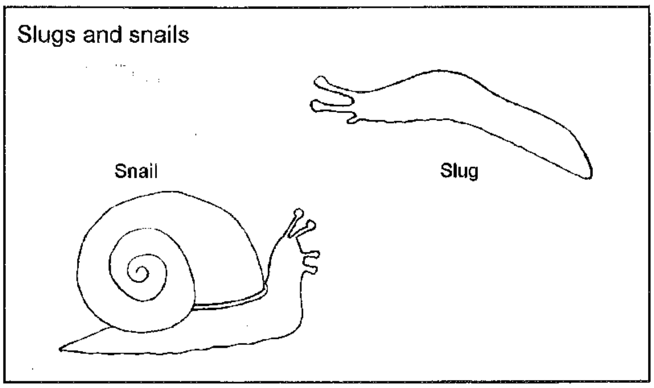
Not all birds are pests.

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.

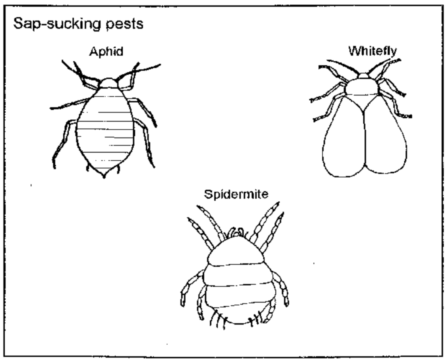


■ Insect Pests

Insect pests can be divided into two categories:

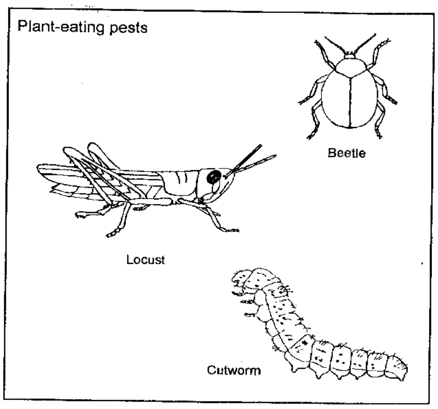
a] Sap-sucking pests

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



b] Plant-eating/chewing pests

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

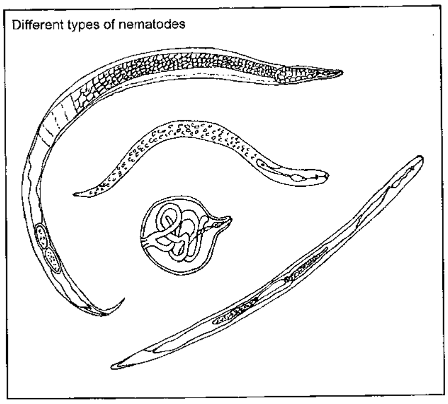


Not all insects are pests.

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.

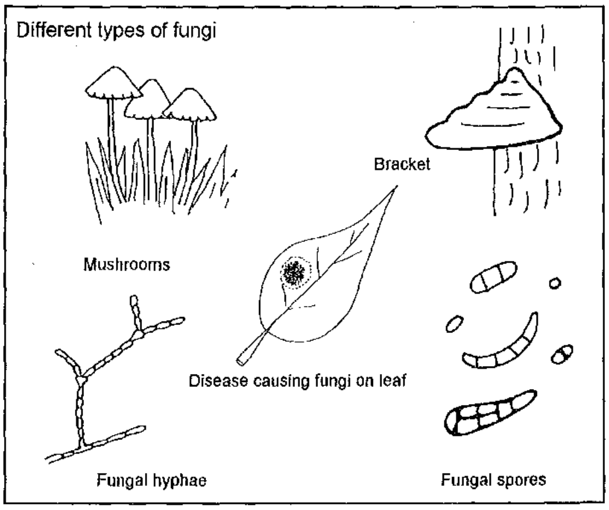
Only a small percentage of nematodes are plant eaters, the rest live on organic material in the soil or feed on small animals in the soil.

15.1.3 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.

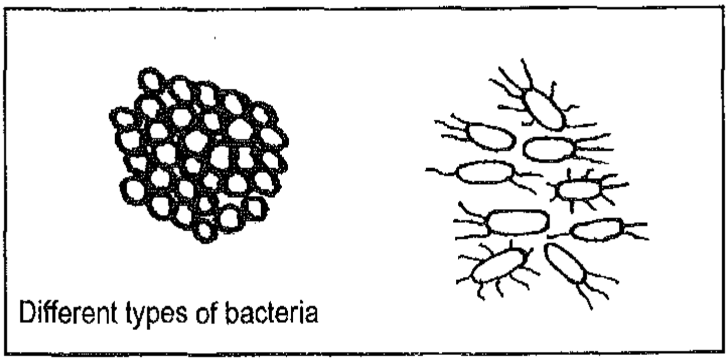


Fungi are not always disease causing.

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.

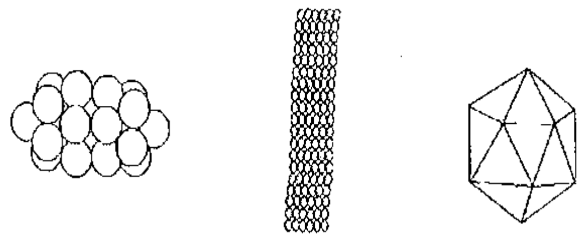
- **Bacteria**

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.

15.2 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.

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

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

15.2.1 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 and cell 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.

15.2.2 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

15.3 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.

Figure 15.1 Amaranthus

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.

15.4 Biological pest control

15.4.1 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:

Figure 15.2: Praying mantis

i. 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.

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.
- **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.

Figure 15.3: Dragonfly

Figure 15.4: Ladybird

Figure 15.5: 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.

Figure 15.6: Robber fly

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

Figure 15.7: Hover fly

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.

Figure 15.8: Parasitic wasp

ii. Pollinators

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

iii. 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.

Figure 15.9: Bee

15.5 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 wild damage your crop.

Figure 15.10: Diadem

- **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.

- **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.

Figure 15.11: Chameleon

Figure 15.12: Spider

15.6 Physical control methods

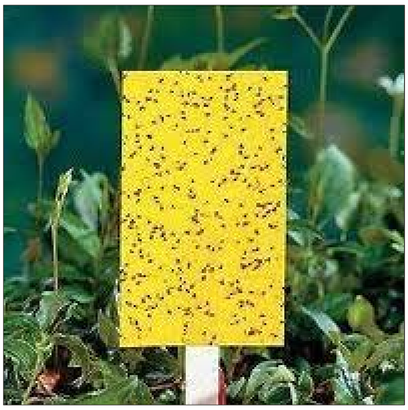


Figure 15.13: A homemade fly and fruit fly trap and a sticky yellow insect trap.

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.

15.6.1 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 both ends, or toilet roll centres, can be placed over seedlings as collars to keep cutworms away from the seedlings. They should be pushed firmly into the soil *(Figure 5.14)*.

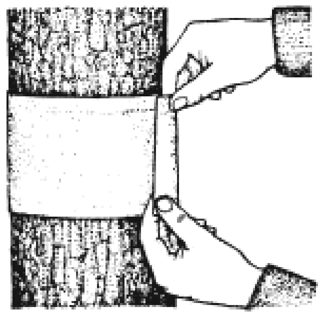


Figure 15.14: Place tin can or toilet roll centres over seedlings as collars.

15.6.2 Traps

Snail and slug traps

Figure 15.15 a & b: A beer trap for snails and slugs

- 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.

- **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.

Figure 15.16: Rodent traps

- **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.

Artifical guards

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

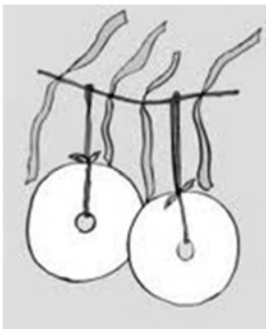


Figure 15.17: Use old cd's.

Figure 15.18: Using shadows of cardboards silhouettes of birds of prey.

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.

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)*.

15.6.3 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.

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.

15.7 Botanical remedies

15.7.1 Remedies made from plant material

In this chapter a few recipes for plant mixtures are given that can be used to control insects and diseases. Be sure to read the warnings, where present, carefully. No responsibility will be taken for damage to plants, animals, people or property.

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.

At least 3000 plant species have already been studied in laboratories to determine their effectiveness for controlling plant pests and diseases. Of these, approximately 1800 plants have been shown to be more or less effective against certain pests.

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 litre 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’ the leaves of plants they are applied to. Always test a new remedy on a small number of plants first.
- For most applications against insects the best time of day to spray is in the late afternoon.

16 Tree planting

It is possible to grow many different types of fruit trees around your homestead. You can acquire your trees by growing them from seeds or cuttings or buying grafted trees from nurseries.

16.1 Choosing a site

Different trees grow better in different climates. The table below will give you some ideas of which trees will grow in your area.

VERY COLD AREAS: Has frost often in winter and sometimes snow	NOT SO COLD AREAS: Has frost sometimes in winter and rarely snow
Apples, pears, peaches, nectarines, plums, almonds, grapes, cherries, apricots, pecan nuts and walnuts	- Apples, pears, peaches, nectarines, plums, almonds, grapes, cherries, apricots, pecan nuts and walnuts - Also: figs, granadillas and citrus fruit (lemons, oranges, naartjies and grapefruit)

Your trees will grow for a long time; so it is important to choose the right place.

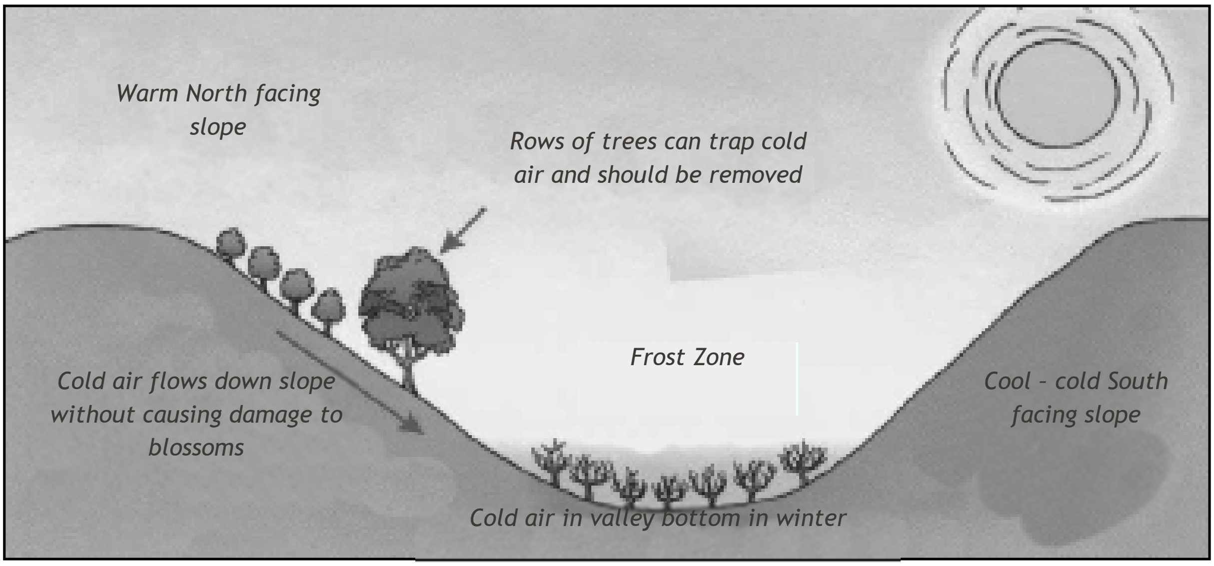


Figure 16.1: Diagram of different zones

You need an area with well drained and deep soil that has enough sun (preferably a north facing slope) where fruit trees can be protected from wind.

As it becomes colder in autumn deciduous trees and vines shed their leaves and go into a state of rest. They all need a certain period of cold weather to break this rest. The degree of coldness needed varies for different varieties of trees.
In some cases when the temperatures in June/July are not low enough the rest periods are insufficiently broken, which results in a state called “delayed foliation”. In spring some buds and leaf blossoms drop of and some branches remain dormant and die back. The trees do not grow or produce well. It is thus important in warmer areas to choose varieties that do not need very cold winters.

16.2 Choosing a variety

Each type of tree has many different varieties and you will need to choose a variety that is suited to your area and climate.

Some varieties grow better in very cold areas and others in warmer areas.

It is also important to know when a tree flowers. Late frost will kill early blossoms on a tree and badly damage the fruit production for that tree. You will need to choose a tree that flowers after the threat of frost has passed.

Another consideration for choosing a variety: Pollinators

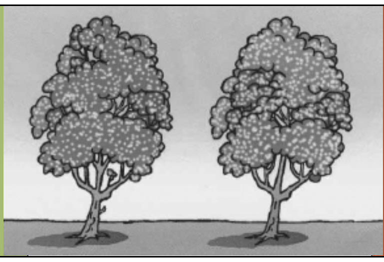
Here you will need two different varieties of the same type of tree (and two specific ones!) For example; you will need to plant both Granny Smith and Golden Delicious varieties of apples.

They will help each other bear fruit, as they pollinate each other. The blossom of the one cultivar/variety will need to be fertilized by the pollen of the other cultivar/variety. They need to flower/blossom at the same time and they need to be compatible, so that both types can bear fruit.

These trees must not be planted more than 30metres apart, so that the pollen can be transported from tree to tree with the help of bees and the wind.

You can plant 1 tree of one type (cultivar/variety) and 4-5 of the other; depending on which variety you prefer. This means that you can have more of one variety of trees, than another.

Which trees need pollinators?

YES		NO
Apples Pears Pecans Some Plums Pawpaws		Citrus Mangoes Grapes

Different varieties/cultivars you can choose from

There are many, many varieties and cultivars and new ones are always being produced. It may help to ask the nurseries in your area which varieties are suitable. In the table below some varieties are mentioned to give you an idea.

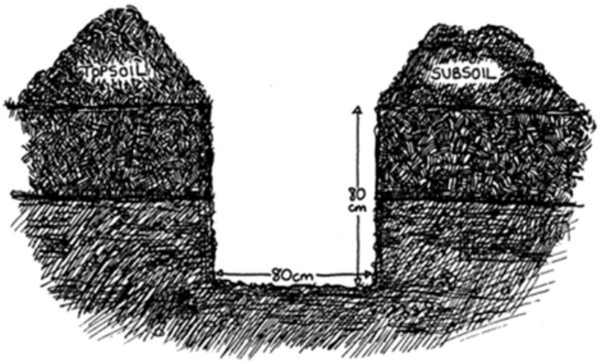
CULTIVARS FOR VERY COLD AREAS			CULTIVARS FOR NOT SO COLD AREA		
NAME	POLLINATOR	FRUIT RIPENS	NAME	POLLINATOR	FRUIT RIPENS
APPLES					
Granny Smith; green apple	Yes: Golden Delicious or Starking /Top Red	April	Granny Smith; green apple	Yes: Golden Delicious or Starking /Top Red	April
Golden Delicious; yellow	Yes: Granny Smith or Starking /Top Red	15 February	Golden Delicious; yellow	Yes: Granny Smith or Starking /Top Red	15 February
Starking/ Top Red: Red	Yes; Golden Delicious or Granny Smith	March	Starking/Top Red: Red	Yes; Golden Delicious or Granny Smith	March
PEARS					
Packhams; Light green	Bon Chretion and Forelle	Mid February	Packhams; Light green	Clapp's Favourite	Mid February
Bon Chretion; Yellow	Self pollinator	March			
Forelle; yellow with red blush	Packhams and Bon Chretion	Early April			
PLUMS					
Santa Rosa: red skin and flesh	Self pollinating	15 December - Begin January	Pioneer; red skin and flesh	Self pollinating	20 November
Songold: yellow skin and flesh	Santa Rosa, Laetitia	15 February	Songold: yellow skin and flesh	Santa Rosa, Laetitia	15 February
Laetitia; red skin and flesh	Songold	30 January	Laetitia; red skin and flesh	Songold	30 January
PEACHES					
Elberta; yellow freestone	Self Pollinating	25 August 1 February	De Wet; yellow freestone	Self pollinating	25 July 25 October
Kakamas; yellow clingstone	Self Pollinating	15 August 15 January	Oom Sarel: yellow cling	Self pollinating	5 August 15 December
Early Dawn: white freestone	Self Pollinating	15 August 20 November	Boland; White Freestone	Self pollinating	15 August 15 December
NECTARINES					
Flavortop; dark red kin, yellow flesh	Self pollinating	20 August 5 January	Sunlite; dark red skin, yellow flesh	Self pollinating	5 August 5 December
APRICOTS					
Peeka; Dark orange	Self pollinating	15 September 25 December	Palsteyn; dark orange	Self pollinating	30 August 30 November

16.3 Planting fruit trees

It is a good idea to prepare the planting site/hole a few weeks before you want to plant the tree. The soil will settle in the hole that you dug and the manure will not be too strong for the roots.

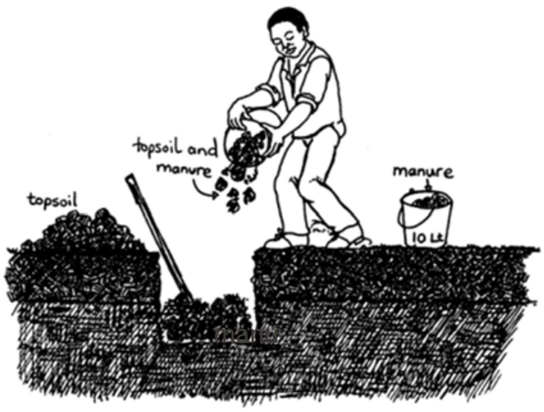
16.3.1 Preparing the hole

1. Dig a square hole that is at least 80 cm wide and 80 cm deep. A big hole means a good tree. Put the top soil in one pile and the subsoil in a separate pile.



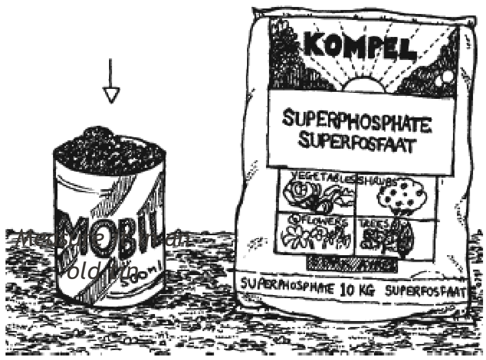
2. Now put 1 bucket (10 litres) of manure in the hole. Mix it with a few buckets of subsoil.

3. Mix in 500 g of superphosphate or 1kg of crushed bone.



4. Next, put in two more buckets of manure and some topsoil and mix them together.

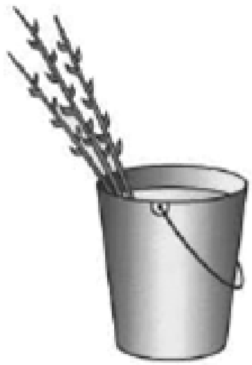
5. Now fill up the rest of the hole with topsoil. You may need to dig up some topsoil from somewhere else.



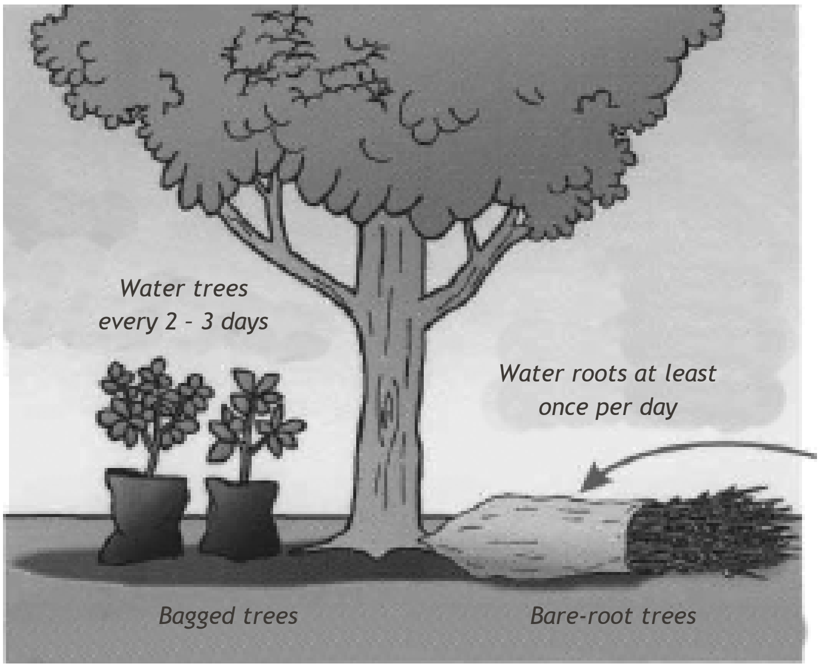
16.3.2 Planting the tree

Caring for the little tree before you plant it.

If it is in a plastic bag, water it every few days.
If it has bare roots, put moist sandy soil over the roots and wrap it in a wet sack until you are ready to plant it. You can place the trees in a bucket of water for 2-3 hours before planting them.



Place bare-rooted trees in a bucket for two hours before planting



Keep trees in a shady place before planting

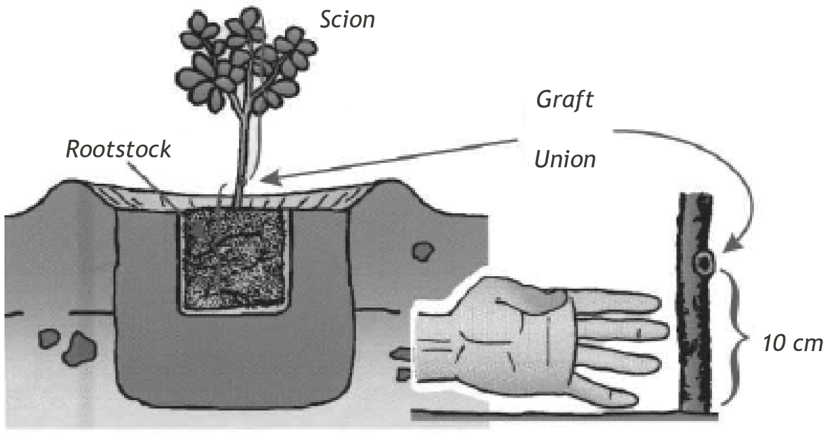
Cover the roots with grass, sawdust, or moist sandy soil

Figure 16.2: Caring for trees

16.3.3 Planting a tree that is in a plastic bag

These trees are usually planted in spring and will have leaves on the trees when you plant them. (September-November)

1. Water the tree in the bag without breaking the soil bundle.
2. Make a hole in your planting hole (which you prepared earlier) the same size as the plastic bag.
3. Take the tree out of the plastic bag.
4. Plant the tree and make sure the roots are covered with soil. The planted tree should be the same depth as it was in the bag.
5. The join or graft/union on your tree must be 10cm above the soil level.



- Dig the hole the same size as the bag.
- Carefully cut the bag and remove it without disturbing the soil around the roots.

NOTE: Graft union must be 10 cm (hand width) above the soil level

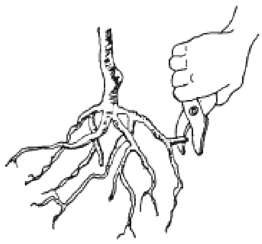
16.3.4 Graft unions

Wild fruit trees grow in many different soils and climates and have very strong roots. But the fruits from these trees are not very big or tasty. Other trees that are not so strong may bear good, tasty fruit. To obtain a tree with both strong roots and good fruit the roots of the wild tree are joined to the branches of the tree with tasty fruit. The process is called grafting; this is done by cutting the stem just above the roots of a wild tree and binding a branch that has been cut from a good fruit bearing tree. The two trees grow together to form a single tree.

The graft union can be seen as a large lump just above the roots. It should always be above the ground when the tree is planted.

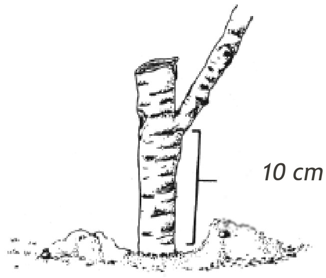
16.3.5 Planting a tree with bare roots

These trees are usually planted in the middle of or towards the end of winter (July- August).



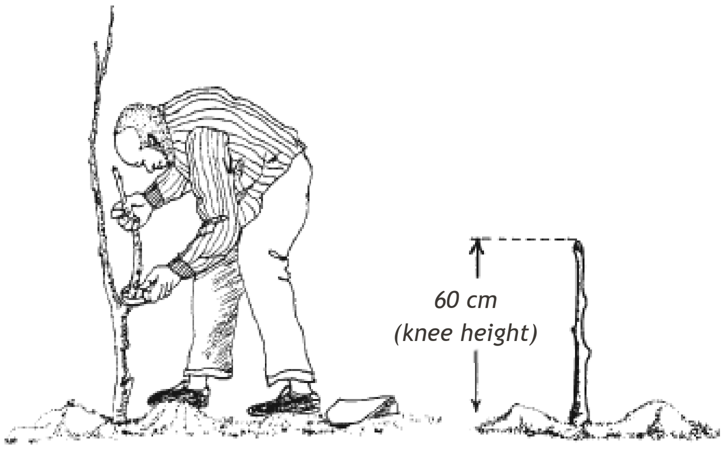
1. Make a hole in the soil you have prepared for planting. It should be a bit bigger than the roots of the tree.
2. Cut cleanly any broken roots to avoid disease.
3. Hold the tree in the hole so that it is a little bit higher out of the ground than it was before.
4. Carefully place the soil around the roots.
   Make sure the soil gets right in between the roots so that there are no air spaces left. The planted tree should be the same depth it was before in the soil.

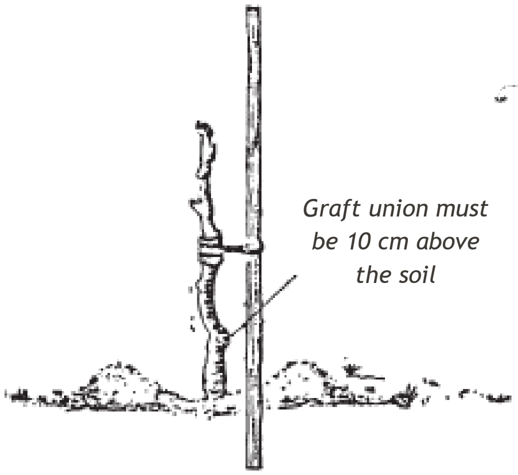
5. The join (bud union) must be at least 10 cm above the soil.



6. Once the tree is planted (bagged or bare rooted),you should prune it. Trees are weak after you plant them, because their roots take time to get used to the new place. It helps the roots to grow strong if you prune the tree after planting. You need to cut off the top and all the side branches.

7. To help the tree grow straight, tie it to a strong stick pushed into the ground. As the trees grow, they will take up more and more space.





It is important to plant them far enough apart. Peaches, plums and apricots should be planted 3 paces (metres) apart in the rows and rows should be 5 paces (metres) apart. Pears, apples and citrus trees need to be 5 paces (metres) apart in and between rows.

16.3.6 Watering your newly planted tree

1. Press down on the soil gently all around the young tree.

2. Make a small dam around the tree to hold water.

3. Give the tree 4 buckets (10 L) of water.

4. Mulch around the tree with dry grass or newspaper or rocks, keeping the mulch away from the trunk of the tree. This will save water for the tree. It will also stop weeds from growing.

5. Water that runs off the roofs and bare ground around the houses can be directed by means of small furrows to the trees, so that when it rains the trees will get a good soaking.

6. Use the following guidelines to water your trees.

TABLE 16.1: GUIDELINES TO WATER TREES.

Year	Spring and Summer	Winter
1	2 Bucket (20 L) every 7 days during dry weather	1 Bucket (10 L) every 14-21 days
2	3 Buckets (30 L) every 7 days	1 Bucket (10 L) every 14-21 days
Year 3 onwards	3-4 Buckets (30-40 L) every 7 days	2 Buckets (20 L) every 14-21 days

16.3.7 Feeding your fruit trees

16.3.7.1 Using kraal manure

Spread the manure on the ground, as far as the branches reach. Do not let the manure touch the stem of the tree. Then cover the manure with mulch, otherwise it will lose its strength.

TABLE 16.2: GUIDELINES FOR USING KRAAL MANURE.

Age of tree	September	December
Year 1	1 (10 litre) bucket	1 (10 litre) bucket
Year 2	2 buckets	2 buckets
Year 3	3 buckets	3 buckets
Year 4	4 buckets	4 buckets
Year 5	5 buckets	5 buckets

From 5 years onwards, you should apply the same amount of manure each year.

16.4 Caring for your trees

16.4.1 Inter planting

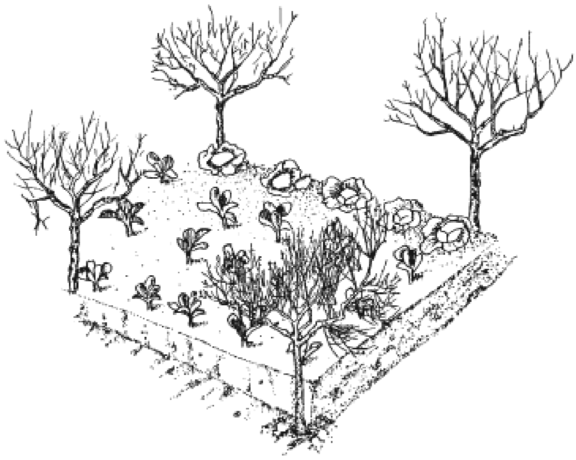


Figure 16.3: Inter-planting

It is more natural for trees and other plants to grow together rather than to stand alone. If you only plant one crop, insects will have a feast. Growing vegetables and other crops between your trees encourages “good” insects that control the “bad” ones and a better balance is maintained.

It is also possible to grow a mixture of other ANNUAL crops such a grasses (oats, annual rye grass) and legumes (vetch, lupins). These grow through winter and die down in early summer to provide mulch and compost.

OR it is possible to grow PERMANENT crops between your rows of trees. Here you would mix grasses (rye grass, fescue), legumes (clover, lucerne) and herbs (comfrey, chicory). These plants can be regularly cut short and the cuttings can be used as mulch, compost or animal feed. A variety of species always attracts a variety of organisms that may help in pest and disease control.

16.4.2 Pest and disease control for fruit trees

Growing healthy trees is a good starting point. They are stronger and more resistant to insects and diseases. Use lots of compost, manure and mulch and weed your trees regularly.

Other ways to grow strong healthy trees include:

Figure 16.4: Marigolds

Growing marigolds, leeks and comfrey nearby deters insects.

Promote the presence of bees. Bees help to pollinate the flowers of the fruit trees and thus to bear fruit.

Promote the presence of insect predators (good insects); these insects live off other insects and provide a natural way to control pests (bad insects). These include ladybirds, lacewings, wasps, praying mantis, dragonflies and frogs.

Figure 16.5: Bees

Figure 16.6: Praying mantis eat many kinds of insects.

Figure 16.7: Wasps lay their eggs in living worms and caterpillars. When the young hatch they feed off these worms.

Figure 16.8: Lacewings eat aphids.

Figure 16.9: Ladybirds eat lots of aphids and other bugs.

Figure 16.10: Frogs eat worms, caterpillars, slugs and even snails.

Figure 16.11: Dragonflies eat flies, aphids and mosquitoes.

Make up simple mixtures or brews that will get rid of insects and diseases

- **Garlic and onions sprays** (deter most insects): up 1 whole garlic or onion bulb. Soak it for 1 day in two teaspoons of paraffin. Add 0.5 litres of water and strain off the onion or garlic from the liquid. Add a medium bar of green sunlight soap and mix it in until it has completely dissolved. This will help to stick the mixture to the leaves of the trees. Dilute this mixture 1:10 with water and splash or spray on the tree.
- **Tobacco mixture:** This should be used carefully as it is a strong poison and can kill bees and useful insects as well. Boil up 0.5 cup of cigarette ends or tobacco in 1 litre of water. Strain off the liquid and mix with 2 litres of water. Splash or spray on the tree.
- **Fruit fly traps:** Fruit flies spoil fruit later in the season by stinging them and laying eggs inside the fruit. Small worms hatch in the fruit and make them rotten. Fruit flies like eating ripe fruit like plums, grapes and oranges. You can fill a trap with some water mixed with fruit (you can use any sweet smelling fruit), water and sugar. The fruit flies will fly into the traps to feed and will not find a way out again.

Figure 16.12: Fruit fly trap

- Another fruit fly trap consists of making up a mixture of Bovril or Marmite and mixing in some poison such as the tobacco mixture above.

Fruit flies can also be controlled by picking up fallen and rotten fruit beneath the trees EVERY day. The fruit is collected in buckets of water, which will drown the small worms. The fruit can also be fed to chickens and pigs. It is important that the small worms do not make contact with the ground. They burrow out of the fruit into the soil and rest there to start a new cycle of fruit flies.

Figure 16.13: Fruit flies

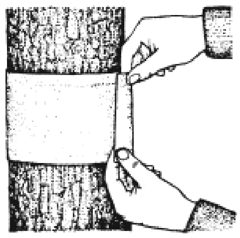


Figure 16.14: Grease covered band of paper of cloth.

Wrap a band of paper or cloth covered in grease around the trunk of each tree. The grease should not touch the bark as it is poisonous to the trees. Any pests, ants and other insects walking up the trees will get stuck on the grease and die.

Diseases such as mildew (a white powdery fungus on the leaves, mostly on apples, pears and vines), black spot (little black spots on leaves and fruit) and leaf curl (mostly on peaches and nectarines) can all be controlled by dusting the trees and fruit with sulphur or copper-oxychloride. These chemicals can only be obtained from gardening shops and some hardware stores.

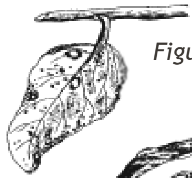


Figure 16.15: Leaf spot.

Figure 16.16: Peach leaf curl.

16.5 Planting trees for wind protection

The movement of air is important to plants. It prevents diseases caused by too much moisture/wetness and lack of air. It also helps to spread pollen (which is necessary for fruit production on some trees and plants) and helps plants to seed themselves.

16.5.1 Wind can affect your plants in negative ways:

- Strong winds can blow over or break your crops and trees
- Dry winds cause the soil and plants to dry out.
- Very hot or cold winds can destroy crops.
- Dust carried by the wind scratches plants like sandpaper.
- Wind can also cause soil erosion, especially in the dry months. Your topsoil can be blown away by the wind, leaving you with the less fertile subsoil.

Some extra advantages of windbreaks

- Can provide firewood
- Can provide fruit
- Can be thorny for protection
- Can provide fodder for animals
- Can provide medicine

16.5.2 Where to place a windbreak

Windbreaks are planted across the path of the main hot, cold and dry winds in your area. Windbreaks are good around homesteads. They can also be planted along roads and paths and also as boundaries around your fields and gardens.

16.5.3 How to make a windbreak

It consists of rows of trees and shrubs, usually of various kinds and heights. They are planted as a semi-solid barrier. This means that some air can still move through the windbreak, but it will be slowed down. The best windbreaks consist of at least three rows of shrubs and trees of different heights.

The trees and shrubs can also be planted in 1 or 2 rows. If you can, make sure that branches and leaves still grow close to the ground. With tall trees only, the lower branches die back over time. The wind will then "tunnel" past these bare stems and damage your crops. The shorter shrubs and plants can be planted on the side the wind is coming from as well.

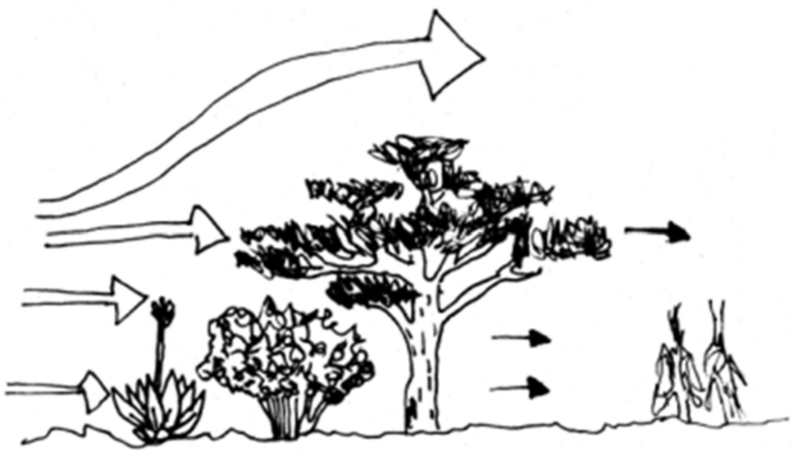


Figure 16.17: A Windbreak

16.5.4 Useful plant species to inter plant as wind breaks

Small shrubs and trees	Medium Shrubs and trees	Large shrubs and trees
■ Aloes	■ Napier fodder	■ Casuarina or Beefwood
■ Comfrey	■ Pigeon pea	■ Acacia or Sweet thorn
■ Wormwood	■ Buddleja or Sagewood	■ Mulberry
■ Herbs; rosemary, thyme, lavender, etc.	■ Halleria or Tree Fuchsia	
■ Marigolds	■ Dovyalis or Kei-Apple	
■ Fennel	■ Carrissa or Num-Num	
■ Runner beans	■ Euclea or Blue Guarri	
■ Vines; grapes, granadilla		

16.5.5 More about some of the suggested small plants, shrubs and trees

- **Aloe**

These are good for protection as they often are thorny. They also provide some protection against fire, as the leaves are fleshy and hold a lot of water. They can be used for medicine. A good kind to use is Aloe maculata. This is a low growing aloe with white speckles on the leaves. The gel in the leaves is very good as a medicine for constipation and contains a trace element known as selenium. Selenium is a very important supplement for your immune system.

- **Marigolds and Fennel**

These are small strong smelling plants that help to protect your garden from insect attack. The white umbrella-like flowers of fennel help to attract insects (predatory wasps) that eat the pests in your garden (worms and aphids). Marigolds can be used to make a poison that will kill small worms (nematodes) in your soil.

- Napier fodder

This is a tough, hardy fodder grass that can be used for hay and silage. It is also good for mulching. It grows fast. It is propagated by taking small rooted clumps from a "mother" plant. It is also possible to lay the canes/grass stems in shallow furrows. These will grow from the nodes/notches in the stem. In cold areas the plants will die back in winter (the dry leaves remain as a windbreak). They will re-shoot in spring.

- **Buddleja salvifolia; Sagewood; Lelothwane**

These are tough, fast growing, evergreen shrubs. This means they do not lose their leaves in winter. They are frost resistant. They will need to be protected when young, but are robust when older. The flowers attract birds and bees. The leaves can be used as tea or as a medicine for eye complaints.

- **Halleria lucida; Tree fuchsia; Lebetsa**

This is a shrub, but can also grow into a small tree. It grows up to about 3-10metres high. It has multiple stems that can be cut for firewood, garden stakes and fencing. It has tubular orange/red flowers that attract birds and bees. The fruit is edible.

- **Euclea crispa; Blue guarri; Mohlakolo, Motsoetla**

This is a shrub or bushy evergreen tree that grows between 1 and 5 metres high. It has small, black pea-like berries that are edible. It grows wild in some places.

- **Carissa bispinosa; Num-num**

This is a branched, spiny evergreen shrub. The leaves are small, shiny and thick. Fruit are small oblong red berries that are good to eat and for making jams.

- **Cajanus cajan; Pigeon Pea**

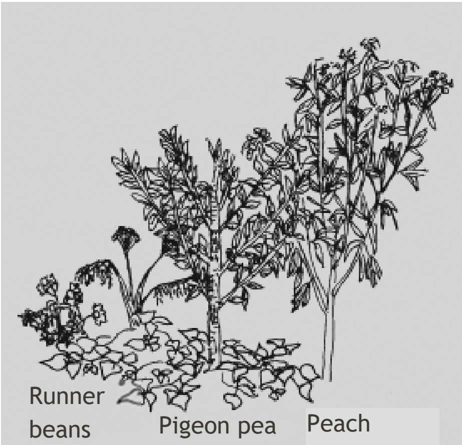
This is a small tree that is native to Africa. It fixes nitrogen in the soil and has deep roots. It can be used for firewood. It is frost tolerant, but needs to be protected when young. The young leaves can be eaten as spinach and the seeds are eaten as beans or "dahl". The leaves are also good fodder for animals; especially cattle and goats.

- **Dovyalis caffra; Kei Apple**

This is a very thorny small tree with fleshy leaves. It makes a good protective hedge. It grows a bit slowly. It is resistant to drought and frost. It needs to be protected from frost when young. The fruit is good to eat and can be made into jams and jellies. The flesh needs to be washed off the seed before planting.

- **Mulberry**

These are large deciduous trees. This means they lose their leaves in winter. The leaves are good animal fodder. The small black berries are very sweet and can also be used for making jam. Mulberries are easy to grow from cuttings. They can be pruned and these branches can be used for fences, stakes and firewood.



It is possible to plant fruit trees together with some of the trees and plants mentioned here. This helps to protect your fruit from pest attack and wind and frost damage. On the right is an example of a peach tree planted with runner beans, marigolds, fennel and Pigeon Peas. Different combinations of plants can be used.

- **Casuarina Cunningham; Beefwood**

This tree originally comes from Asia and Australia. It is a large shady tree with leaves that look like pine needles. It grows very fast and can grow in poor soil. It provides good timber and firewood. It can be planted easily from seed. It is moderately frost resistant and should be protected when young.

- **Acacia Karoo; Sweet Thorn**

These are very hardy, fast growing, very thorny trees. They are frost and drought resistant. They fix nitrogen into the soil. The tree provides good firewood. Leaves, flowers and pods are good animal fodder.

Advantages	Disadvantages
Trees are multi-functional, they provide: oxygen,, shade, food, medicine, furniture, trees can be used as wind breaks, places to sit and enjoy nature, we can climb them, they are low maintenance, we can use the dead branches and leaves in our compost heaps and we can mulch with them, increases biodiversity, is a place for beneficial insects and animals to live	It's a long term investment

17 Agro-forestry

17.1 What is the aim of agro-forestry?

Agro-forestry combines or integrates trees and or shrubs with other crops and or animals in a farming system. Trees and shrubs may be grown at the same time alongside crops or in rotation with crops.

Agro-forestry imitates a natural ecosystem, in which a great variety of living and non-living creatures interact in a highly productive and sustainable fashion. The same land is used more productively to yield a variety of crops and maintain fertile conditions. It can mitigate against environmental degradation and has the potential to ensure food security and fodder supplies for livestock consumption.

17.2 Planting trees for soil fertility

Trees in a farming system have a number of functions and advantages:

- They add substantial amounts of organic matter to the soil from leaf litter and root decay.
- They absorb nutrients from deep soil layers. They begin the cycling of nutrients by mining and accumulating available nutrients. As more nutrients enter the biological system and vegetative cover is established, conditions for other non-pioneering species become favourable.
- They reduce erosion and promote recycling of nutrients.
- They can improve the physical properties of soils, including water holding capacity and break up hard layers.
- Pioneers like nitrogen fixing trees tend to benefit other forms of life by boosting fertility and moderating harsh conditions.
- Constant leaf drop nourishes soil life, which in turn can support more plant life.
- The extensive root systems stabilize soil, while constantly growing and atrophying, adding organic matter to the soil and creating channels for aeration.
- They also provide numerous useful products and functions, including food, wind protection, shade, animal fodder, fuel wood, living fences, and timber.

There are a number of fast growing leguminous trees that are used commonly in agroforestry systems. These include for example Sesbania sesban. Leaucena spp, Cajanus ss (Pigeon Pea), Acacia spp and Moringa oliefea (Drumstick tree). To follow is a reasonably comprehensive list of species that can be tried.

Nitrogen Fixing Trees

- *Acacia leucophloea* - shade and fodder for livestock in arid environments;
- *Acacia mearnsii* - multipurpose highland legume tree;
- *Acacia nilotica* - pioneer for dry lands;
- *Acacia karroo* - for dryland fodder and soil stabilization;
- *Acacia tortilis* - fodder tree for desert sands;
- *Albizia lebbeck* - a promising fodder tree for semi-arid regions;
- *Albizia odoratissima* - Tea Shade Tree;
- *Albizia procera* - white Siris for reforestation and agro forestry;
- *Albizia saman* - pasture improvement, shade, timber and more;
- *Azadirachta indica* - neem, a versatile tree for the tropics and subtropics;
- *Cajanus cajan* - it's more than just a pulse crop;
- *Casuarina cunninghamiana* - the river she-oak;
- *Casuarina equisetifolia*- an old-timer with a new future;
- *Casuarina glauca* - a hardy tree with many attributes;
- *Chamaecytisus palmensis* - hardy, productive fodder shrub;
- *Dalbergia latifolia* - the high-valued Indian rosewood;
- *Dalbergia melanoxylon* - valuable wood from a neglected tree;
- *Dalbergia sissoo* - the versatile rosewood;
- *Erythrina edulis* - multipurpose tree for the tropical highlands;
- *Erythrina poeppigiana* - shade tree gains new perspectives;
- *Faidherbia albida* - inverted phenology supports dryzone agro forestry;
- *Flemingia macrophyla* - a valuable species in soil conservation;
- G*leditsia triacanthos* - honeylocust, widely adapted temperate zone fodder tree;
- *Gliricidia sepium* - the quintessential agro forestry species;
- *Grevillea robusta* - a versatile and popular tree for farm forestry;
- *Guazuma ulmifolia* - widely adapted tree for fodder and more;
- *Hippophaë rhamnoides* - an NFT valued for centuries;
- *Honey Mesquite* - a multipurpose tree for arid lands;
- *Hymenaea courbaril* - the flour tree;
- *Leucaena diversifolia* - fast growing highland NFT species;
- *Leucaena leucocephala* - a versatile nitrogen fixing tree;
- *Moringa oleifera* - a perfect tree for home gardens;
- *Myroxylon* - balsam and much more;
- *Pongamia pinnata* - a nitrogen fixing tree for oilseed;
- *Prosopis alba* and *Prosopis chilensis* - subtropical semiarid fuel and fodder trees;
- *Prosopis pallida* - pioneer species for dry, saline shores;
- *Pterocarpus erinaceus* - an important legume tree in African savannas;
- *Pterocarpus indicus* - the majestic N-fixing tree;
- *Robinia pseudoacacia* - temperate legume tree with worldwide potential;
- *Senna siamea* - a widely used legume tree;
- *Sesbania grandiflora* - NFT for beauty, food, fodder and soil improvement;
- *Sesbania sesban* - widely distributed multipurpose NFT;
- *Ziziphus mauritiana* - a valuable tree for arid and semi-arid lands.

17.3 Systems for inclusion of trees

- **Alley cropping**

This is a system where food crops are grown in alleys in between rows of trees or shrubs, preferably nitrogen fixing. When trees are pruned or cut the plant material can be turned into the soil as a green manure, composted, or left on the surface as a mulch.

Figure 17.1: A field with a row of trees planted along the edge and further in lines within the field. Crops are planted in the 'alleys' between the trees.

- Resources required:
  Space, trees, shrubs and or seed of suitable plants (refer to list)
- Method:
  Investigate where the wind comes from, what nitrogen fixing trees are available to you, where you can get them from etc. Plan and design your garden well so that it works for you. Plant the trees and crops.
- Practical considerations for implementation:
  Green tree leaves keep their high nitrogen content throughout the year. This means it makes a good green manure and good material for compost heaps.

- **Improved fallow**

The trees can be densely planted in an area with poor soil fertility and left to grow for 1-3 years. The trees are then cut (green material, leaves and small stems are left on the soil as plant residue) and rain fed crops grown. This has a considerable effect on soil fertility and structure, but is labour intensive and problematic if land is at a premium.

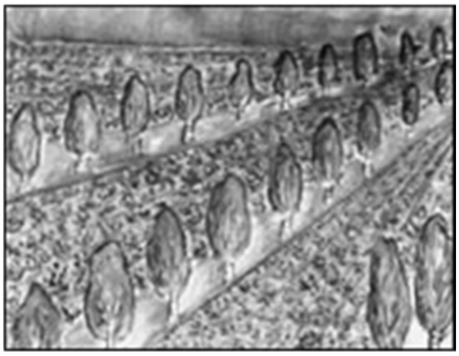


Figure 17.2: Shelterbelts planted on contour in between rows of crops.

- **Contour hedgerows, shelter belts and clump plantings**

Figure 17.3: Clumps of trees planted as shelter for livestock and to improve veld condition. (From: www.agf.gov.bc.ca/ resmgmt/ agroforestry/)

Here trees are planted along contours but are interspersed in the cropping landscape as hedges and windbreaks. This system is less intensive and does not interfere with the field crops, but the potential advantages in soil fertility are also reduced. The trees now have the additional function of creating suitable micro-climates for crops and animals in terms of shading and cooling effects on the one hand, or in terms of creating sun trapping, warm microclimates in colder areas. Another function is for these trees to serve as living fences.

The diagrams below show some examples of possible layout using the NTF (Nitrogen Fixing trees) species in a cropping system.

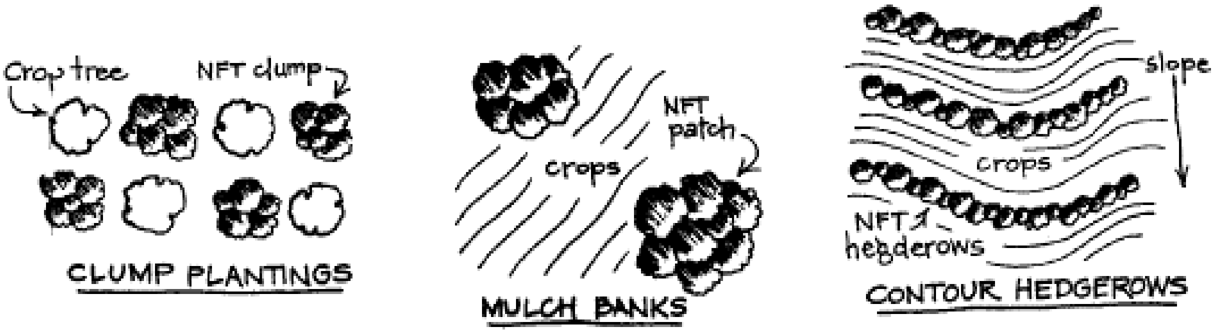


Figure 17.4: Possible layouts using NTF species

i. In the first diagram NTFs are planted in between tree crops such as citrus, coffee, nuts and other food and fruit trees;
ii. In the 2nd diagram clumps of trees are interspersed in cropping fields; mainly to accumulate biomass and provide mulching material for the crops;
iii. In the 3rd diagram tress are planted on the contour in hedge rows – meaning that they form hedges that help with protection against wind and creating favourable micro-climates for crops.

17.4 Biomass Accumulation

This refers to the accumulation of organic material to work with. If you have many trees and plants in your garden you will have lots of organic matter (leaves, twigs, etc.) to make compost and mulch and improve soil health. It is always good to increase biomass (organic matter) supplies.

17.4.1 Advantages and disadvantages of Agroforestry

Advantages	Disadvantages
Indigenous species can be used, tree roots penetrate soil deeply, grow without irrigation in the dry season, take nutrients up from deep in the soil and accumulate biomass Provides a source of wood and energy, fodder, food, oils in seed and other products year round, improve soil fertility (by fixing nitrogen), can provide a source of income and increased natural diversity. Used as windbreaks, assists in pest and disease control (integrated pest management), pollinator forage, prevents soil erosion, living fences, medicine, green manure and liquid manures, habitat, noise reduction, Trees release oxygen and shelter animals.	Long term investment, long term results, need lots of land/space. Most will not thrive in shade or fertile conditions. Because of their ability to thrive under poor conditions, they can easily become weedy. Therefore, if possible, use only NFTs which are already established in your area, or that have a history of not becoming weeds. NFTs can also become competitive for available soil nutrients, especially in arid areas.

18 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.

18.1 Inter-cropping

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.

18.1.1 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 (Figure 18.1) on the cauliflower. It takes into account nutrient consumption, rooting depth, insect repellent properties (onion and fennel), timing and shade tolerance.

Figure 18.1: Aphids

- **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:

Figure 18.2: Swiss chard inter-planted with fennel and garlic

Figure 18.3: 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.

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

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, - beans
Cabbage	- strawberries
Pumpkin	- potatoes
Tomatoes	- potatoes, - cabbage
Beans	- onions
Sunflowers	- potatoes

18.1.2 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.

18.2 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.

18.2.1 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 build up of specific weeds.

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!)

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.

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.

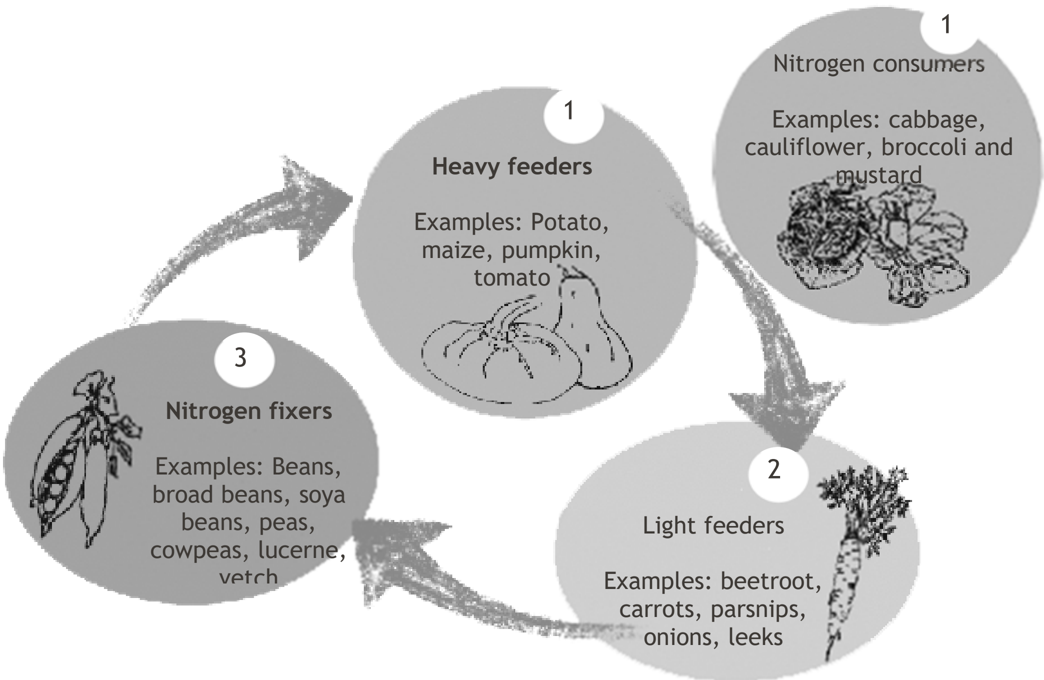
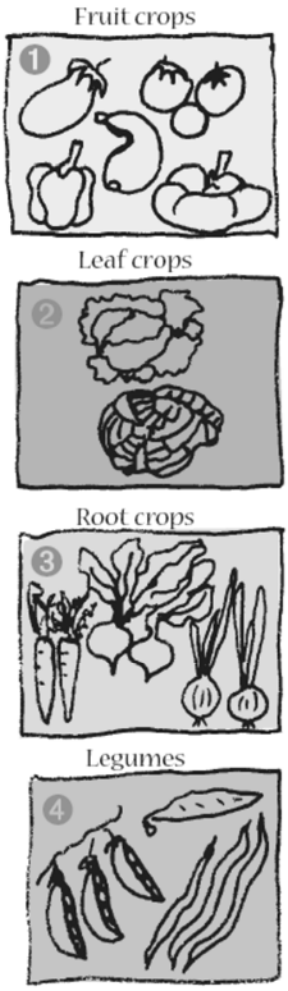
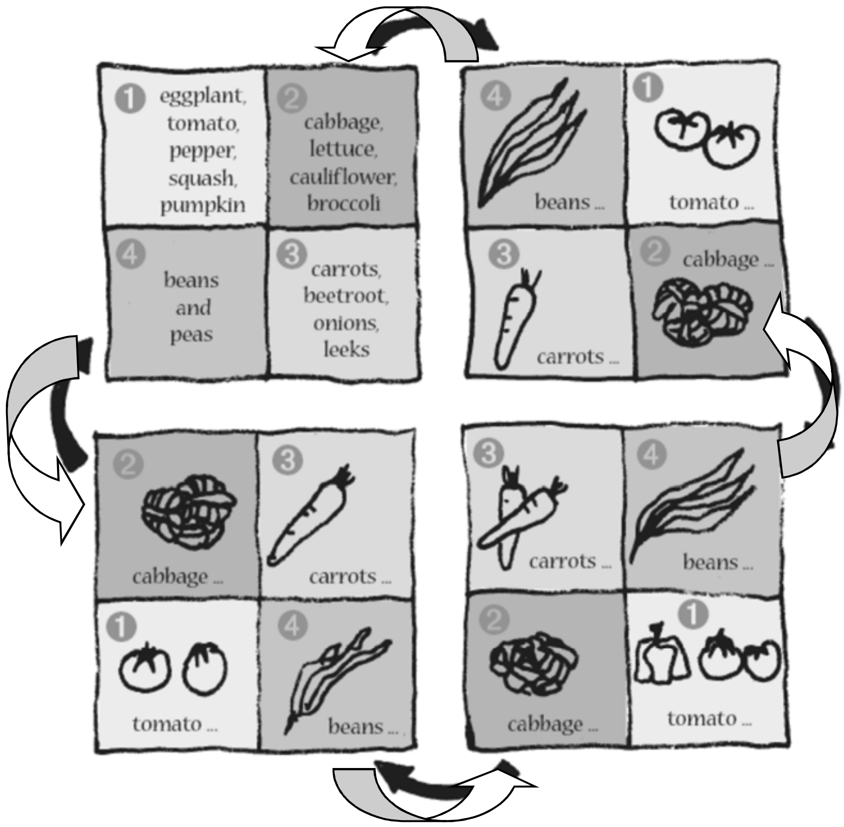


Figure 18.4: A 4 year rotation for vegetables.

This alternative system is presented below:





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.

18.2.2 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

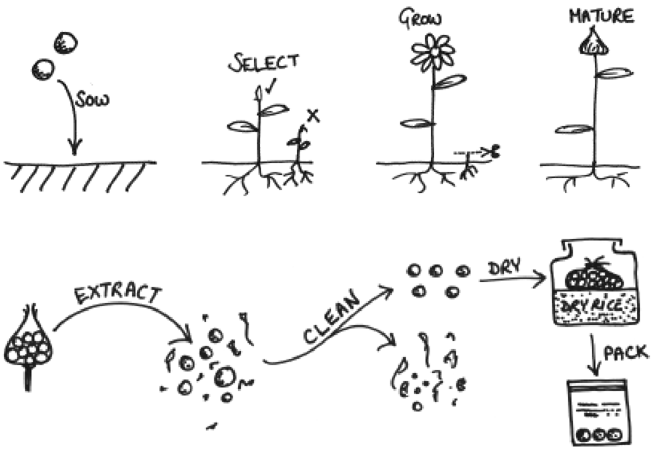
19 Introduction to seed saving

In agriculture and gardening, **seed saving** is the practice of saving seeds or other reproductive material (e.g. tubers) from open-pollinated vegetables, grain, herbs, and flowers for use from year to year for annuals and nuts, tree fruits, and berries for perennials and trees.

Keeping your own seed is central to your independence as a homestead food gardener. You can choose which varieties and types of crops you like and keep these seeds. You do not need to go to the shop to buy seed. There are still many varieties of seed that farmers keep or that you can buy from a shop that you will be able to keep for yourself once you have grown the crop.

Growing from seed to seed, involves the following process:

- Germinating seeds,
- Transplanting seedlings,
- Looking after selected healthy plants until they mature, so that
- Their seeds can be collected, and
- Stored for the following year.



Plants adapt to the environment they are grown in and produce seeds that carry those local adaptations, producing healthier plants that are better able to cope with the local environment.

There are a few things about how plants work that you need to understand to help you to successfully keep your own seed. In the sections below we will discuss pollination (self-pollination and cross- pollination), how pollination happens (pollinators), and how you select and store seed.

Flowers

Figure 19.1: An example of a perfect flower where the stigma is surrounded by the

Many vegetable species produce flowers with the male part (anther) and the female part (stigma) in the same flower. These are called perfect flowers.

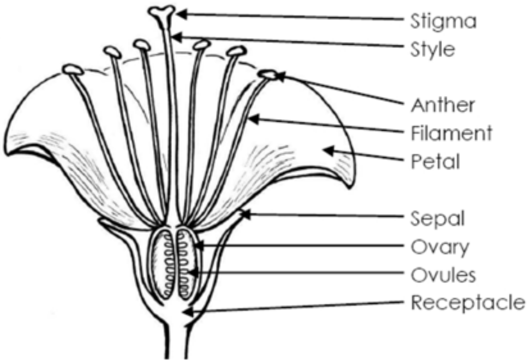
However, in maize and most varieties of the cucurbit family (cucumbers, melons, pumpkins, etc.), the anthers and the stigma are in the same plant but on different flowers. These are called imperfect flowers.

Figure 19.2: The male and female flowers of a pumpkin plant cut open to show the stigma and anthers in different.

19.1 Pollination

Pollination occurs in plants when pollen from the anthers of the flower is deposited on the stigma. In some perfect flowers, self pollination occurs.

19.1.1 Examples of pollination for perfect flowers



- **Lettuce, tomato, capsicum (peppers) and okra** have the stigmas so close to the anthers that the slightest wind movement can cause the pollen to drop onto the stigma within the same flower. They self-pollinate, but belonging to the same family they can cross pollinate as well.

Figure 19.3: A bee cross-pollinating a head of onion flowers.

- Generally, plants that self-pollinate can be grown quite close together (4-200m) without them crossing with each other. It is still a good idea however, to separate different varieties of the same plant from each other (e.g. different varieties of lettuce), as some crossing can still occur -especially those where pollen is carried by wind. These include also spinach and beetroot.
    - **In peas and beans**, self-pollination occurs even before the flower opens.
    - Other types of perfect flowers require cross-pollination. An external pollinator such as an insect is necessary. **Onion, carrot** (cross pollinated by wasps and flies), **cabbage, and radish,** for example, belong to this type. This means that all the different varieties in these families will cross with each other.

For example, all brassicas cross pollinate with each other; thus cabbage, broccoli, cauliflower, kale and Brussel sprouts all cross. Then Chinese cabbage, turnip, radish and mustard spinach will all cross as they are in the same family.

Cross-pollinated plants produce more varied offspring that are better able to cope with a changing environment.

Figure 19.4: A cabbage plant seeding

19.1.2 Examples of pollination for imperfect flowers

Plants with imperfect flowers require wind or insects such as bees to transmit pollen from the anthers of the male flowers to the stigma of the female flowers.

Maize, for example, is cross-pollinated by wind. Most other grains are also wind pollinated, including sorghum, millet and Imfe. Pollen picked up by the wind can travel very far (many kilometres) on air currents before coming to a rest. Cucurbits (pumpkin, melons, gourds and cucumber) are cross-pollinated by bees. Other examples are paw-paws and asparagus.

19.2 Open Pollinated and Hybrid crops

Vegetable seeds can be saved to sow new crops in the future, but not all seeds are suitable for saving. Varieties suitable for seed saving include local varieties that have been grown in one region for a very long time, self-pollinating crops (for example, beans and peas), and open-pollinated varieties of some cross-pollinating crops (for example, pepper, cucumber and carrot).

Commercial F1 hybrid varieties are popular among many vegetable growers today. However, the seed of hybrid fruits should not be saved, because the F1 hybrid seeds were produced by forcing across between two different parent varieties, that would not naturally cross. Seed saved from hybrids will either be sterile or the plants of the next generation may show wide variation.

You know that a packet contains hybrid seed when the sign on it says: F1

19.2.1 How to take control of cross-pollination

Any insect or wind pollinated plant will need to be isolated from other varieties of the same plant to stop them from crossing with each other. Below are four techniques you can try to achieve purity in your seed.

- **Grow them apart**

Grow two varieties that cross-pollinate at least 500 m or more apart. This is how far most insects fly, although bees can fly up to 4 km. Obstacles that deflect wind or insects such as hedges, buildings and ridges can greatly reduce cross-pollination.

- **Isolate them in time**

This is possible for crops where all the plants flower at the same time, such as maize and sunflowers. Crossing can be avoided by growing early, mid- and late season varieties that shed their pollen at different times.

- **Cage them**

Caging is needed for species that flower over a long period of time, such as cabbages, peppers and chillies. Put cages made of fly or nylon netting over the flower stalks of the different varieties to exclude all insects. Pollinate by hand.

Figure 19.5: Caging of individual pepper plants in small nylon neeting cages.(From Saving your own vegetable seeds. World Vegetable Centre)

- **Cage one and then the other variety**

This can be used instead of hand pollinating varieties that are flowering at the same time, for varieties that are insect pollinated. Cage one variety while insects pollinate the second variety.

Then cage the second variety while insects pollinate the first one. Once they have been pollinated, both varieties should be caged until flowering has stopped.

Making an isolation cage

Figure 19.6: A vegetable garden for growing seed with a number of isloation cages in the garden (from www.alcoopershomecountry.blogspot.com /preserving our seed heritage)

To make a simple isolation cage ideal vegetables, you need some cheap nylon fly-screen or other netting of 1m by 5m will, four canes or thin stakes, and some string and garden wire. This gives a cage large enough to cover 3 or 4 plants.

Figure 19.7: Example of a simple cage made from nylon. (From www.realseeds.co.uk)

Cut a square piece of screen 1m x 1m to make the top of the cage, and then fold the remaining strip of fly-screen round and sew its ends together. The resulting band will be the sides of the cage. Then sew the top to the sides, making a cube of fly-screen with the bottom missing.

Figure 19.8: A pollination cage made from sticks and netting held down with stones to stops insects form getting in.

To put up the cage over your plants, hammer the four canes into the ground in a square a little smaller than the cage top, so that they stick up a little less than the height of the cage. Twist a short piece of wire tightly round the top of each cane, and then run string in a square around the tops of the canes, supported by the wires to stop it slipping. Run a second piece of string around the stakes lower down to stop the sides of the cage blowing in against the plants. Then slip the cage over your plants, and weigh it down with earth or rocks.

Bagging and Hand Pollination

Figure 19.9: Maize flowers or 'heads' are covered with paper bags for the duration of pollination to ensure pure lines/varieites (from www.info.seedsavers.org)

If none of the above isolation techniques are practical for you, or you want to maintain a high degree of control over which plants pollinate each other, you can individually hand pollinate flowers or flower heads and enclose them in cloth or paper bags. This technique works well with large-flowered plants such as pumpkin or maize.

Bagging is only necessary from the day before the bud opens until the flower falls off the plant, so the bags do not need to be long lasting. They must, however, be well secured to the plant, as the plant is open to cross-pollination if the bag blows off or becomes unsecured.

Bags must be made of a porous or "breathable" material so the plant has access to light, air, and water. Paper bags work in drier climates but may introduce rot or block light in wetter climes.

Hand pollination of cucurbits involves choosing the female and male flowers to be used for pollination the day before, as they start opening. These are then taped closed till the next morning when pollen from the male flower is introduced to the female flower. which is closed again to allow the pollen to fertilize the flower. The tape is left on until the flower withers and falls off the stem. This fruit is then tagged for collection of seed.

Figure 19.11: A femla squash flower taped closed for pollination (from www.chickensintheroad. com / hand-pollinating squash)

Figure 19.10:: A porous plastic 'cloth' bag held in place by a clothes peg protects a pumpkin flower. (From www.realseeds.co.uk)

19.3 Criteria for selecting seed

- The seeds should possess the same quality as the variety that was planted. If you planted a long, purple brinjal, collect seed from a long purple fruit. If the fruit looks different, the seed will also be different.
- Take out plants with undesirable characteristics before they start flowering. Examples are slow growers, sick/diseased plants or ones that bolt (start seeding) too early.
- Harvest seed only from strong, good looking plants
- Harvest seeds from plants that perform well under stress, such as extreme weather conditions, and plants that resist disease or insect attack.
- Harvest seed only from healthy plants. If the leaves or fruit have rotten spots or a mottled appearance, do not use seeds from these plants. These diseases are carried in the seed and will appear next time.
- Also do not harvest seeds that have diseases such as brown blotches or mould growing on them.

You should harvest seed from at least six (6) plants of each variety or type that you want to keep. For some crops, such as onions, you need to keep seed from at least 20 plants and for crops such as sunflower and maize you need seed from 50-100 plants. In multi-coloured maize you may lose some colours and insect resistance if too few plants are used.

- Do not harvest seed from plants that have bolted. Bolting is when the plant goes to seed much quicker than it normally should. It could be due to stress, such as hot and dry conditions, but is also in-built. So, if you take seed from plants that have bolted, you are selecting for a plant that bolts, or goes to seed very easily. This is particularly important for crops such as mustard spinach and lettuce where you are looking for a prolonged leaf stage.

- Harvest the seed when it is ready. Immature seed will usually not germinate, as it has not fully formed (if the seed is still green or wet when picked). Over-mature seed tend to go rotten before you plant them. Do not harvest seed that has been damaged by insects or in any other way. They can only germinate if they are whole.

19.4 Seed Saving Instructions for specific crops

19.4.1 Plant Isolation Distances Table

Plant	Isolation Distance	Pollinator
Amaranth	~1000m	wind, insects
Lamb's Quarters	~ 1000m	Wind
Bean, Common	0m	self
Bean, Lima	0 to 2m	self
Cowpea	0 to 2m	self
Sorghum	800m	self
Maize	800m- 3200 m	Wind
Chinese Cabbage	~ 400m	Insects
Chinese Mustard	~ 400m	Insects
Kale	~ 400m	Insects
Mustard	~400 m	Insects
Okra	500m or more	self, insects
Pumpkin	400m - 800m	Insects
Watermelon	400m - 800m	Insects
Gourds	400m-800m	Insects

Working with isolation distances can be very tricky unless one individual or group grows one variety of a crop and another person grows another variety. These distances are good to get an idea how far you have to be form your neighbours so that what you are growing does not cross with theirs.

19.5 How to know where to find the seed?

19.5.1 Seed heads

Some plants carry pods which contain the seed, like beans and peas. These are called **legumes**. They are mostly self pollinating, so you do not need to be too careful in separating different varieties.

Figure 19.12: Beans

To collect the seeds, allow the pods to mature fully on the plant until they start to yellow and dry out. In wet weather, collect the pods individually as they get to this stage; then spread out somewhere out of the rain with a good airflow until the pods are fully dry and brittle. Once they are dry, shell out the beans and dry further out of the pods. The beans should be dry enough that they break when you bite on them, rather than leaving a dent.

Store in an airtight container – If they are well dried, and stored in a cool dark place, the beans will last around 3 years.

If you have problems with weevils eating your seeds, put the sealed container in the freezer for a week immediately after drying the beans; this will kill any insect eggs before they hatch. When you take them out, let the container come up to room temperature before opening it, otherwise the beans will absorb moisture from the air.

Leafy crops like lettuce and swiss chard will send out stalks from the middle of the plant. The flowers and seeds will be produced on these stalks.

Figure 19.13: Lettuce

Brassicas (the cabbage family) will first make a head, or compact leaves. Examples are cabbage, cauliflower, broccoli, kholrabi, kale, chinese cabbage and mustard spinach. Then, in the next warm season, a flower stalk will grow out and seed pods will be produced on these. Sometimes a deeply cut cross needs to be made across the head to assist the tlak to come through This can take up to 18 months.

The cabbage family requires bees or other insects to carry pollen between plants. You need as many plants as possible to collect seed from (at least 6, but up to 20). One plant on its own will produce hardly any seed. Brassicas can cross with any member of the family. A cabbage can cross with a cauliflower or a broccoli or chinese cabbage!!! It is important to isolate different members of the cabbage family to obtain seed.

Root crops like carrots: With this type of root crop, the bulb will start to go woody and harder and send out a long stem on which flowers and seed will develop. This will take about 9 months. Wasps and flies carry pollen from one "umbel" to another or from one plant to another. Other crops in the **Umbelifferae** family (umbrella shaped flowers), behave in a similar way. Examples are celery, parsley, fennel and parsnips.

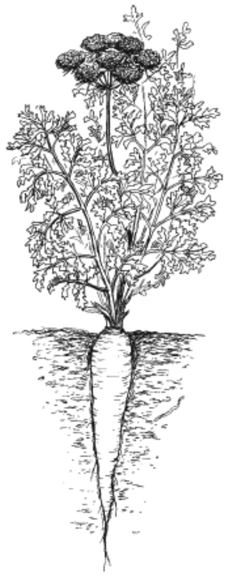


Figure 19.14: Carrot plant - flower and seed head

Figure 19.15: Onions

Root crops like onions: With this type of root crop, the flowering stalk develops in the second warm season, as the crop is biennial. This stalk is leafless, hard and hollow, and can grow very tall.

Other plants in this family (**Amaryllidaceae**) are leeks, shallots, garlic, spring onions, chives and garlic chives. These plants are pollinated mostly by bees. Pollination occurs between the little flowers on the same flower ball and between flowers from one plant to another. Seed from at least 20 plants needs to be kept to keep the variety strong. Seeds don't all ripen at the same time and they need to be harvested as they become ready, as they tend to shatter and are blown away by the wind.

Leave these seeds on the plant to dry. For those plants where the seed heads shatter and scatter seeds, you will need to collect them as they dry, rather than waiting until all the seeds are ready. Examples are lettuce, carrots, parsnips and onions.

19.5.2 Seeds in fruit

Fruit is produced only after the fertilisation of the ovules has taken place. These ovules develop to produce the seeds inside the fruit.

Fruit is picked when it is slightly over-ripe. Examples are tomatoes, chillies, capsicums (green peppers), gooseberries and brinjals.

Tomatoes and capsicums are self pollinating. The other plants in the Solanaceae family like chillies and brinjals are cross pollinating. If you are growing more than one variety of chilli, they need to be isolated from each other. Otherwise you may get some HOT surprises!

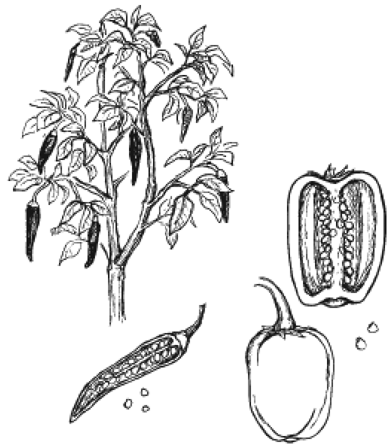


Figure 19.16: Capsicum – Chilli fruit & seeds.

Pumpkins, melons, gourds and squashes are picked when over-ripe and then left for a few more weeks for the seed to mature further. There are many different kinds of pumpkin and melons. All different kinds of pumpkins will cross with each other, but they will not cross with melons, cucumbers or marrows which are all in the same family (Cucurbitaceae). In this family there is crossing in each species, but not between them. A cucumber for example will not cross with a pumpkin.

The best (and usually the only0 way to save pumpkins seeds at a home level is to hand pollinate the fruit.

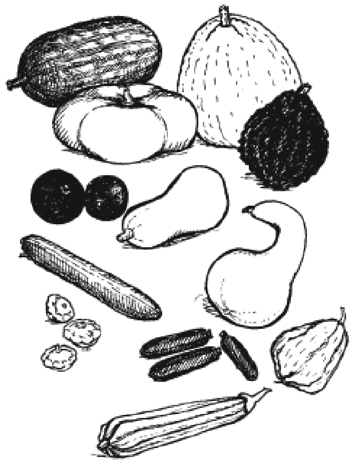


Figure 19.17: Pumpkins variety

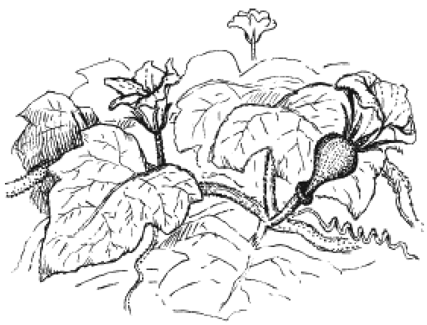


Figure 19.18: Male and female flowers on a vine

In this family, plants have both male and female flowers. The male flowers grow on long thin stems and open before the female flowers, which grow on a short stem and have a small swelling at the base.

Cucumbers and marrows are left on the plants until they are fully mature; cucumbers will go brown and marrows will go yellow (and VERY big!).

19.5.2.1 Seeds that are eaten

Examples here are maize, beans, peas and sunflowers. These are left on the plants until they are mature and dry.

How to know when your seed is ready?

- The fruit has a **hollow sound** and/or is **disconnected** from the branch. *Examples:* pumpkins, cucumbers. For these fruits it also helps to leave the seed inside the fruit for several weeks after picking.

- **Colour, size and shape** of fruit. *Examples:* tomato and chillis (red), aubergines (purple or yellow). Green peppers need to be left until they go red. They are immature when green!!!
- **Shattering** of pods. *Examples:* beans, peas, cowpeas.
- **Dryness**. *Examples:* carrots, coriander, lettuce, swiss chard, cabbage (seed head goes brown and dry)

19.6 Cleaning seed

19.6.1 Winnowing

Chaff and stems need to be removed from seed, as they can hide insects that can attack your stored seeds.

- Seeds and chaff are tossed into the air and the chaff is wafted away with a gentle breeze. Elongated flat baskets work well.
- Or put the seeds in a bowl and shake them until the debris floats to the top. Gently blow the chaff away.
- Large quantities of podded seeds (peas, beans) can be placed in a sack and the seeds separated by stomping on the sack or beating it with a stick. The dried empty pods can then be winnowed out.

19.6.2 Wet cleaning

This is used for plants that **carry their seeds in moist flesh or fruit** such as tomatoes, melons, pumpkin and cucumbers.

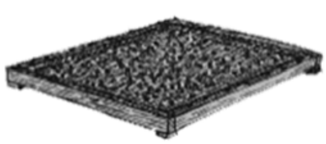
- Scoop the seeds out into a large container of water and rub vigorously. Pour off the water and place seeds on a flat surface to dry.
- Ferment the seeds of tomatoes and cucumbers. These seeds are encased in the flesh of the fruit and have a slippery jelly around them. This jelly needs to be removed before the seed will germinate. It also rids the seeds of unwanted seed-borne diseases.

Method:

Place the seed in a container. Cover with water. Add one to two table spoons of sugar and stir until it is dissolved.
Now leave this mixture for 3-5 days (NOT LONGER!!!). A foam or crust will form showing that the fermentation has occurred and the jelly has dissolved.

Rinse the seeds with large amounts of water.

Spread them out to dry in a cool place and store in an airtight container like a glass jar.



19.7 Drying seed

Large seeds need longer to dry than smaller seeds. A simple test for large seeds (such as beans) is to try to bite one of the seeds. If no impression is made on the seed (tooth marks) it is ready.

- You need to dry seeds away from the sun in a dry and breezy, airy place.
- In wet or cold weather, place seed on screens for fly netting and place them high up on racks in a warm room, such as the kitchen.
- Hang up small quantities in paper bags in a breezy spot.
- Lay larger quantities on screens or hang them up in hessian sacks. Do not use plastic bags.

Most seed can be stored for a period of 3-5 years and remain viable. **Viability** is the ability of the seed to germinate. Your seed may look perfect, but if it is not viable, it will not grow!

19.8 Storing seed

If you store your seed in hot, light (sunny) and wet conditions they will lose their viability very quickly. You may even not be able to plant them in the following season. They like cool, dark and dry conditions to germinate.

The length of time that seed can be stored depends on:

- The seed type;
- The quality of the seed; and
- The storage conditions.

19.8.1 Storage conditions

- **Darkness**

Find a way to keep the seeds in darkness. Use paper bags, dark coloured plastic and galls jars and place them in cupboards. DO NOT place the seeds on a shelf in clear glass jars.

- **Moisture**

Even if the seeds are dry, if you store them in a damp environment they will absorb that moisture/water. This seriously affects how long your seeds will be viable. Mostly we can only dry our seeds in the air. Do not dry them in the sun, but in a shady place where the air can move (ventilated). When the weather is very wet with a lot of rain and mist, it will be difficult to dry seeds, especially the larger ones, like beans and peas.

The life of seed doubles when the moisture content is lowered by 1%.

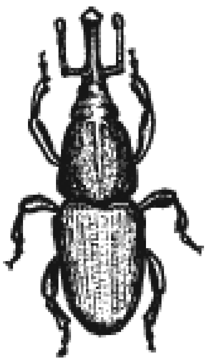
- **Temperature**

Seeds last longer in cold, but not freezing conditions. Choose a cold place such as near a river, under trees, under the ground or inside a clay jar.

The life of a seed doubles when the storage temperature is lowered by 5°C.

19.9 Pests

Storage weevils, fungi and bacteria shorten the life of seeds.



- Weevils begin to multiply when the moisture content gets high enough (10% or more). The eggs are laid inside the seed, under the seed coat, and the insects hatch from there.

- Storage fungi/ moulds begin to grow when the moisture content is high enough (around 13% or more) and bacteria start growing around (20% moisture). Mostly we cannot measure the moisture content of our seed. All we can do is keep our seed as dry as possible.

Store your seeds in dry, clean, airtight glass jars or other airtight containers. AND LABEL THEM - Give them names!! By next year you will not remember what it was.

Materials that stop the growth of pests can be used:

- **Dry ash:** this absorbs moisture inside the container and also prevents the growth and increase of weevils. Add ½ kilogram ash to 1 kilogram seed.
- **Lime:** can be used in the same way as dry ash. Mix 15 teaspoons (50 grams) with every kilogram of seed.
- **Cooking oil**: mix cooking oil with your seeds to prevent increase of weevils. Use only 1 teaspoon of oil for every kilogram of seeds.
- **Dried and powdered leaves of different aromatic plants**: weevils are sensitive to aromatic or strong smelling plants. Try the following:
  - CHILLI: mix 4-6 teaspoons of chilli powder with 1 kilogram of seed.
  - WORMWOOD (MHLONYANE): Dry and crush the leaves and mix with seed. Use 4-6 teaspoons for every kilogram of seed.
  - ALOE: As above.

AWARD is a non-profit organisation specialising in participatory, research-based project implementation. Their work addresses issues of sustainability, inequity and poverty by building natural-resource management competence and supporting sustainable livelihoods. One of their current projects, supported by USAID, focuses on the Olifants River and the way in which people living in South Africa and Mozambique depend on the Olifants and its contributing waterways. It aims to improve water security and resource management in support of the healthy ecosystems to sustain livelihoods and resilient economic development in the catchment.

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About USAID: RESILIM-O

USAID: RESILIM-O focuses on the Olifants River Basin and the way in which people living in South Africa and Mozambique depend on the Olifants and its contributing waterways. It aims to improve water security and resource management in support of the healthy ecosystems that support livelihoods and resilient economic development in the catchment. The 5-year programme, involving the South African and Mozambican portions of the Olifants catchment, is being implemented by the Association for Water and Rural Development (AWARD) and is funded by USAID Southern Africa.

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