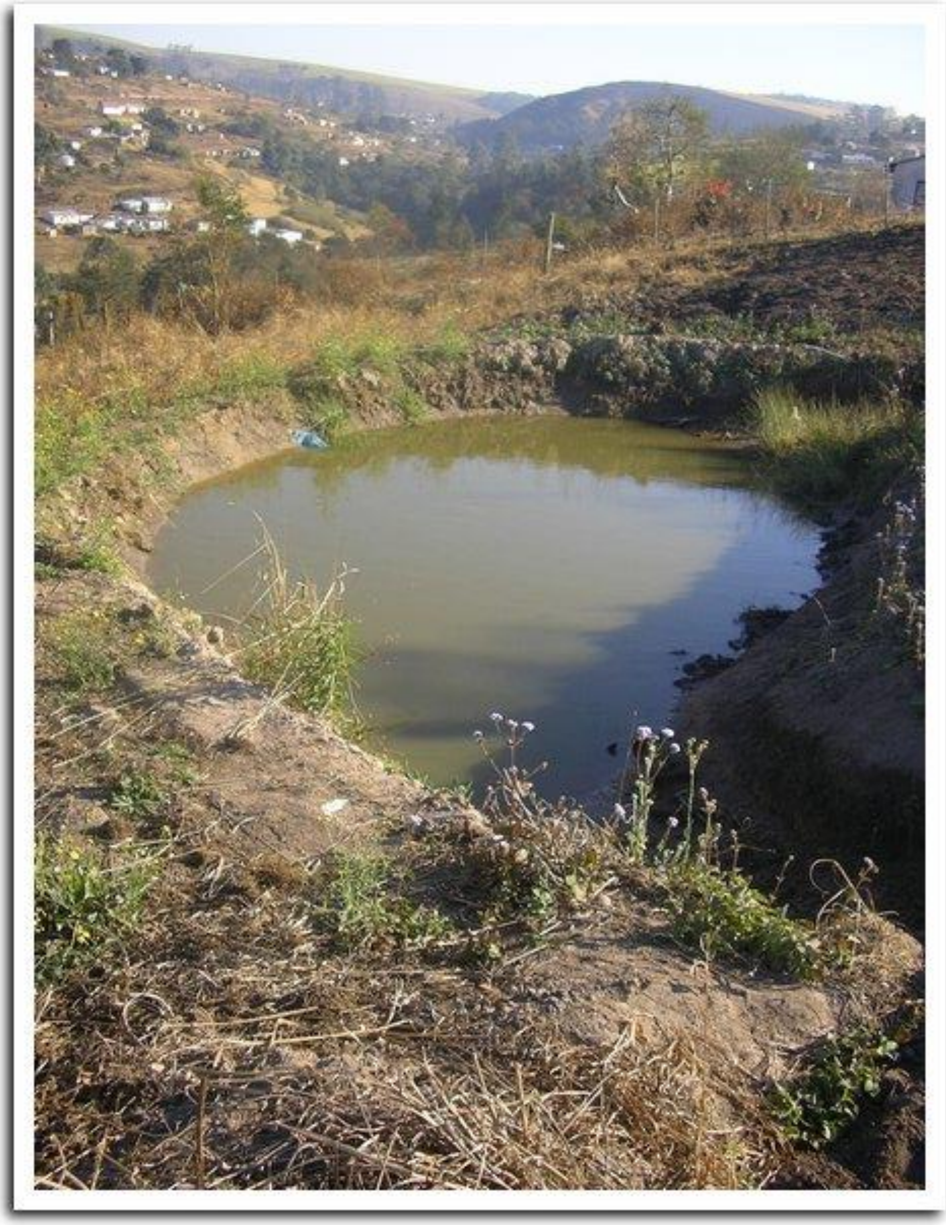
Water and soil conservation practices for smallholder farmers. Session 2 ToT Masilimeni Programme. July 2016

Lima RDF and Mahlathini Development Foundation



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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. Many farms have become unproductive, and those which are marginally productive cannot survive recurring drought. As a result, many farmers have abandoned their farms, while others have been forced into subsistence farming.[1]

Figure 1.1 A view from the top of the Maseko farm

vishavane 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 loca-ted 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.

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.[2] 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.

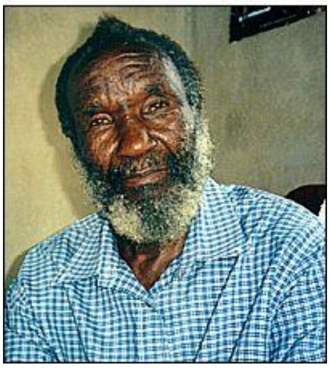
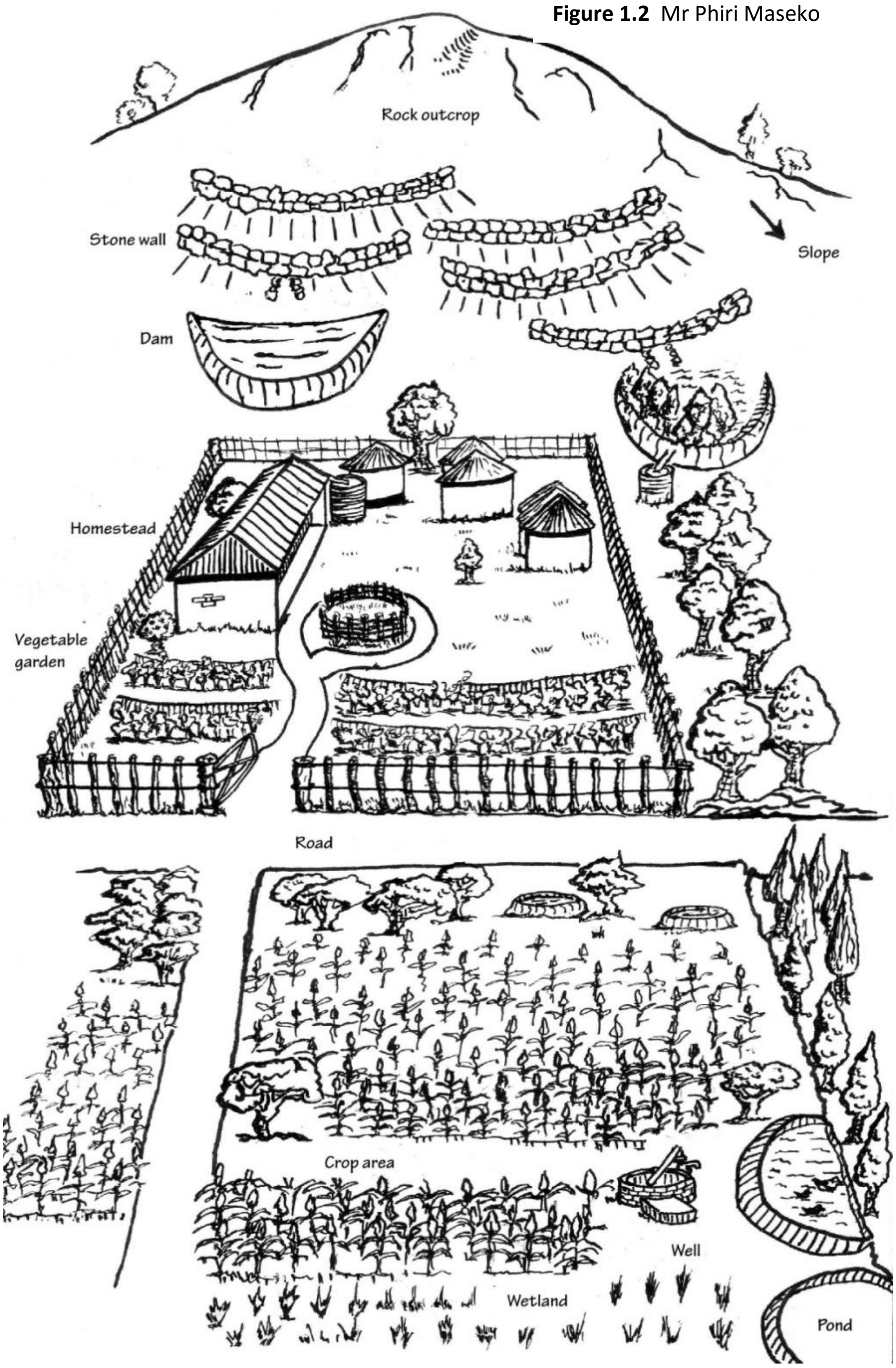


Figure 1.2 Mr Phiri Maseko

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.



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.

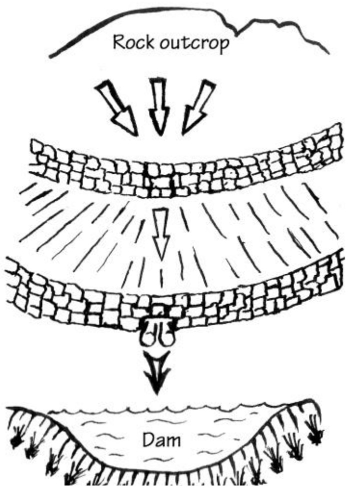


Figure 1.4 Rainwater is directed

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*.

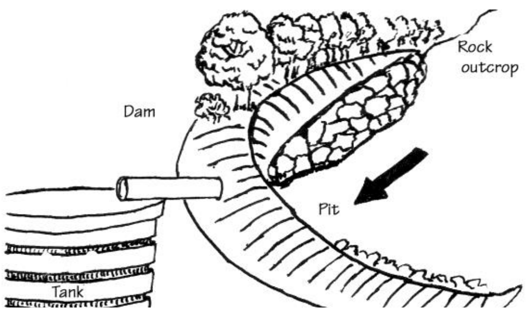


Figure 1.5 Water overflow is directed into a storage tank

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.[4] *Phiri also built three wells in the cropping area. One of these is carefully protected so that the water can be used for drinking. The other two are used for irrigation and for washing clothes. A network of pipes and canals has also been constructed so that crops can be watered during times of drought.*

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

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

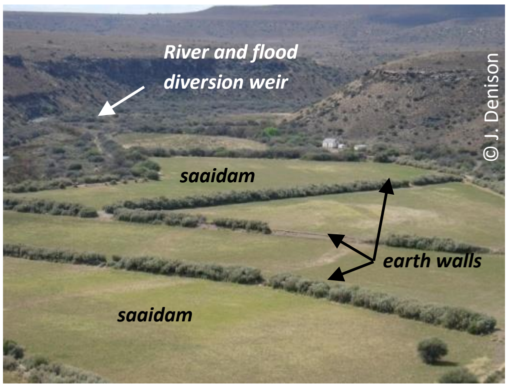
Through observation, inspiration, innovation and dedication, Phiri Maseko changed the landscape not only of his farm, but also of his life. In 1986 he founded the Zvishavane Water Project, a Non-Government Organisation (NGO) which was established to educate people about water harvesting and conservation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

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

Dirk van der Merwe

In the arid western part of South Africa, small livestock farming is practised and supported by a water harvesting system called a 'saaidam'. 'Saaidam' is an Afrikaans word literally meaning 'planting dam' and is the name of a flood-water harvesting system that is also found in North Africa, the Middle-East and Pakistan. Dirk van der Merwe Jnr. and his family live on Diepdrif Farm in the Northern Cape near the town of Calvinia and his family have practiced this method since the 1920's. Dirk Jnr. is a qualified veterinary surgeon and follows in the farming footsteps of his father (Dirk van der Merwe Snr.) who bred many South African Champion Merinos at Diepdrif Farm over the years.

Their farming business revolves mainly around lucerne production and sheep. The sheep graze on the lucerne fields (which are dependant on the saaidam water harvesting method) and also on the dry surrounding Karoo-veld pastures. The area receives only about 170mm of rainfall per year, and as a result the veld-grazing is very sparse – so sparse that each sheep needs approximately 40 hectares to sustain them (40 hectaries is roughly the same size as 50 soccer fields – to graze just one sheep!). The lucerne production, which is watered using the saaidam water-harvesting system, is a critical part of the profitable lucerne and sheep farm business there.



The saaidam itself is a large flat field which is surrounded on all sides by a low earth wall, similar to a small dam-wall. But the wall is low, only about 1m to 1.5m high. Once a year, or once every two years, a flood comes rushing down the dry river-bed from the mountains about 120km away. This floodwater is diverted into the saaidamme over a few days of extremely busy activity by everyone on the farm, through a system of large channels and water-gates. The water is held knee-deep in the saaidams for 2 to 3 days and soaks deeply into the soil and then excess water is released. The soils in the area are very deep, even up to 10m deep in places, and because lucerne has a very deep tap root it can draw up the moisture, as the soil slowly dries out.

The van der Merwe's farm has 600 ha under lucerne in the saaidams and they farm more than 2500 sheep as well as cattle. This example shows that water-harvesting has an important place on different kinds of farms, some small and others large, some producing fresh produce, others animal fodder and meat.

1.1 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.”[7]

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.

1.2 Defining Water Harvesting and Conservation

The term rainwater harvesting refers to collecting, conveying and storing rainwater for various end uses.[8] 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.”[9]

“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.”[10]

“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.”[11]

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.

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

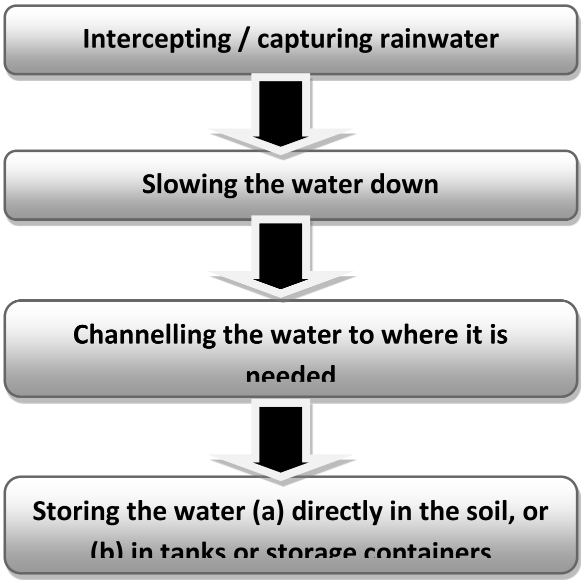
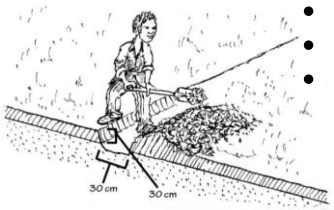


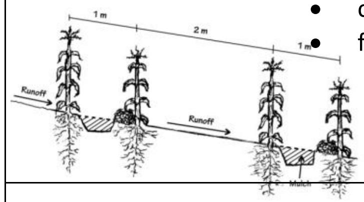
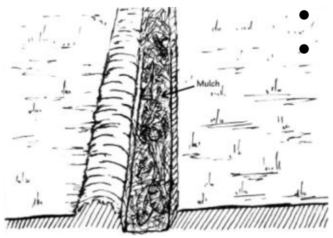
Figure 1.8 The water harvesting and conservation process

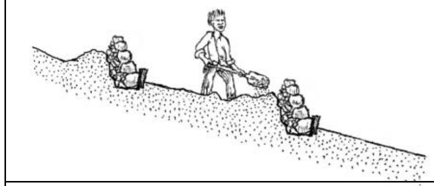
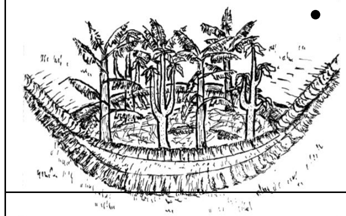
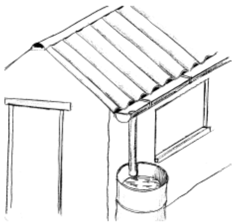
1.3 Overview of WHC Methods

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

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

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

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

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

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.
domewater 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.[4] 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.[5] 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.

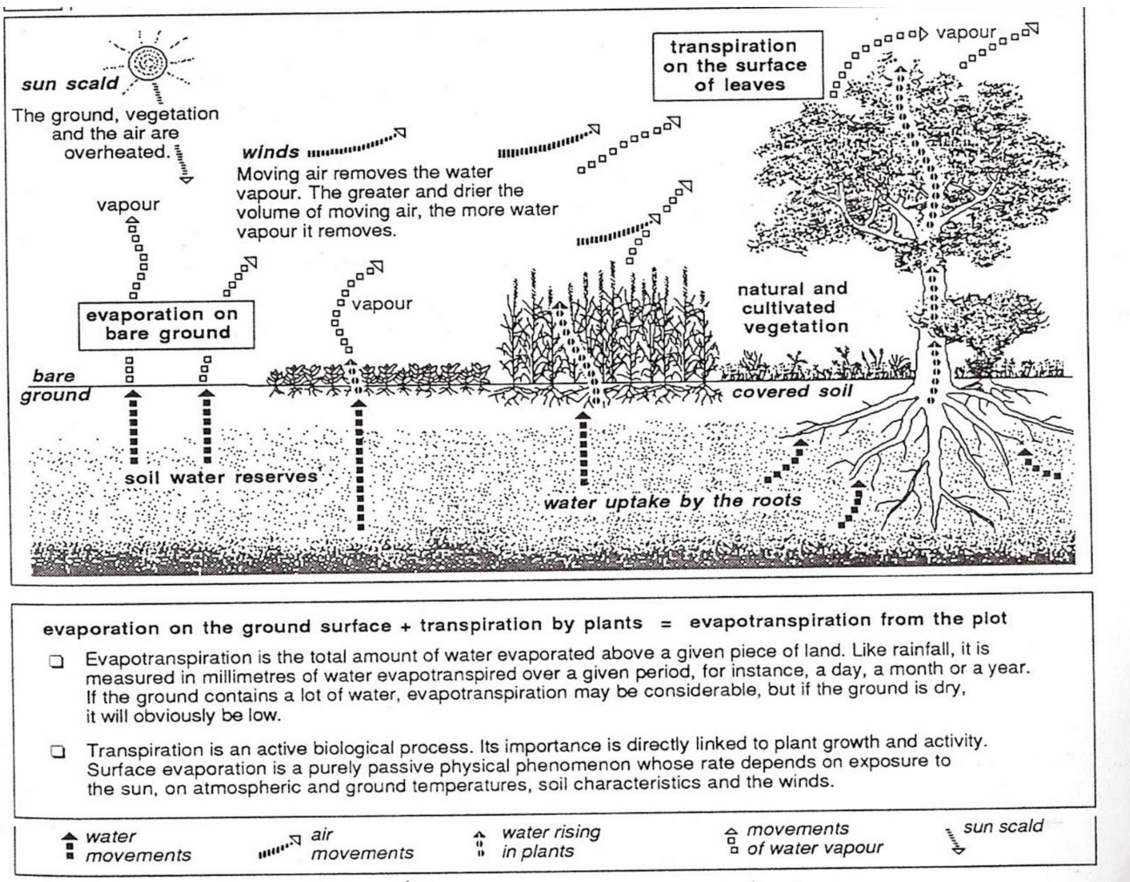
Further rainfall runs off into puddles, streams, rivers, lakes and finally into the ocean. Ultimately all water will end up back in the ocean to start the whole process again. No new water therefore enters the cycle and no water ever leaves the cycle

(QUESTION: So if it is getting drier – where is the water going?)

Evapo -transpiration

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.



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

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***.

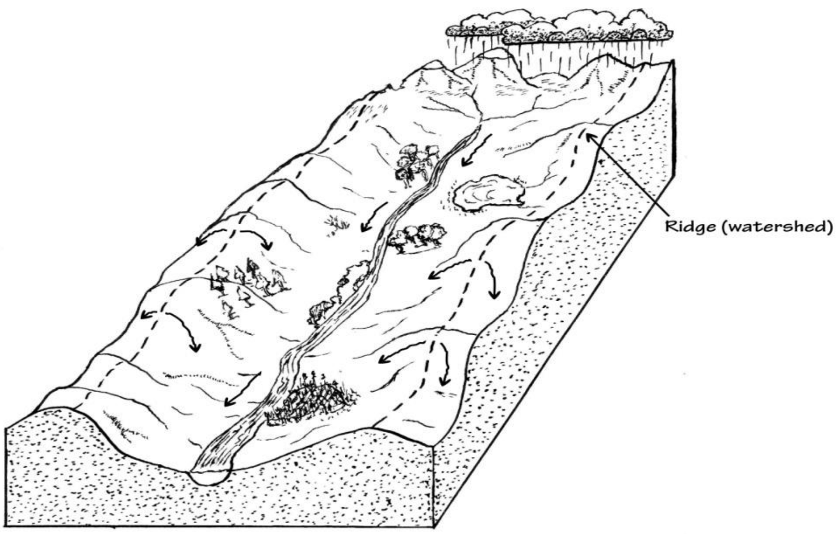


Figure A water catchment

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

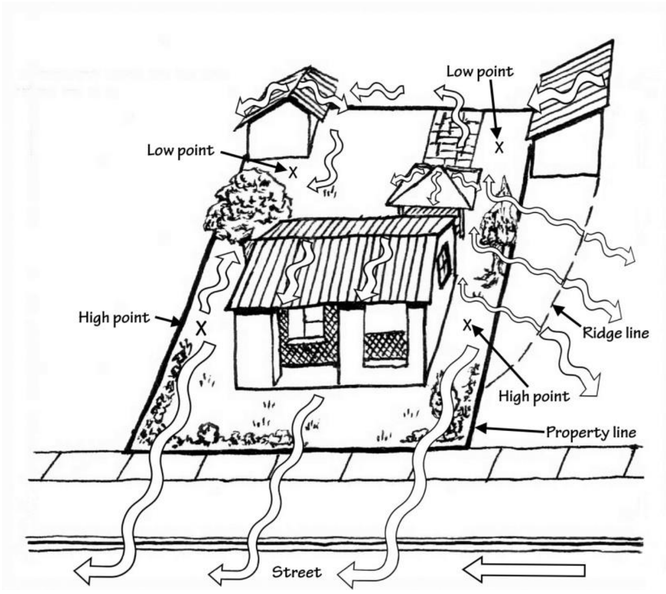


Figure An urban water catchment

2.3 Topography – Aspect and slope

Aspect

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

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

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

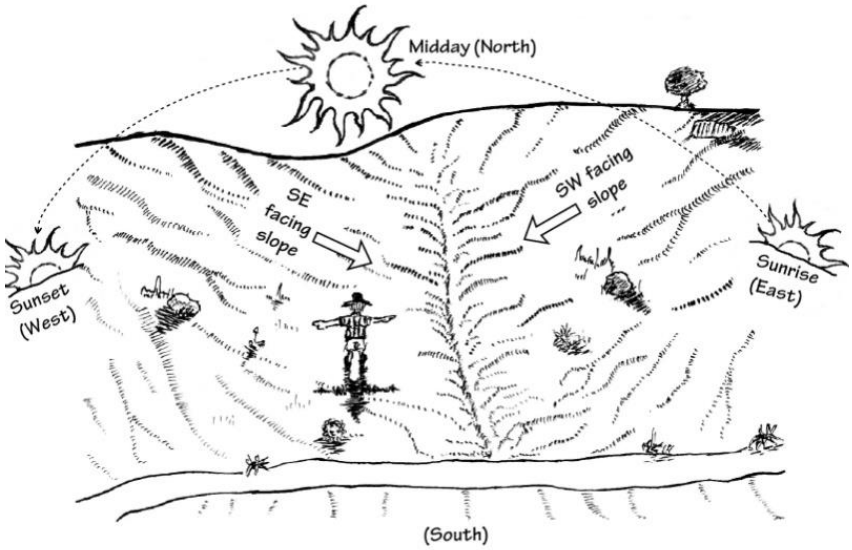


Figure 6.1 How to determine aspect (Method 1)

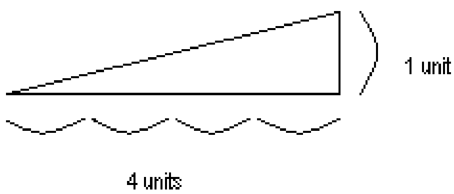
Slope

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

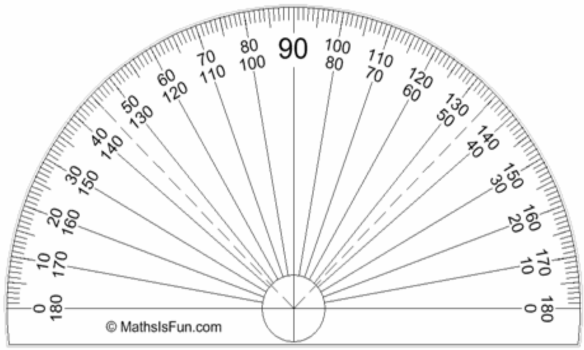
Slope also needs to be taken into account when planning and implementing most WHC methods, mainly to ensure that soil erosion does not occur.

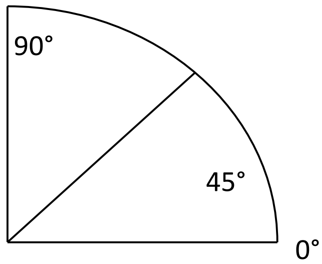
Slope can be expressed in the following three ways:

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



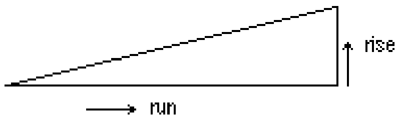
Degrees – this is a measurement used to represent the angle of a slope. Degrees can be measured with a protractor or with survey instruments. Land that is completely flat (horizontal) is 0°, while a vertical cliff is 90°.





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

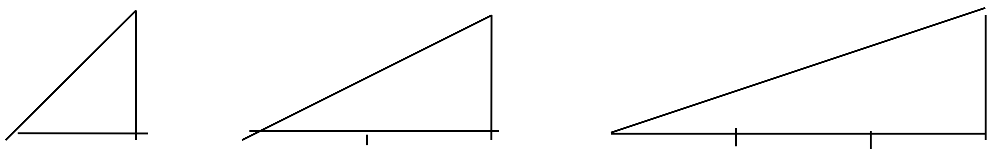
$$\text{Slope (\%)} = \frac{\text{rise}}{\;} \times 100$$



<u>Example</u>: 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:

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

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

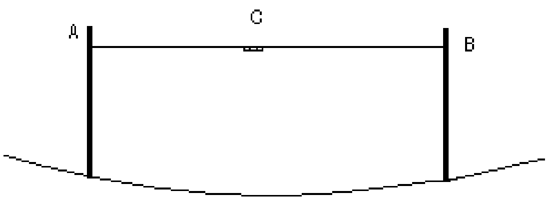


1:1 = 45° = 100%　　1:2 = 26° = 50%　　1:3 = 18° = 33.3%

<u>Marking out contour lines on a slope using a line level</u>

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

(Not to scale)



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

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

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

Measuring slope using a line level

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

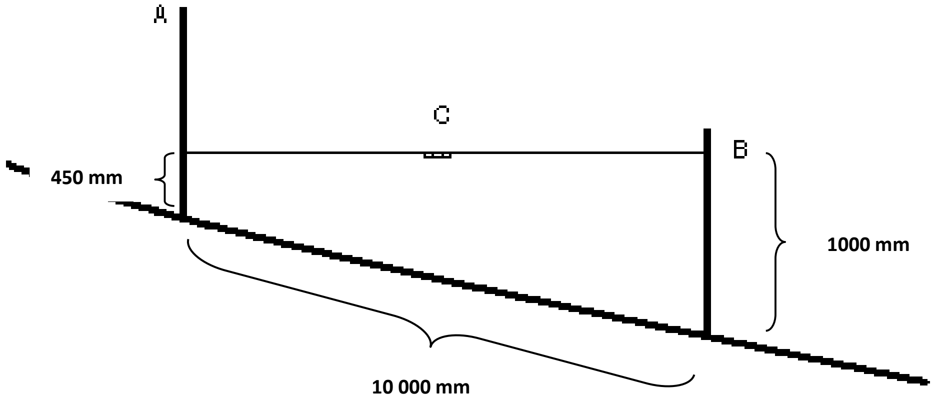


Figure 6.2 Using a line level to measure slope

Figure 6.3 A level reading on a line level

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

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

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

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

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

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

$$= 5.5\ \%$$

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

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

Degrees	Percentage	Recommended distances between contour lines in metres (m)
1	1.7	57.3
2	3.5	28.7
3	5.3	19.1
4	7.0	14.3
5	8.8	11.5
6	10.5	9.6
7	12.3	8.2
8	14	7.2
9	16	6.4
10	17.6	5.8
11	19.4	5.2
12	21.3	4.8
13	23.1	4.5
14	25.0	4.1
15	27.0	4.0
16	28.7	3.6
17	30.6	3.4
18	32.5	3.2
19	34.4	3.1
20	36.4	3.0
21	38.4	2.8
22	40.4	2.7
23	42.5	2.6
24	44.5	2.5

25	46.6	2.4
26	48.8	2.3
27	51.0	2.2
28	53.2	2.1
29	55.4	2.1
≥30	≥57.7	2.0

2.4 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.

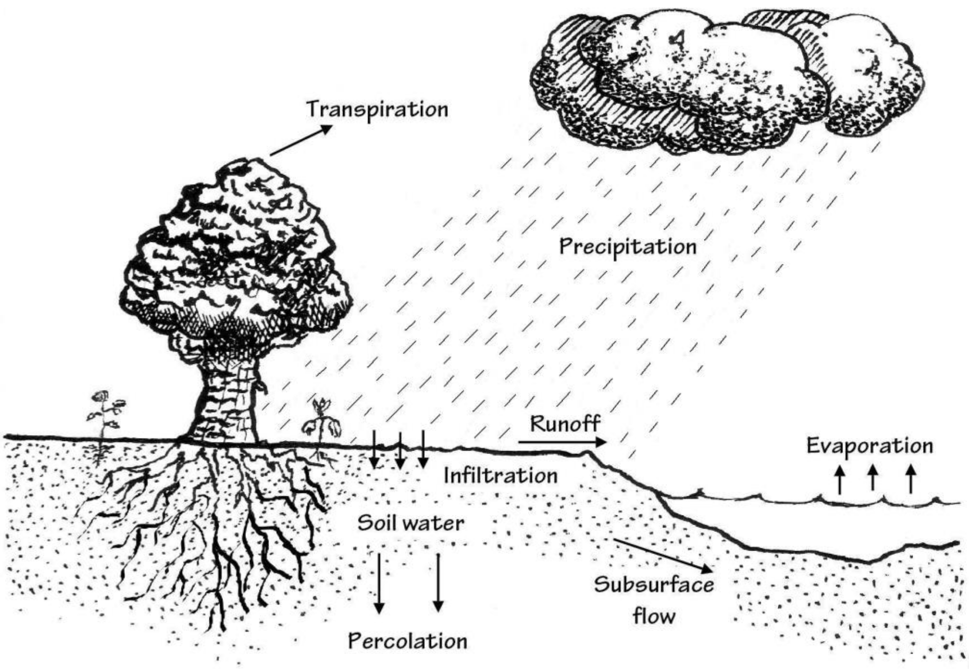


Figure 5.1 Water movement through the soil

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.[6] 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.

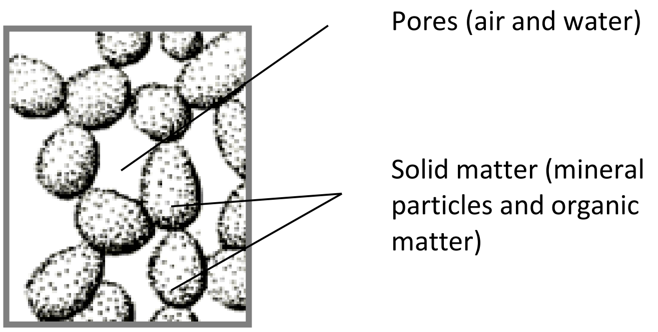


Figure 5.3 Soil composition

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

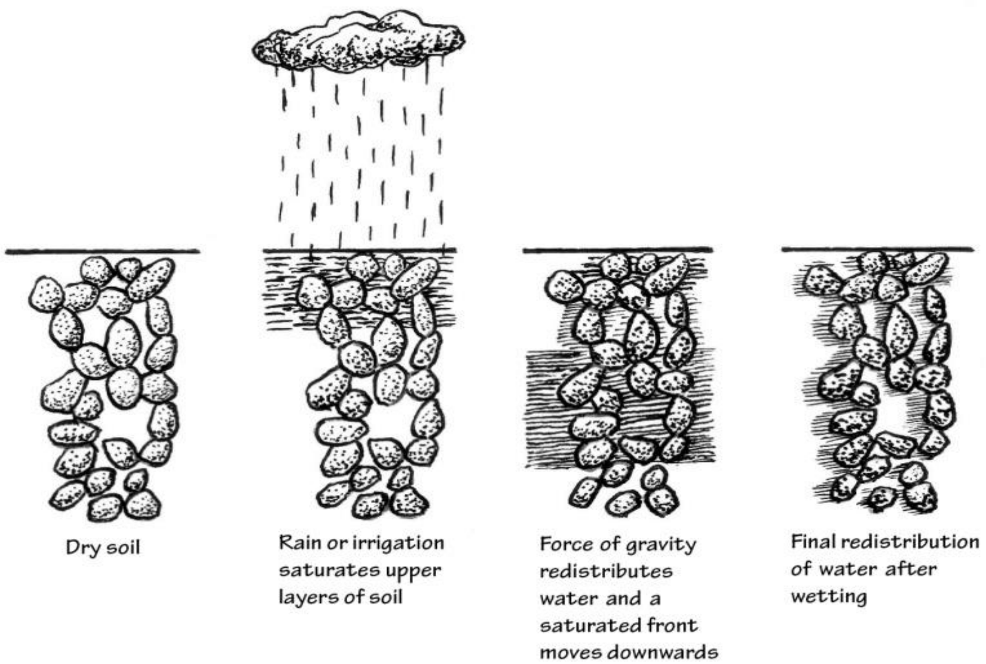


Figure 5.4 Water in the soil

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.

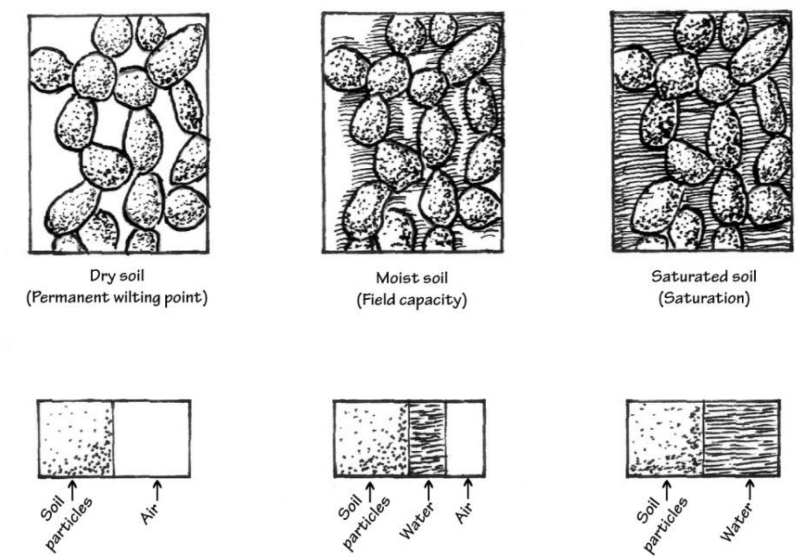
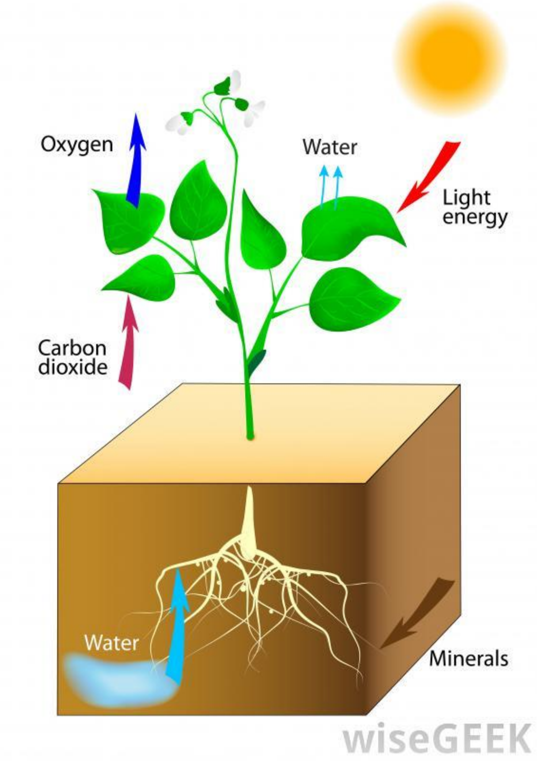


Figure 5.5 Amount of water and air in dry soil, moist soil and saturated soil

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.

See Healthy Soil chapter for Conservation Agriculture Manual

3. Set up a Detailed Farm or Garden Plan

Applying the elements of layout to the home garden

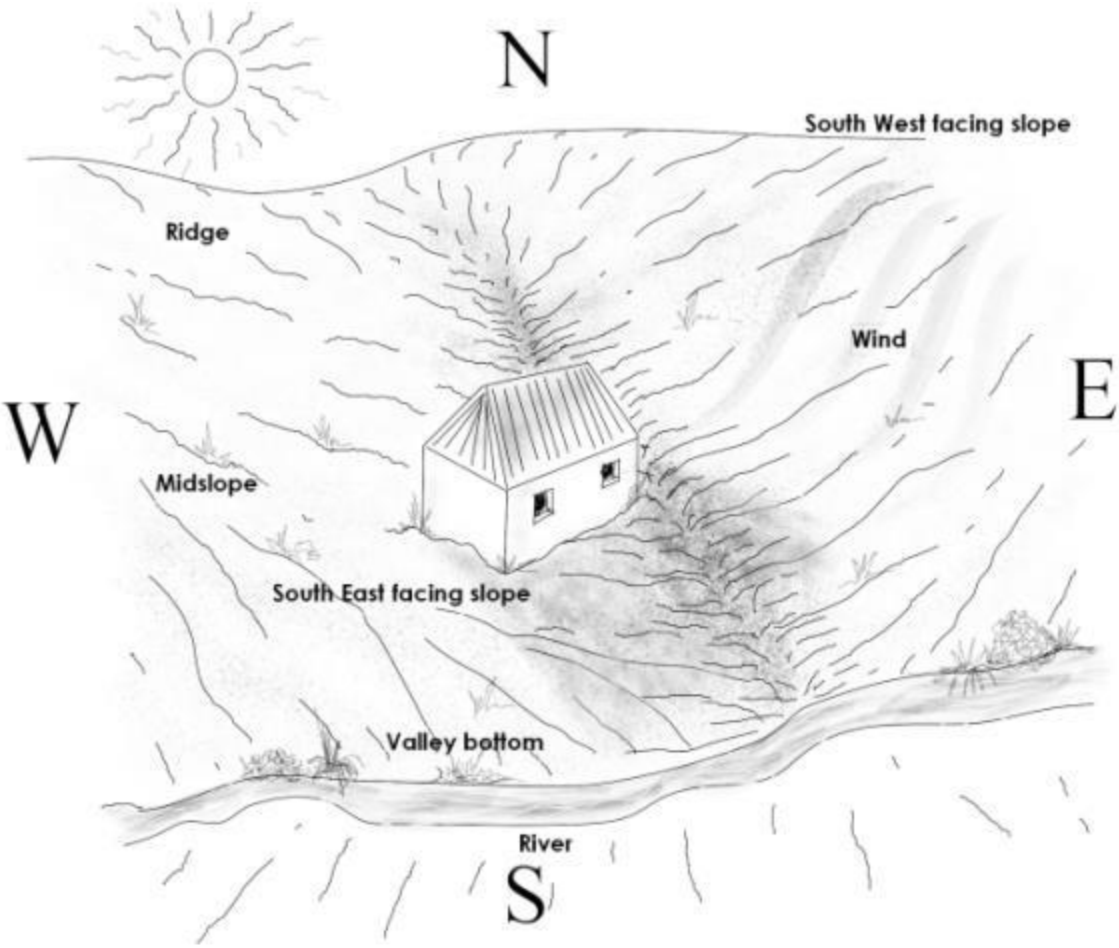
Stepwise process for garden layout planning

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 17: Step 1 – Considering the location of the homestead in the landscape



In Figure 17, 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

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

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.

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

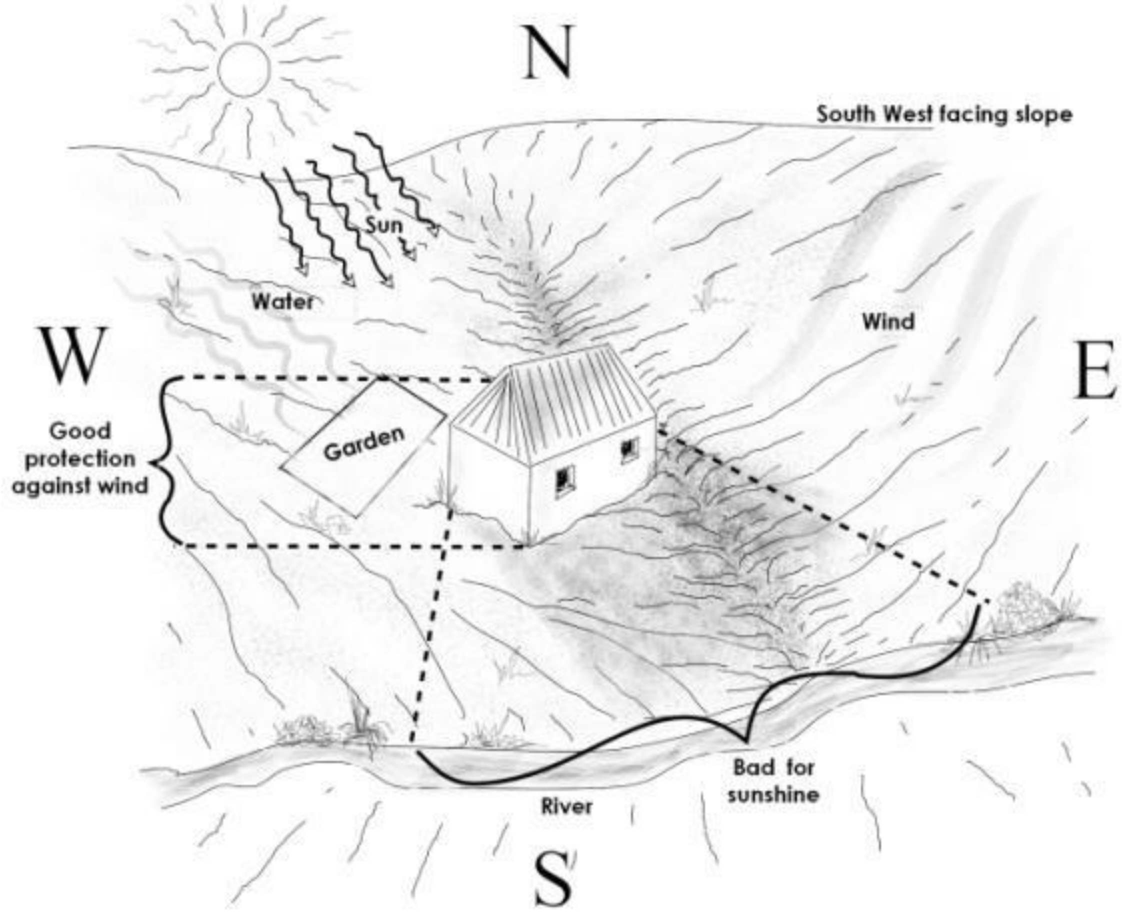
Choose an area to make your garden, then test your choice: is it the best place for you? No site is ever perfect, but the ideal would be: Fertile soil. Easy to get water to it. North side of the house or buildings. North-facing slope. Protected (or can be protected) against wind, and against animals. 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 18: 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!

3.1 Turning runoff into 'run-on'

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

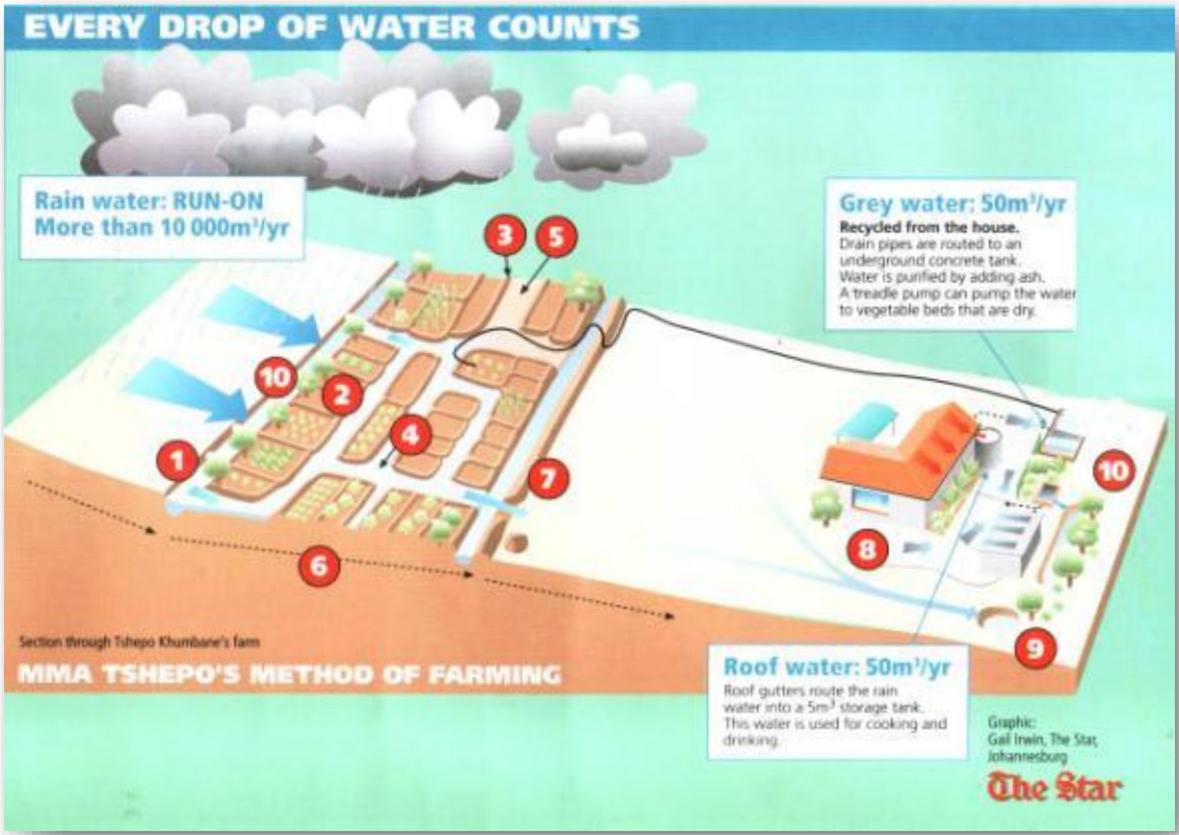
Compare this photo to the diagram overleaf.

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

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

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

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



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

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

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

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

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

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

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

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

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

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

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

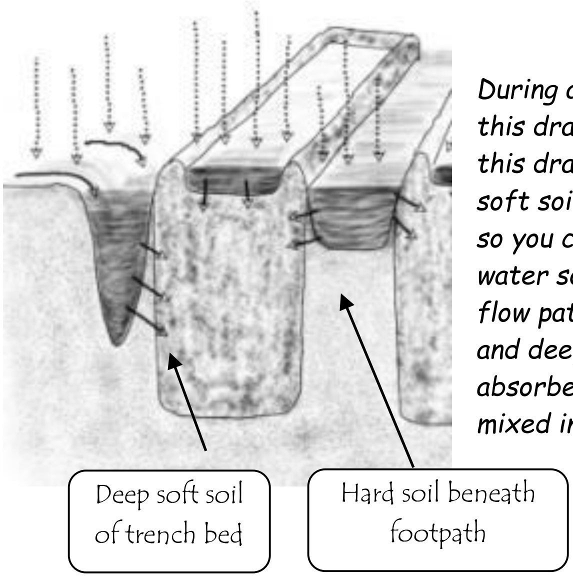
The challenge with run-on systems is to explain them in the simplest possible way, so that people will be encouraged to start experimenting with them. Further learning can then be built on their own experience.

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.

‘Baby’ steps – preparing deep-trenched beds to soak up the water:

In Chapter 2 – on “facilitation” you learned how deep trenching is introduced to enable gardeners to achieve early successes with gardening. In Chapter 6 – on “soil fertility management” you will learn in detail how to make a trench bed. You will also discover how deep trenching creates ideal soil conditions for plant growth. Here in Chapter 5 – on “water management” we will look at how deep trenching helps the soil inside your planting beds to absorb and hold more water. You will also learn how to lay out your garden so that water can pool around your deep trenched beds to maximise infiltration.

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.

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!!

‘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 runoff supply furrow brings water to the planted trench bed in MaTonisi’s new garden.
Photo: J Denison, Upper Nqumeya, Eastern Cape.

‘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!

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

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

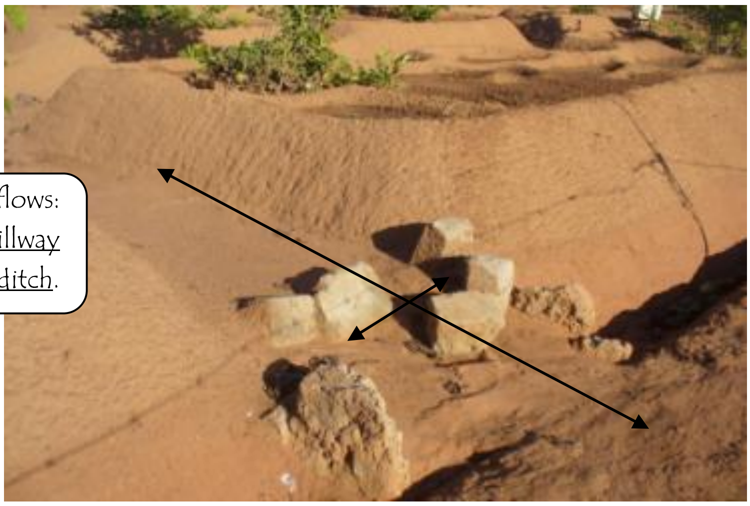
Therefore, before we discuss how to lay out the rainwater flowpaths inside the garden, we will first learn how to take control of how water flows into and out of the garden:

- ❖ 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!

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.



Escape routes for excess rainwater flows: (1) <u>escape spillway</u> and (2) the long <u>bottom ditch</u>.

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.

'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; and

-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:

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

1.1 Find the highest point along the garden perimeter.
1.2 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.
1.3 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.)

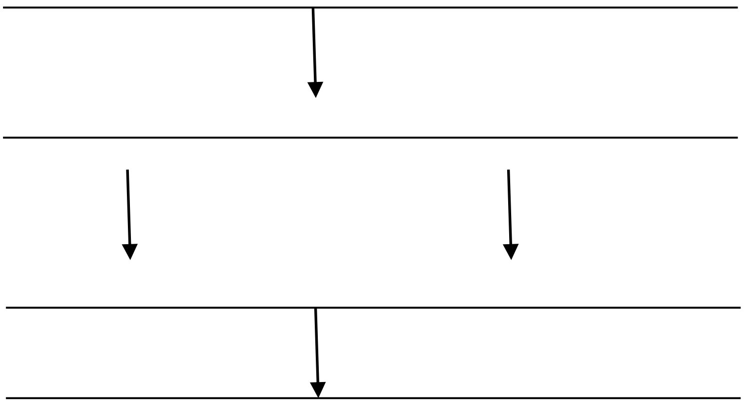
2. Mark out the top and bottom cut-off ditches and rainwater flowpaths in the garden

2.1 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).

2.2 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.

2.3 Now draw the position of the connecting pathways, staggering them to prevent long uninterrupted downhill pathways.

2.4 If you have already made your first trench bed earlier, incorporate it into your overall design. Your layout could look some thing like this:



3. Dig the top ditch

3.1 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.

3.2 Heap the topsoil all along the lower edge of the cut-off ditch, thereby creating a **sidewall** for the ditch.

3.3 If you have too much, place the excess topsoil all along the lower edges of the long flowpaths.

3.4 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.

3.5 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.

3.6 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.

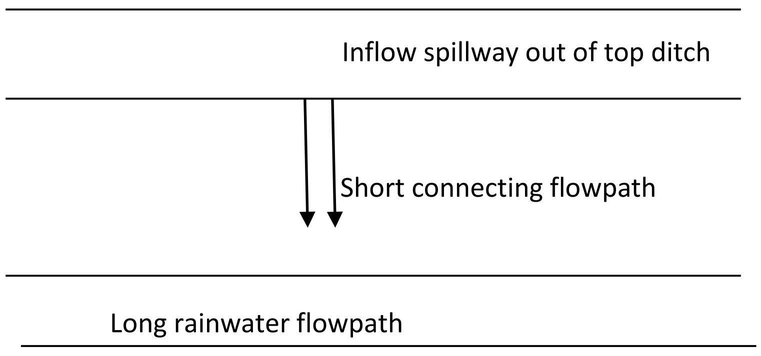
Remember that because you are just shaping the soil, you can always reshape it later once you have observed how your system responds during a rainstorm.

- *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.*

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

4.1 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.

4.2 Find the point where the **connecting flowpath** from the **inflow spillway** out of the top ditch joins the **first long flowpath**.



4.3 From this point, dig out the connecting flowpath, working back upslope towards the inflow spillway. Make sure the flowpath comes out level and even!

4.4 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.

4.5 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.

5. Dig the bottom ditch

5.1 Dig out the **bottom cut-off ditch** along the lower edge of your garden. Make sure that its bottom is level.
5.2 This is a deeper ditch, but not a pathway, because no-one will need to walk in it.
5.3 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.

6. Secure the escape spillway

6.1 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.
6.2 You can pack flat stones wherever you want to protect the soil against flushing out and eroding.
6.3 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.

'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!

3.2 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.

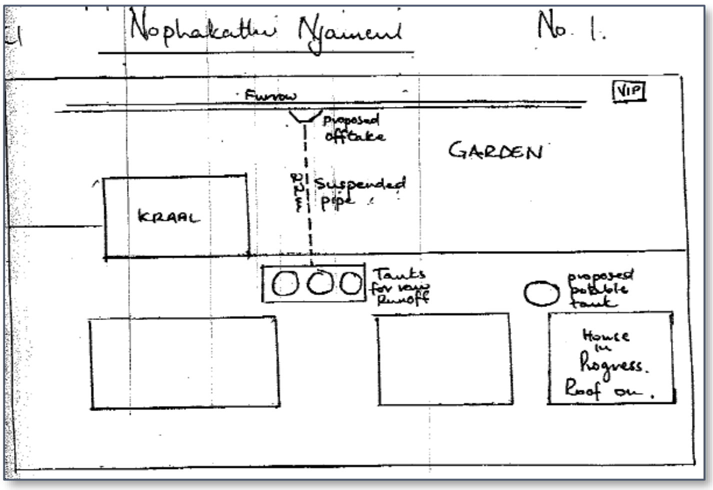
j) Mark out some contour lines in the garden for swales, trenches or tied-ridges, or mark out contour lines for cut-off furrows outside the garden if farmers want to try this.

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

4.1 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.



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 *<u>detailed</u> 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

1. Diversion Furrows

also called:	used in:	
• feeder channels • trenches • run-on ditches • ex-field RWH	gardens	✓
	fields	✓
	grazing land	

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 7.1 Diversion furrow leading to a catchpit

Figure 7.2 Diversion furrows leading to trench beds

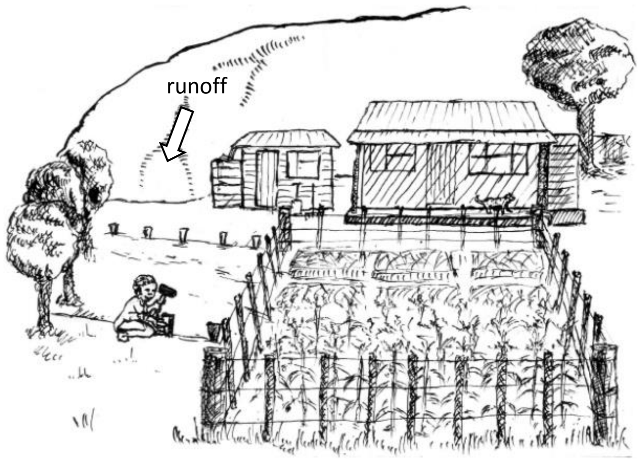
Figure 7.3 Diversion furrow leading to a trench bed

PLANNING

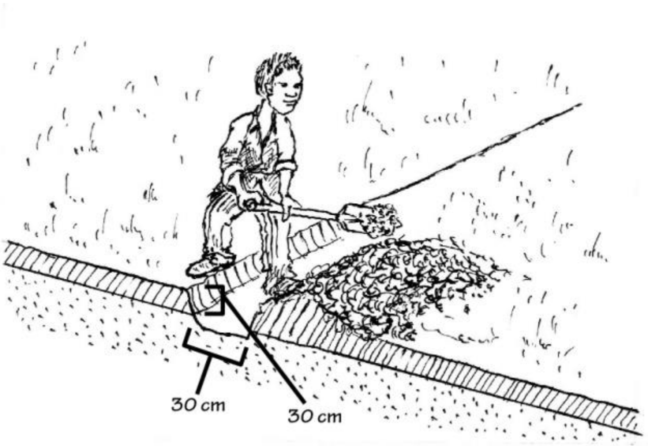
Soil	Slope	Rainfall	Tools & Equipment
Any soil. Where soils are easily erodible or hillside slopes are steep, the diversion furrow should slope gently downwards so as to avoid erosion.	Any slope. On steeper slopes, care must be taken to prevent erosion.	Any rainfall. In higher rainfall areas, measures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

METHOD

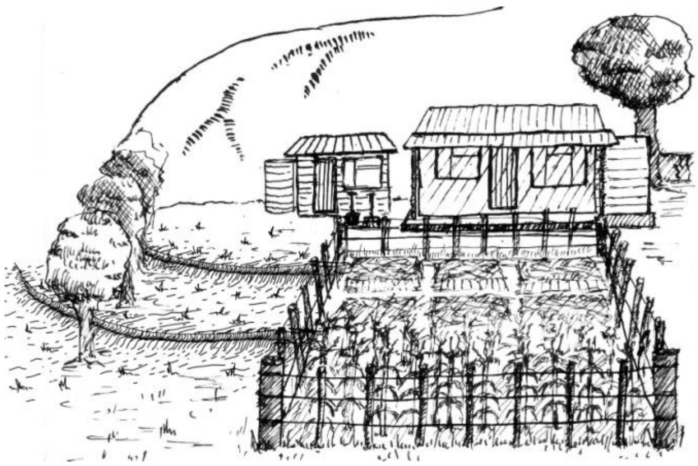
1. Look at the ground when it rains to see where the storm water runs, and decide which of this water you want to divert. Mark out a route for your furrow which will intercept this water and carry it to the garden, field or storage tank.



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



3. 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.



2. Stone Bunds

also called:	used in:	
• stone lines • stone banks • contour stone bunds	gardens	✓
	fields	✓
	grazing land	✓

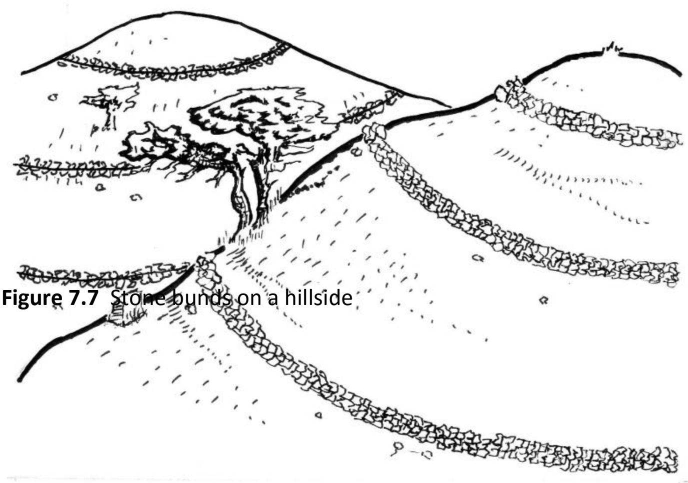


Figure 7.7 Stone bunds on a hillside

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 7.8 Natural terraces which have formed from an accumulation of sediment

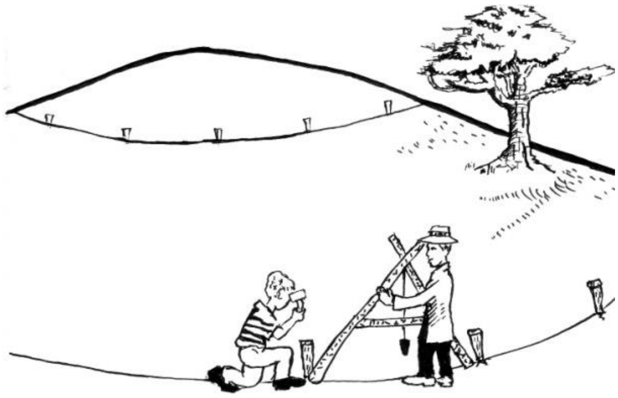
Figure 7.9 Stone bunds being maintained

PLANNING

Soil	Slope	Rainfall	Tools & Equipment
Any soil.	0.5 to 3%, preferably below 2%	200-750 mm (arid to semi-arid areas)[12]	stones of various sizes* wheelbarrow* spade A-frame or line level **essential*

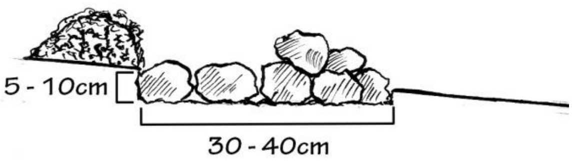
METHOD

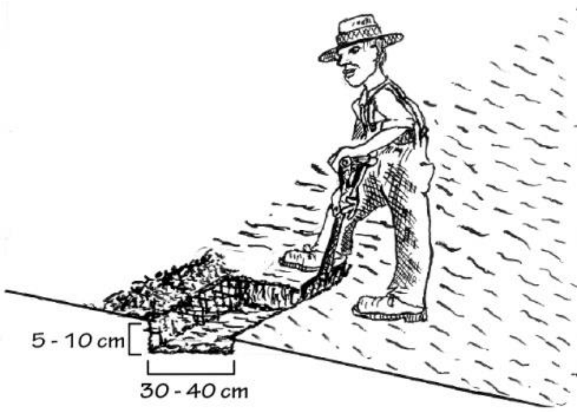
Slope	Spacing of bunds[13]
<1%	20 m
1-2%	15 m
2-5%	10 m



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

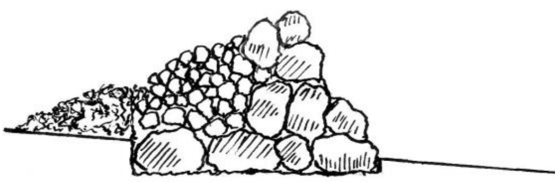
2. Mark out each contour line using an A-frame or line level. If necessary, make slight adjustments to the position of the pegs so that the lines form a smooth curve.





3. 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.

4. Place large stones along the base of the trench and on the down-slope side to create an "anchor line."[14]



5. 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.

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

3. Tied Ridges

also called:	used in:	
• in-field RWH • partitioned furrows[15] • cross-ridges • furrow dikes[16]	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 7.10 Mulch placed in furrows to minimise evaporation

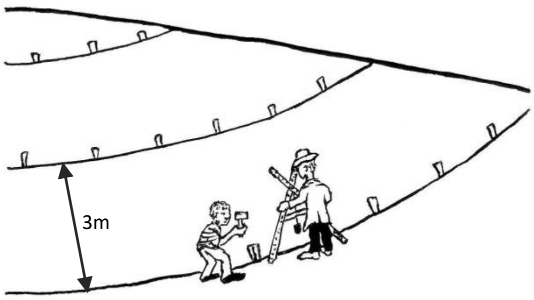
Figure 7.11 Water is captured in furrows

PLANNING

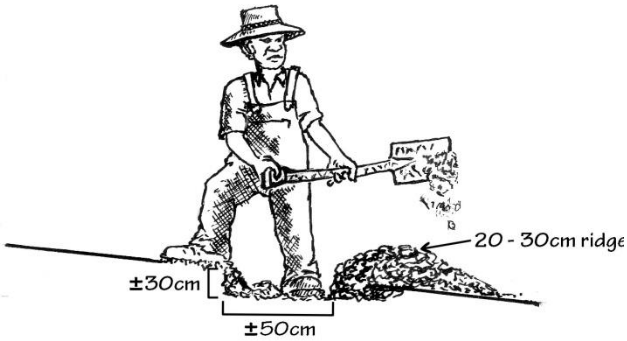
Soil	Slope	Rainfall	Tools & Equipment
Soil depth of 700mm -1000mm.[17] Soils should be relatively stable. The best soils are clay or soils with a relatively permeable topsoil over a less permeable subsoil.[18]	Can be up to 7% on non-erodible soils.[19]	Annual rainfall of 400–700 mm.[20]	spade* fork tape measure string, sticks mulch wheelbarrow A-frame or line level **essential*

METHOD

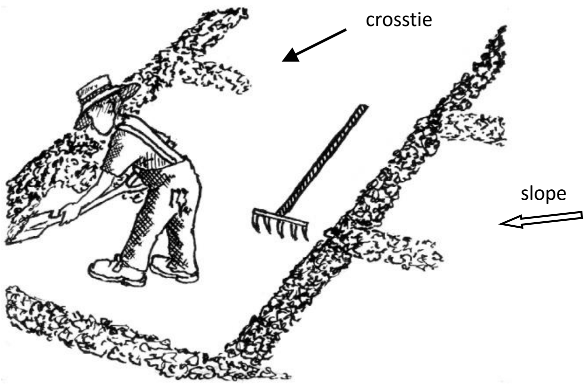
1. Select a site and clear the ground of rocks, bushes, grass and weeds.



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

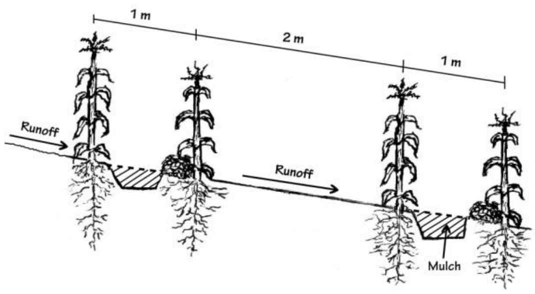


3. Dig out a shallow furrow (about 50 cm wide and 30 cm deep) along each contour and place the soil on the down-slope side of the furrow to create a ridge (about 20–30 cm high).



4. 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.

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



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

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 7.12 Swales prepared for planting

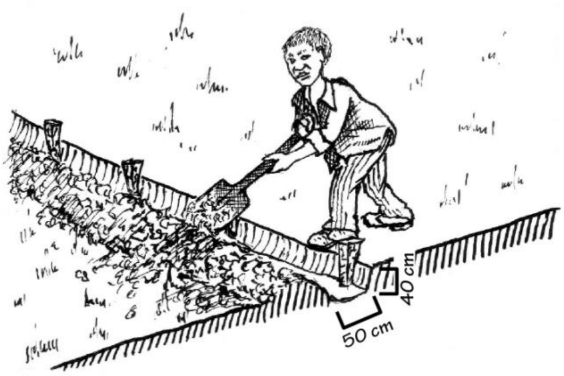
Figure 7.13 Vegetables growing on the swales

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*

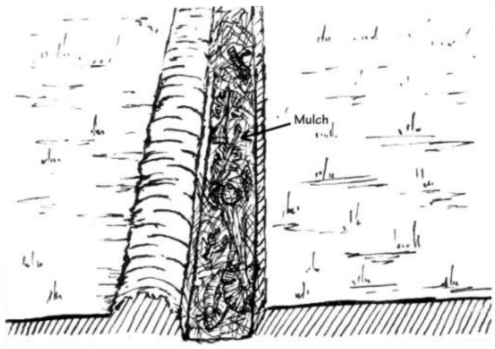
METHOD

1. 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).



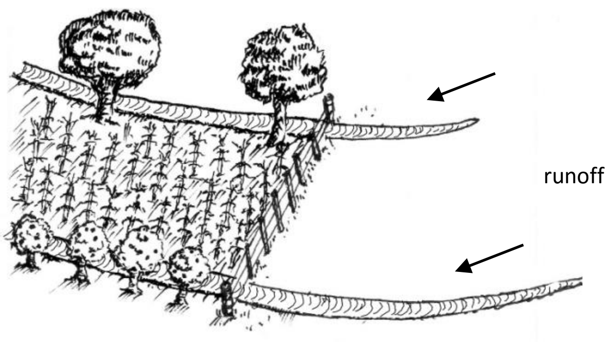
2. Dig a shallow furrow along each contour line (30 – 40 cm deep and 50 cm wide) and place the soil on the down-slope side of the furrow.

3. 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



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

5. 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.



5. Terraces

also called:	used in:	
• Benches[23]	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 7.14 a terrace built easily and cost-effectively using old tyres packed with soil.

Figure 7.15 A farmer standing at her stone terrace wall

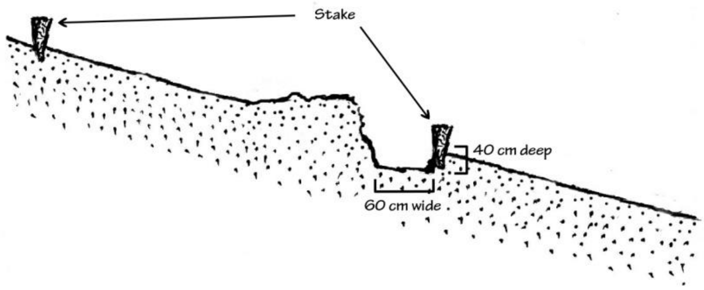
PLANNING

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

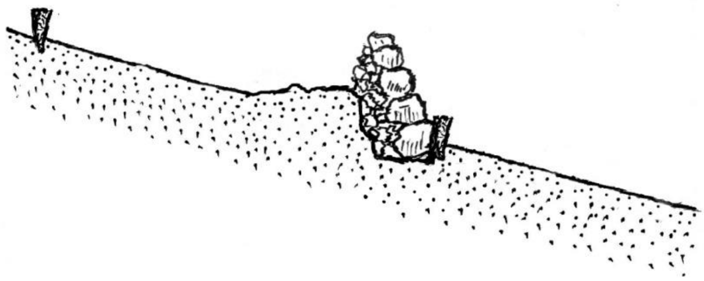
METHOD

1. 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.

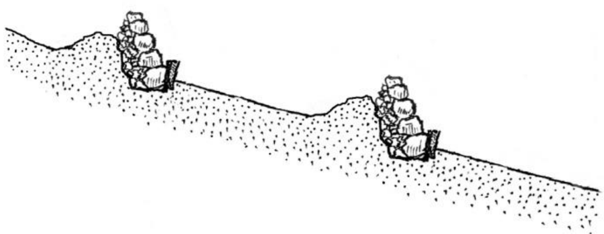
2. Dig a trench about 40cm deep and 60cm wide along the first contour line (see Table 1). Place the excavated soil upslope of the trench.



3. 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.



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



5. 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.

6. 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.

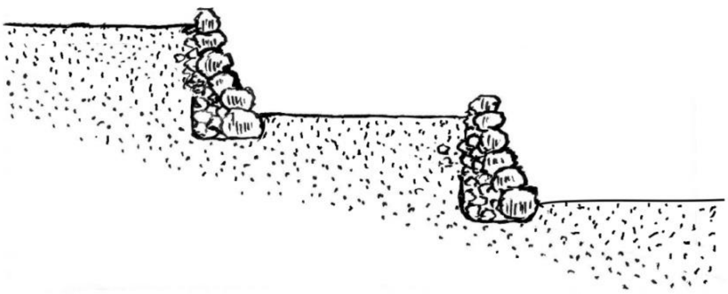
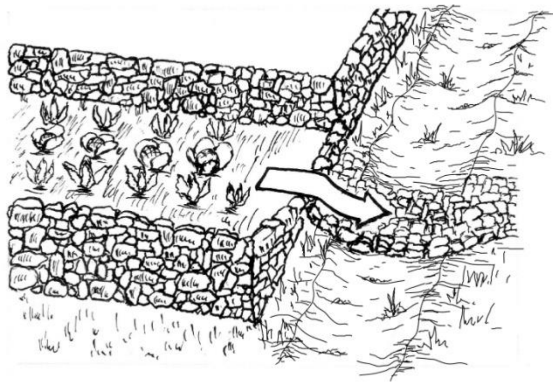


Table 1: Terrace spacing and dimensions

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.



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 7.16 Fertility pit filled with organic material

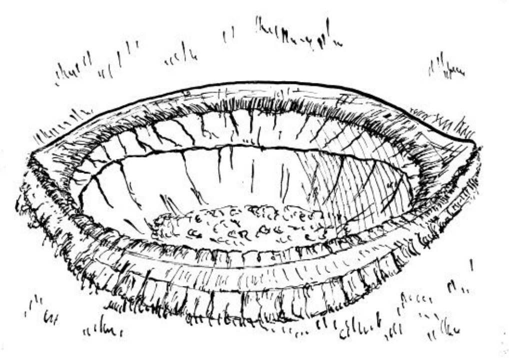
Figure 7.17 A fertility pit being prepared

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*

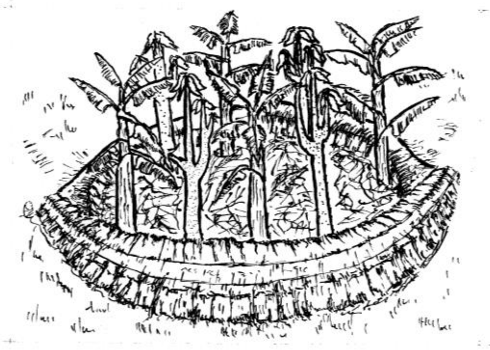
METHOD

1. 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.



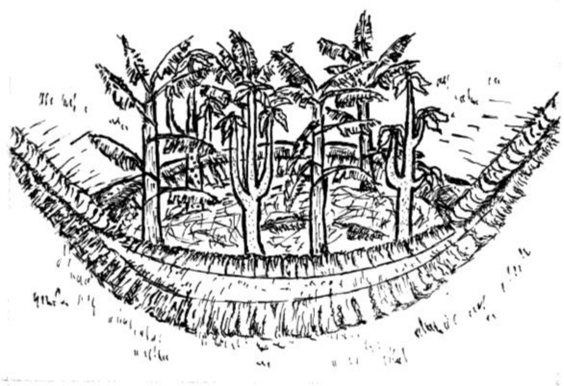
2. Shape the soil around the edge of the pit to form a ridge or mound. If the pit is on a slope you can dig diversion furrows to direct runoff into the pit (see step 5 below).

3. 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.



4. 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.

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



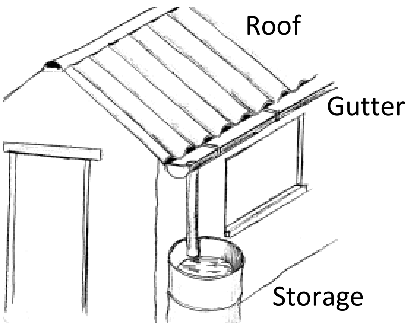
7. Roofwater Harvesting

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.

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.[33]

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.[34]

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 7.21 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.[38]

Figure 7.22 U-Round guttering used in Cata Village, Eastern Cape

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.

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.

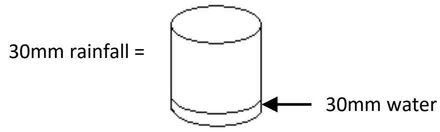
Calculating roof runoff volumes

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

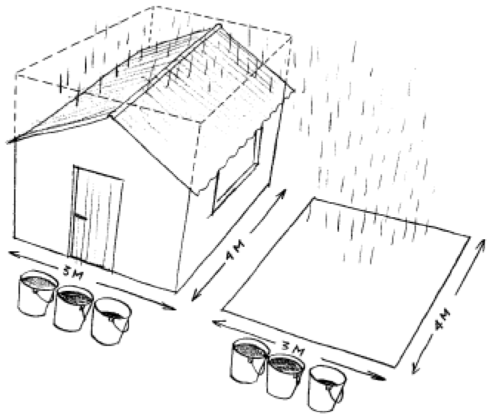
1. Rainfall

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.



2. 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 1m² is 1 litre

3. 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 1: Runoff coefficients for different roof materials (with effective guttering in place)[40]

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).

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**.

<u>Step 1: Calculate the total roof surface area</u>

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

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

The symbol π is "pi". The value 3.14159 can be used in the calculation.

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

<u>Step 2: Calculate the January runoff from the roof</u>

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 2).

Table 2: 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.

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 3: Approximate water requirements for vegetable crops where intensive WHC methods are used (litres/month/m^2)[41]

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: Garden water requirements across the year for a garden of 50 m^2

Month	Season	Crop water demand (see Table 3)	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**

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 1: 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)			

Water use/water need	Typical quantities needed	Quality required	Suitable water sources	Recyclable portion and quality
Cement-block making	20 liter per 20 large blocks or 40 maxi-blocks	Raw water (free from chemicals and silt)		

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 5, 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 5: 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.

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.

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.

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.[42] 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.

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

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.

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

Right: 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.

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 skeptical that vegetables could be grown succesfully 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.

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!

Right: 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.

What vegetables can be grown?

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.

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

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.

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.

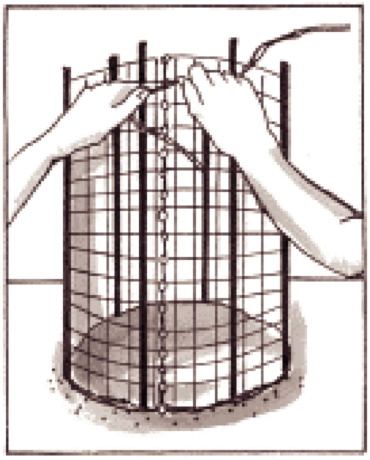
Ground surface: The ground needs very little preparation; all that is needed is to level and compact a circular area of at least 1m in diameter. It should also be noted that the tower would need enough sunlight for vegetables to thrive. In very hot areas it can be beneficial to cover the tower garden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

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.

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.

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.



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.

Right: 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.*

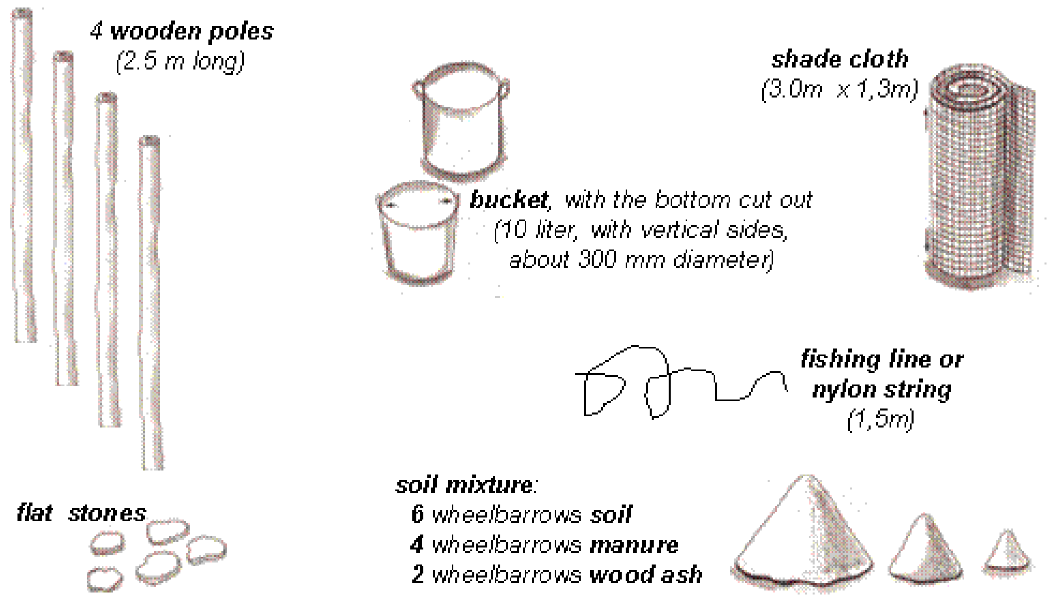
Conclusion

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:

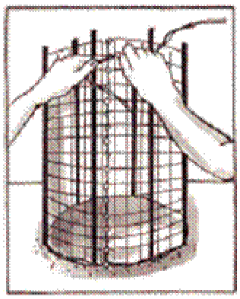
- it was not well fenced and was sooner or later destroyed by goats and/or chickens;
- it was too far from the kitchen to easily make use of the grey water; and/or
- the household received water supply on site, which enabled them to start a larger, conventional garden.

What material does one need to make a Tower Garden?



How does one make a Tower Garden?

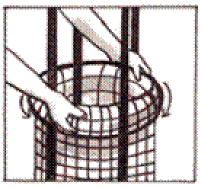
Step 1:
Choose a flat piece of ground (1m x 1m), as close to the kitchen as possible, but make sure that goats and chickens won't be able to get to your Tower Garden.



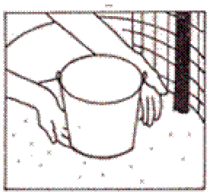
Step 2:
Plant the 4 wooden poles to form the four corners of the Tower.

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.

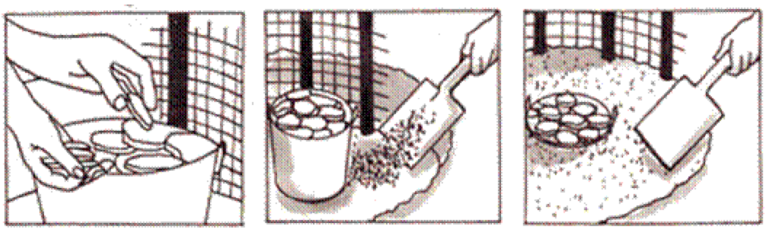


Step 5:
Using a spade, mix the soil, manure and ash very well, then mix in some water to make it slightly damp (not too wet!), so that you can place the soil mixture without compacting it.



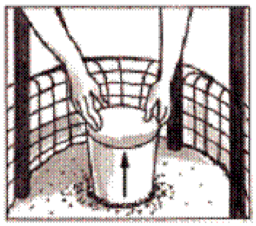
Step 6:
Fill the first 30cm (one ruler height) of the Tower with the soil mixture.

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



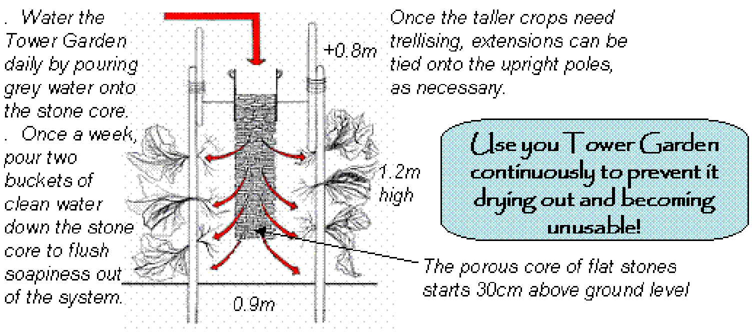
Step 8:
Pack flat stones carefully in the bucket, in such a way that water poured into the top would run through nice and slowly. This gives water time to seep sideways into the soil to the plant roots.

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.



9. Ploegvore

also called:	used in:	
• imprinting • pitting	gardens	
	fields	
	grazing and degraded land	✓

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.[45] This method is particularly effective for rehabilitating degraded soils and for improving grazing land in arid areas. When used for these purposes, the pits are typically created by machine (a bulldozer or tractor with a specialised imprinter).

Figure 7.23 Degraded land Ploegvore Same land 15 yrs later 'Happloeg' on tractor for pitting

PLANNING

Soil	Slope	Rainfall	Tools & Equipment
Any type of soil, including barren, crusted soils and clay soils with limited infiltration.[46]	Below 2%.[47]	Recommended for relatively low rainfall areas (100 – 350 mm).	tractor* imprinting implement ("happloeg") or specialised bulldozer* **essential*

In other parts of the world, similar pits – called Zai or Vitengo pits – are constructed by hand for crop production, whereas in South Africa, ploegvore (a local variation where imprints are made with machines) are used to improve grazing or degraded land.[48] Hand-pitting at an extensive scale for grazing improvement in South Africa seems highly unlikely given the labour input; however, hand-pitting for crop production could have local application. In reality there are numerous WHC methods which overlap in terms of agro-climatic and soils suitability and Zai pits for crop production show little advantage over other proven and locally modified methods such as "in-field RWH" (***tied ridges***), trench beds, contour bunds and swales. Pitting is therefore recommended to improve grazing and rehabilitating degraded land, using tractors and a 'happloeg' or a specialised bulldozer. Specialist advice on happloeg design can be obtained from Glen Agricultural College, the University of Potchefstroom or Elsenburg Agricultural College.

10. Dome Water Harvesting

also called:	used in:	
• No other names	gardens	✓
	fields	✓
	grazing land	

Figure 7.24 Dome of 1.2ha in size, near to fields

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.

Essentially the dome acts as a large roof, and a low diversion wall around the base of the dome collects and channels water in the same way as a roof-gutter. Domes offer high runoff rates (80% to 90% of the rain runs off) and they are often sizeable, extending more than 1 or 2 ha in size. The high runoff rate and the large surface area results in significant volumes of water that can be collected at relatively low cost.

Figure 7.26 Domewater harvesting feeding field crops

Figure 7.25 Massive granite dome with large runoff volumes

The method provides valuable drinking water in arid areas, and can be very effective for agricultural use where domes are located close to agricultural lands in both arid or wetter climates. Experience shows that cultural beliefs and communal resource-use issues should be directly addressed in relation to dome water harvesting.[49]

Soil	Slope	Rainfall	Tools & Equipment
The hard rock domes are used for water collection, but crop production takes place away from the domes. Soil type in the agricultural lands therefore does not affect the system directly, but should be considered generally in relation to soil-water storage and crop choice.	Any slope is suitable, but construction practicality of the low diversion wall around the base of the dome (i.e. the gutter) becomes difficult when the dome slope is 45 degrees or more.	In low rainfall areas, runoff can be channelled directly to fields or stored in reservoirs. In medium and high rainfall areas, storage is likely to be needed given the high runoff volumes that will result.	spade* A-frame or line level* cement trowel* hammer* crowbar* steel chisel* **essential*

METHOD

On a small scale on rock slabs or domes up to 1000m^2 in size, this method could be applied by someone with basic house-building or construction knowledge. On larger domes, there is a greater need for technical engineering input in relation to the sedimentation tank, channels or pipelines, and water holding dams or reservoirs.

The sequence of construction is set out below.

1. The slab or dome is typically cleared of all loose rock, soil and vegetation. Large cracks and crevices can be sealed with cement mortar (dagga) to increase yield.
2. A low wall, about 0.4 m high, is built around the base of the dome and channels water to where it will be stored. Walls can be built using a range of materials including brick, natural stone or concrete.
3. Typically, an open sedimentation tank is built to catch sand, gravel and debris before the water overflows into the storage reservoir (or is channelled directly to the planted area if no storage is put in place). Sedimentation tank size can be estimated roughly at 1/20th of the storage volume for small systems, but should be sized by a technical person for larger systems.
4. Storage volumes (size of reservoirs) are calculated from the monthly runoff minus the monthly use. In wet months the runoff will be higher than the use and the storage reservoir will fill up. In dry months the use will be higher than the rainfall runoff and the tanks will be slowly emptied. This inflow-outflow balancing calculation must therefore extend over the whole year to arrive at a suitable tank size and can be done by an engineer or technician. On a very small scale, storage in 5000 litre plastic tanks could be implemented a few tanks at a time, increasing the storage after a year or two by adding additional tanks, based on experience. On a larger scale it will be necessary to get some technical or engineering advice, both on the sizing of the reservoir and on tank or reservoir construction.