4. Soil and water conservation

Introduction

Effective soil and water management practices can improve soil fertility and increase yields in a sustainable way. The purpose of this session is to highlight some of the techniques that conserve soil and water, preserve soil moisture and/or drain water sustainably to avoid soil erosion, land sliding and depletion of soil nutrients.

Time required: 8 hours

The SALM practices in soil and water conservation fall into four broad groups. Some of these techniques are described in this chapter.

SOIL MOISTURE CONSERVATION TECHNIQUES	• Terraces • Contour bunds • Broad beds and furrows • Semi-circular bunds • Trash lines • Diversion ditches and cut-off drains	• Retention ditches • Pitting • Trenches • Tied ridges • Grass strips • Irrigation
RAIN WATER HARVESTING TECHNIQUES	• Roof catchment • Ground surfaces and rocks • Irregular surfaces	
WATER STORAGE TECHNIQUES (impermeable surfaces)	• Tanks • Birkas • Pans • Ponds • Dams • Wells and boreholes	
SUSTAINABLE SANITATION SYSTEMS	• Ecological sanitation • Kitchen water	

4.1 Soil moisture conservation techniques

4.1.1 Terraces

Terracing is the process of reducing the length and/or steepness of a slope in a planted zone using soil embankments and channels that are constructed across the slope. The change in slope profile reduces runoff speed - especially on erosion-prone highlands - thus reducing soil erosion. It also allows some water to sip into the soil (infiltration), improving soil for more vegetation cover.

EXERCISE

How would you reduce the speed at which the water across your agricultural land?

The A-frame

Terraces are constructed with the aid of an A-frame, consisting of:

- 2 bars that should be 200 cm long, made of wood or metal.
- 1 bar, 180 cm long.
- 1 bar, 60 cm long.
- A balancing water tool to show the balancing mark, for example a small transparent plastic tube of water.
- Nails to assemble the A-frame.

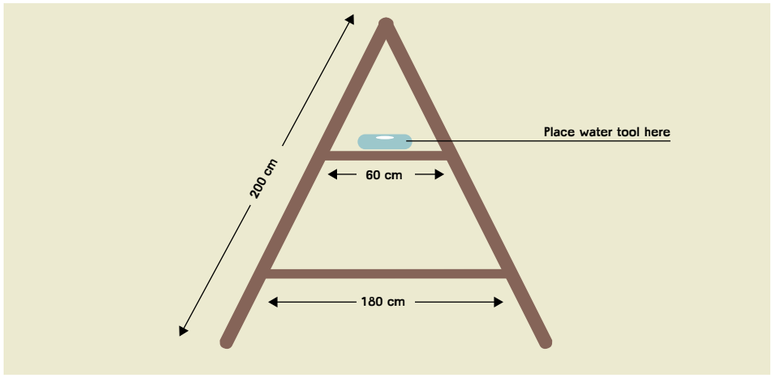


Illustration: A-Frame

Instructions: How to make a terrace and contour bunds using the A-frame

1. For this you need your A-frame and a large number of small poles to mark your contour bund.
2. Explore the shape of the terrain in your field and check for steep slopes and observe any signs of erosion. The first terrace should be made at the highest point of the slope

3. Set out the first contour line (line joining points at the same altitude) 25 m from the top of your field. Place the first pole at that spot. Place the A-frame horizontally to your field and next to the first pole (as indicated in the illustration).

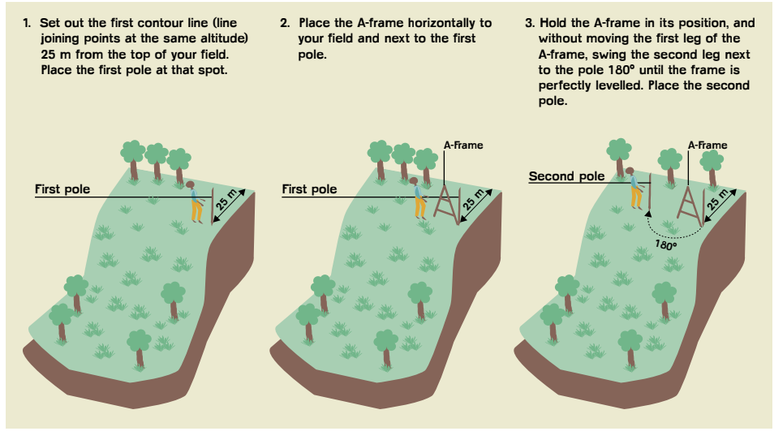


Illustration: How to use the A-frame

4. Hold the A-frame in its position, and without moving the first leg of the A-frame, swing the second leg next to the pole 180° until the frame is perfectly levelled. Place the second pole.
5. Repeat this process, placing a pole each time you use the A-frame, until the end of the field.
6. The poles now mark your contour line. Smoothen the sharp angles to make it easier for ploughing.
7. Plough the land following the poles along the contour line. If it is clay soil it is enough to do the ploughing two times on each side of the contour line. If it is sandy soil, plough at least three times. (You can also dig a retention ditch along the contour line.)
8. Throw the soil of the outer lines on top of the contour line.
9. The contours should be 60 cm wide and 25 cm deep.
10. If it is clay soil, the contour lines do to not need to be compacted. If it is sandy soil, the contour lines needs to be compacted.
11. On steeper slopes, terraces need to be built closer together. On gentler slopes, establish your terraces every 15 m.
12. Sow your crops on the benches, parallel to the contour bunds. On the ridges, you can sow grass and trees.
13. Depending on your farm's agro-ecological zones, (see chapter 2), the climate, seasons and rains, either leave the furrows open at each end of the field so that rainwater can drain out of the field, or close the furrows to create a retention ditch where the water infiltrates the field.

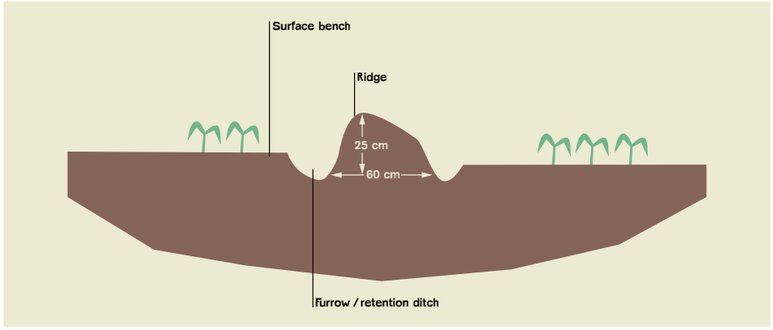


Illustration: How to make a contour bund

Once established, bunds need some maintenance in the first two years. It is advisable to strengthen the bunds by placing stones and/or grow grass along and/or to the top of the ridges.

For a video demonstration on terraces and contour bunds, visit:
http://www.accessagriculture.org/node/511/en

4.1.1.1 Types of terraces

a. Bench terraces

Bench terraces are a conservation structure where a slope is directly or slowly converted into a series of level steps (looking like staircase on slope) and ledges. The flat area between the terraces (the horizontal step) is used for growing crops such as grass and legumes (which capture water and nutrient runoff), and for animal feed.

Close the terrace by growing grass on the last flat area at the bottom of the terrace.

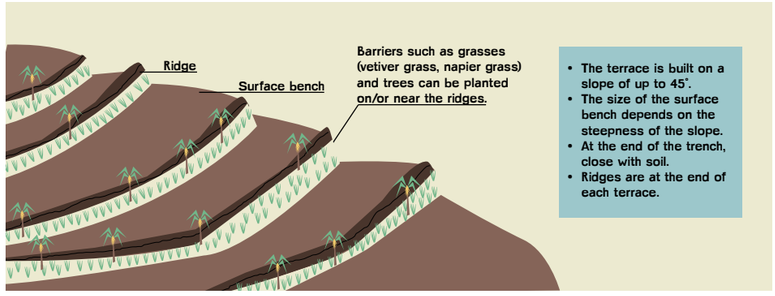


Illustration: How to build bench terraces

b. Fanya juu

Fanya juu means throw the soil upwards. To make this kind of terrace dig a ditch and throw the soil uphill, to form a ridge. The ditch traps the water and makes it infiltrate the land slowly. The ridge prevents the soil from moving downhill. Fanja juu terraces are often used in the highlands where water

speed is high.

Ensure there is a ridge at the bottom of the terrace, to close off the fanya juu terrace.

Instructions: How to make fanja juu terraces

1. Dig a trench and throw the soil upwards to form a ridge of 40 cm - 50 cm in height.
2. The trenches could be 10 m - 20 m apart depending on the steepness of the field.
3. Grasses or trees are often grown on the ridges to stabilise the bank, e.g. napier grass (in higher rainfall conditions). Bananas can be planted in the trenches.

Note: Regular maintenance is necessary.

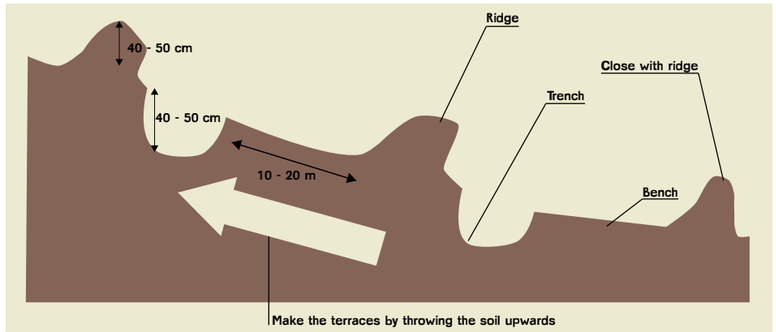


Illustration: How to build fanja juu terraces

For a video demonstration on fanya juu, visit:
http://www.accessagriculture.org/node/893/en

c. Fanya chini

Fanja chini means throw the soil downhill. To make this kind of terrace, dig a ditch and throw the soil downhill to establish a ridge. Grow tree or fodder on the ridges. Close off the terrace with a final ridge. Fanja chini terraces are often used in the lowlands with moderate slopes.

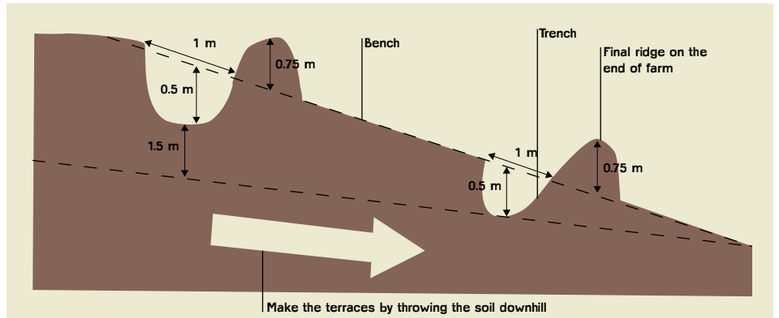


Illustration: How to build fanja chini terraces

d. Water terraces

Water terraces are built in flood-prone areas by communities to help the farmers to cope with flowing water, to deal with water masses, water speed and/or change the water direction. Water terraces are similar to bench terraces except that at the end of the trench, there is no final ridge stopping the flow of water. Instead, furrows are constructed under the benches to catch runoff water.

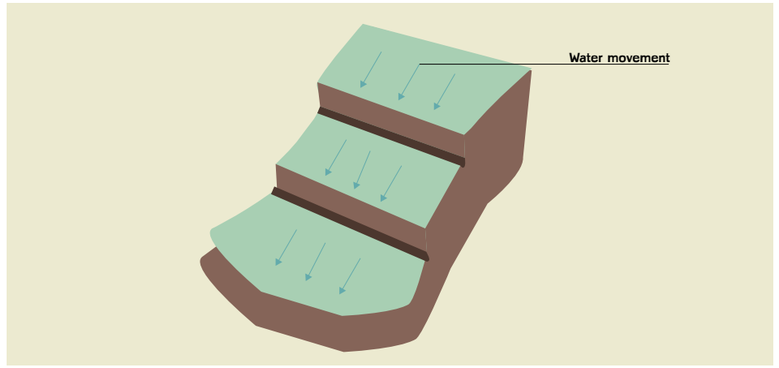


Illustration: How to build water terraces

e. Stone terrace

In stone terraces, stones are used to create strong embankments on steep slopes. The stone terraces have the potential to slow down runoff, increase water infiltration, and form the basis for improved production in semi-arid areas. By using the contours of low slopes, water harvesting is improved and crops can be grown in low rainfall years.

Instructions: How to make stone terraces

1. You need a mix of small and large stones (25 cm – 30 cm in height) depending on the size of your land and terrace.
2. Dig trenches, 10-15 cm deep. Trenches should be 15-30 m apart.
3. Place the selected large stones in the trench.

4. Place, on the side **not blocking** the water, smaller stones to support the larger stones.
5. Place on top and in between the smaller stones sediments or top soil that can be distributed along the soil together with the rain water.
6. Plant grass or trees along the stones to support the stone terrace.

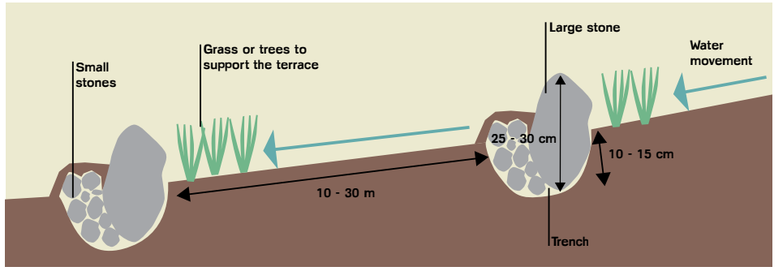


Illustration: How to build stone terraces

For a video demonstration on stone lines visit:
http://www.accessagriculture.org/node/891/en

4.1.2 Contour bunds/contour farming

Contour farming involves ploughing, planting and weeding along the contour, i.e, across the slope rather than up and down. Contour lines are lines that run across a slope such that the line stays at the same height and does not run uphill or downhill. As contour lines travel across a hillside, they will be close together on the steeper parts of the hill and further apart on the gentle parts of the slope.

Did you know?

Experiments show that contour farming alone can reduce soil erosion by as much as 50% on moderate slopes. However, for slopes steeper than 10%, other measures should be combined with contour farming to enhance its effectiveness.

Contour bunds are permanent ridges of soil that are built by excavating a channel on a slope along a contour line (line joining points on same altitude). These soil conservation structures resemble “fanya chini” terraces (see 4.1.1.1, c). Contour bunds are popular in the highland and in semi-arid areas and are mostly used to harvest water, enhance the retention of runoff water, and prevent soil erosion and flooding. Contour bunds are made using an A-frame (see 4.1.1).

Note: If contour lines are incorrectly established, then they can actually increase the risk of erosion.

EXERCISE

Study your land and visualise where the contour lines will run. This can be done by one person directing another person in walking to the other side of the area to be contoured such that he/she stays at the same height as the first person.

4.1.3 Broad beds and furrows

Furrows are narrow ditches dug in the field between crops. Runoff water is diverted into furrows. The furrows are blocked in the lower end. When one furrow is full the water backs up into the head furrow and flows into next furrow. Between the furrows are broad beds where crops are grown. Furrows work in the same way as infiltration ditches.

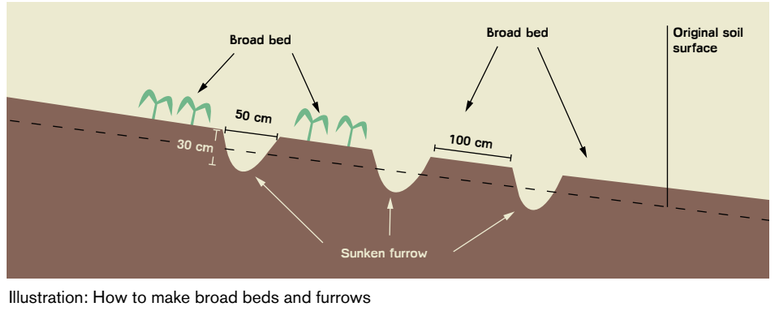


Illustration: How to make broad beds and furrows

4.1.4 Semi-circular bunds

Semi-circular bunds are made by digging holes on the tips of the contours, in the form of half-circles. Semi-circular bunds are used to harvest water, conserve soil and water, and improve soil fertility (when manure or compost is added).

The dimension of the holes and spacing of the contours are determined by the type of crop or the farming system. The bunds are staggered so that the water which spills round the ends of the upper hill is caught down the slope. The excavated planting pits are filled with a mixture of organic manure and topsoil to provide the required fertility and help retain moisture.

Instructions

1. Semi-circular bunds are constructed on the gentle slopes of 1 – 2 % in areas with 500 mm – 700 mm rainfall.
2. Mark the points along the contours and get smooth curved lines across the slope 8 m – 50 m apart depending on slope starting at the top of the field.
3. Mark points on lines where water affects the agricultural field and demarcate these areas to be constructed with the bunds.

4. To develop a bund, mark 6 m - 20 m radius and make a semi-circular bund down the slope and form a bund to bund measures 3 m - 10 m along the lines while from the bund line to another line ranges 3 m - 30 m.
5. At the inner part of the semi-circular demarcation, dig a trench of 20 cm – 30 cm throwing soil downward and create a semi-circular ridge/embankment.
6. In the trench or mid/ends of the bund fill with loose stones and plant some trees or shrubs on the ridges and inside bunds plant fodder crops and trees etc. to maintain during rainstorms.
7. 1.5 m wide and 0.5 m deep diversion ditch can be constructed within the bunds field to drain excess water during rainstorms.

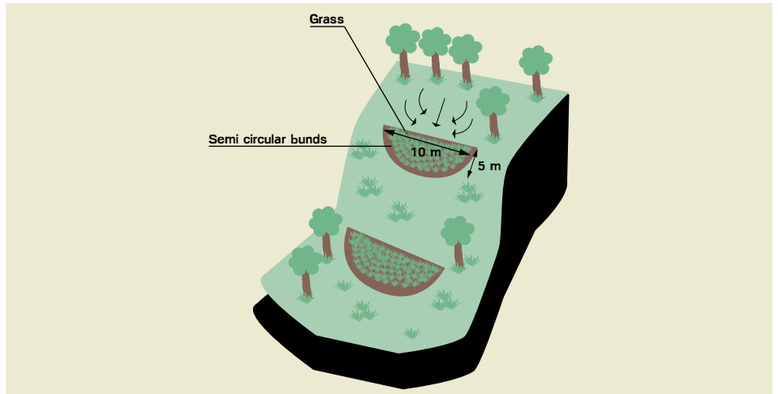


Illustration: How to make semi-circular bunds

For a video demonstration on semi-circular bunds, visit:
http://www.accessagriculture.org/node/903/en

4.1.5 Trash lines

Trash lines are created across the slope along the contour using previous seasons' crop residues (millet, maize and sorghum stalks), grasses, litter and other dead vegetative organic materials. Trash lines control surface runoff, soil erosion and enhance infiltration. Trash lines can be 1 m wide.

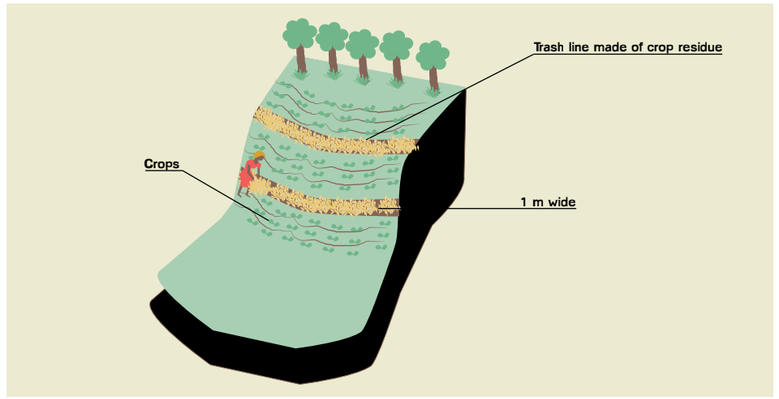


Illustration: How to make trash lines

4.1.6 Diversion ditches and cut-off drains

A diversion ditch is a graded channel excavated to intercept surface water running down a slope and divert it to a safe outlet, waterway or farm. The structures can be in the form of a trench, a narrow base channel or a hillside ditch.

Cut-off drains are channels built to collect runoff from the land above and to divert the water safely to a waterway or river, thus protecting the land below from excessive erosion. The ditches can be made of earth, loose rock or other material depending on the available resources and needs.

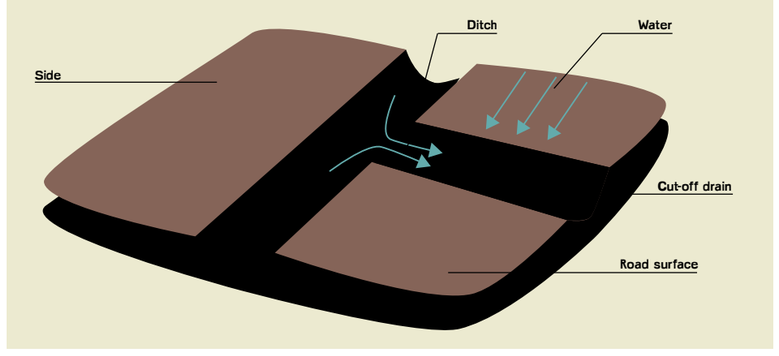


Illustration: How to make cut-off drains

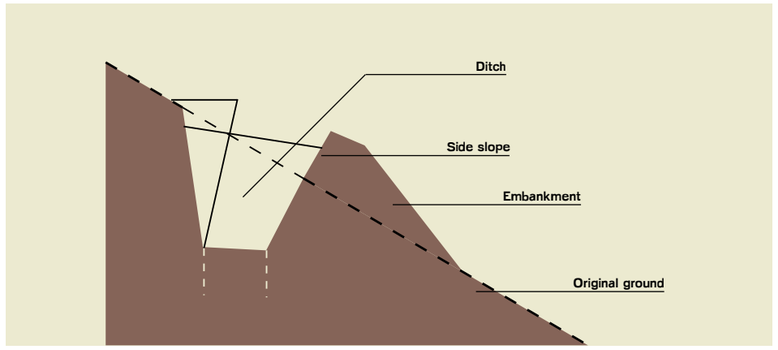


Illustration: How to make a diversion ditch

4.1.7 Retention ditches

a. Contour drainage ditches

Contour drainage ditches drain excess water out of the field, and if closed at the end, retains water for use or infiltration into the downslope fields. These can stop downslope water movement as the water falls into the ditch. These structures are some of the most useful for small-holder hillside farming since these require less work than terraces, are simple to build, and can be used to either divert or to retain water. They divert excess water to protected drainage ways, reduce soil erosion and leaching of nutrients. The uppermost ditch, called storm water drain, is very important if a great deal of water enters from above the field.

Illustration: Contour drainage ditch

b. Contour infiltration ditches

Contour infiltration ditches are short ditches or pits dug along the contour and upslope from a crop field. Water is diverted from the roadside into the ditch, which is blocked at the other end. The water trapped in the ditch seeps into the soil gradually.

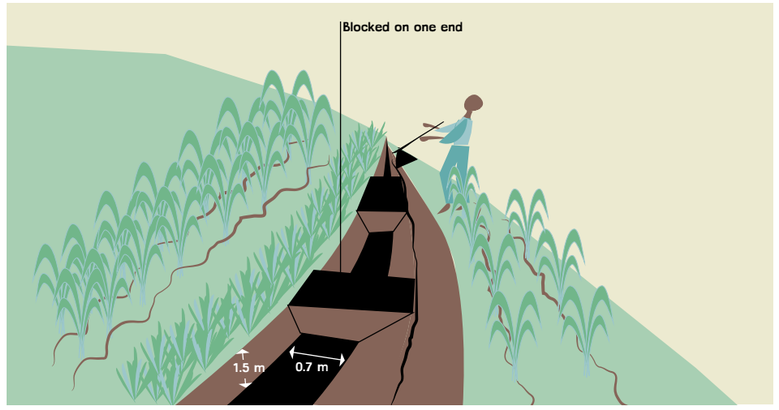


Illustration: Contour infiltration ditch

4.1.8 Pitting

Pitting is the digging of holes of various sizes to grow crops such as banana, coffee, tea, and grains (maize, millet and beans). The pit acts as a water harvester and a conserver of both moisture and fertility. Manure is added to increase fertility in the pit for a long time. You can plant crops repeatedly in the same place. Often, a series of planting pits are dug in the same field.

a. Zai pits

Zai pits are shallow, wide pits in which cereal crops such as maize are planted. Topsoil from the excavation or compost is mixed with manure and put back in the pit where a few cereal seeds are then planted. The zai pit is suitable in areas with sandy soils and often used in semi-arid areas. It has been modified in some areas to fit the climate circumstances. For example, Katumani, Machakos has the katumani pit, a smaller version of the zai pit. In Njombe, Tanzania, with annual rainfall of about 1,000 mm, the pits are bigger and deeper (at least 0.6 m deep). For the bigger pits, 15 – 20 seeds are planted in each pit, and about 20 litres of manure added to each pit. The result is double the yield compared to conventional tilled land.

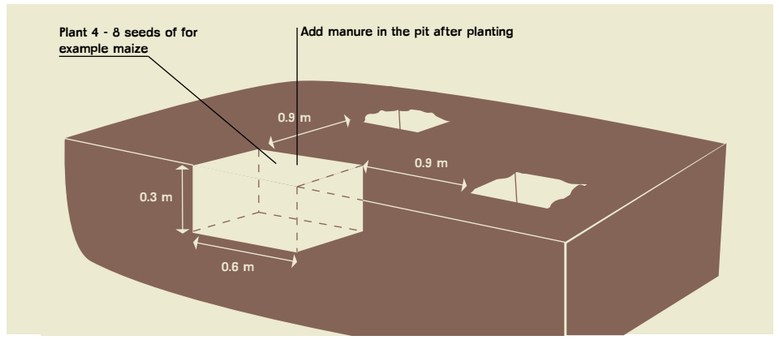


Illustration: How to make zai pit

For a video demonstration on zai planting pits, visit:
http://www.accessagriculture.org/node/901/en

b. Tumbukiza pits

This is a pitting system that involves digging huge pits, and filling the pits with trash and vegetative material, including farmyard manure and topsoil. Tumbukiza means “throw all in”.

Tumbukiza pits have been modified for fodder production and improved soil fertility. A fodder crop, preferably napier grass, is usually grown in the pit. At the end of one cutting cycle (30 days), the fodder has grown enough to allow the next round of cutting. Excavating the pits is labour - intensive.

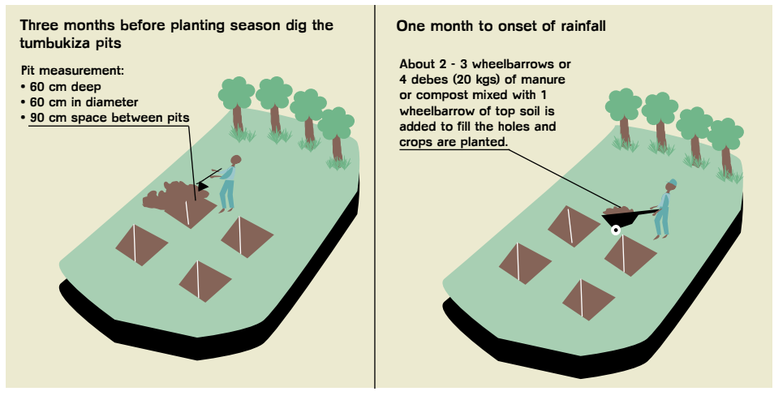


Illustration: How to make tumbukiza pits

c. Chololo pits

Chololo pits are dug, planted and filled partly with ashes, manure and crop residues to hold the water and add nourishment to the plant. Crops grown in chololo pits can survive periods of severe rainfall deficits, and yields can be tripled. The pits are easy to make and not very labour-intensive.

d. Ngolo pits

Ngolo pits are characterised by a combination of soil conservation techniques of pits and ridges on slopes about 35 % - 60 % steepness. The pits are laid out on sloping land forming a grid to cover the entire surface. A major feature of the ngolo system is that the fields contain a large number of pits. Soil taken from the pits is used to form ridges around the pits. Crops are grown on the ridges, and the weeds and crop residues are thrown into the pits. The pits also conserve water. The pits combine a two-crop-rotation system (maize and beans for example), repeated in a 2-year cycle. In the event of a decrease in the maize yield, the field is fallowed for several years until it is fully covered with shrubs or tall grasses, and then used to grow crops. The pits are regularly moved and new ridges built where the organic matter has accumulated. The yield from ngolo pits has been shown to be superior to that of a crop obtained through terracing methods. Ngolo pits are also known as ingolu or matengo pits.

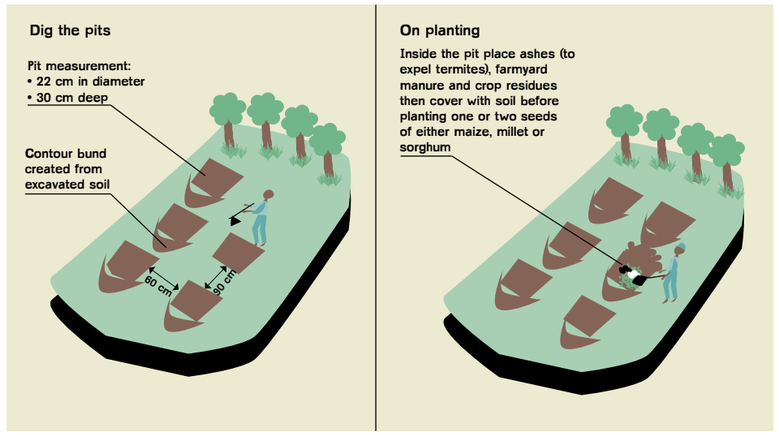


Illustration: How to make chololo and ngolo pits

e. Five by nine pits

Five by nine pits are square-shaped pits, larger than zai pits that are used to plant maize crops. The pits measure 60 cm square and are 60 cm deep. The name “five by nine” is based on the five or nine maize seeds planted at the pit diagonals (five for dry areas, and nine for wet areas). This type of pit can hold more manure than a zai pit. Hence, it is capable of achieving higher yields that have a long-lasting effect. The pit can be re-used for a period of up to two years.

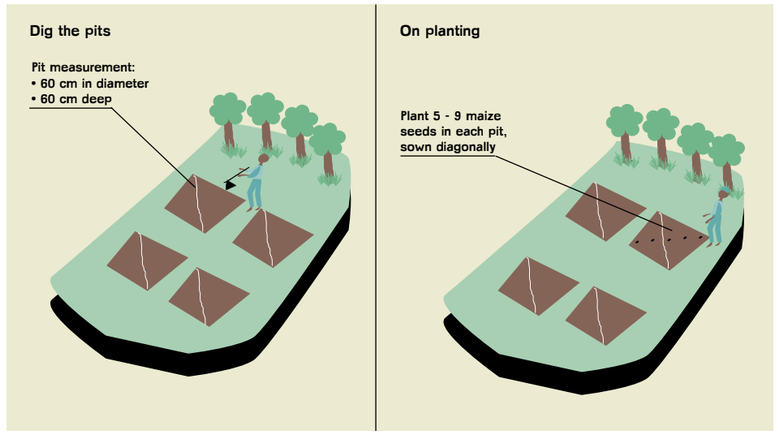


Illustration: Five by nine pits

4.1.9 Trenches

Trenches are short ditches or pits dug across the slope to trap water. Trenches help recharge underground water and maintain a supply of water for wells and springs, protect the soil down slope from erosion and enable trees to grow quickly in dry lands. Embankments of trenches are planted with grasses, legumes and trees stabilising soils and enhancing vegetation grows leading to both biomass and soil carbon.

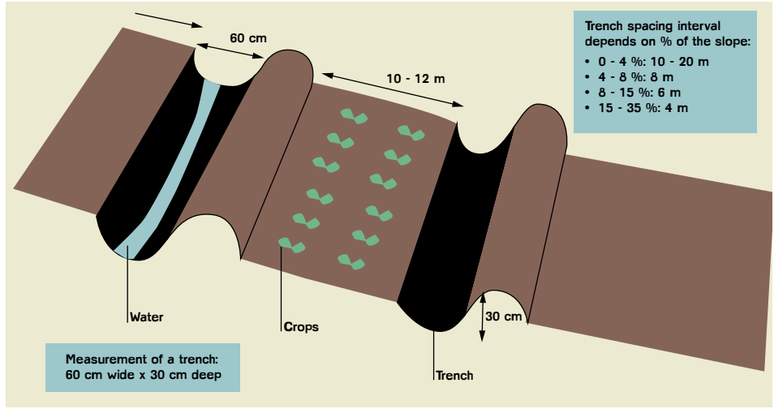


Illustration: How to make a trench

4.1.10 Tied ridges

Tied ridges are a series of cross-ridges that interrupt or block the furrows in areas with dry soils and prevent water from flowing along the furrows. This allows the water trapped between the ridges to seep into the soil. Tied ridges conserve soil moisture in drought-prone areas increasing crop yields, prevent water erosion, and its simple to use and maintain with farmers.

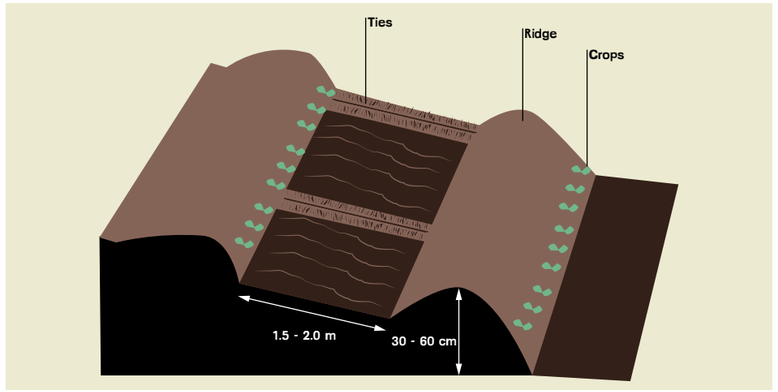


Illustration: How to make tied ridges

4.1.11 Grass strips

Grass strips are 1 m-wide strips of grass planted on terraces along contours to reduce the amount of water flowing down the slope and conserve soil. This technique can be practiced in wet and moist areas. Grass strips are planted with fodder grass such as Napier or are left with natural grass, thereby they provide fodder for livestock (cut and carry.)

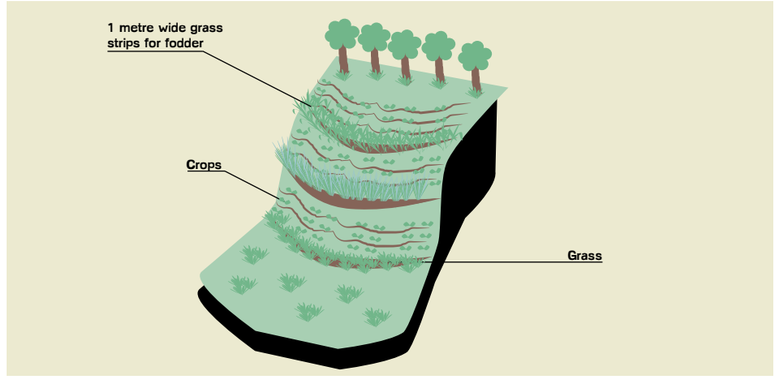


Illustration: How to make grass strips

4.1.12 Irrigation

Irrigation is the use of collected or harvested water for agricultural purposes. The practice improves soil moisture and mitigates against drought, allowing crops to use the available water efficiently.

Drip or trickle irrigation

In drip irrigation, water is led to a farm through a pipe system. A tube is installed in the farm, next to the plants. Holes are then made in the tube at regular intervals, and an emitter attached to the tube is used to supply water slowly, drop by drop, to the plants. This system is suited to small farms. There are different types of drip irrigation based on what materials you as a farmer have available. Examples are bottle irrigation, bamboo tube irrigation and bucket irrigation.

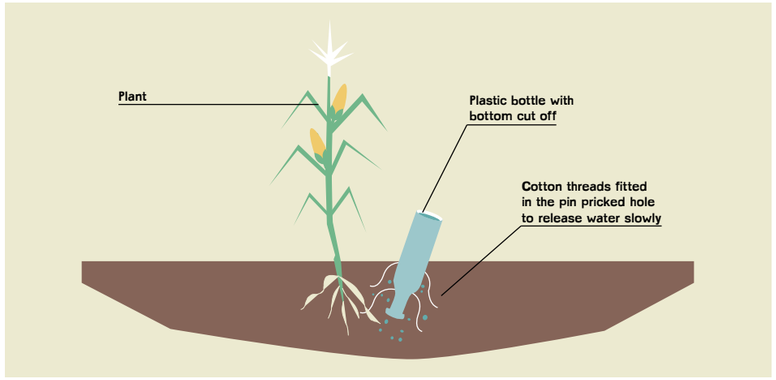


Illustration: Bottle irrigation

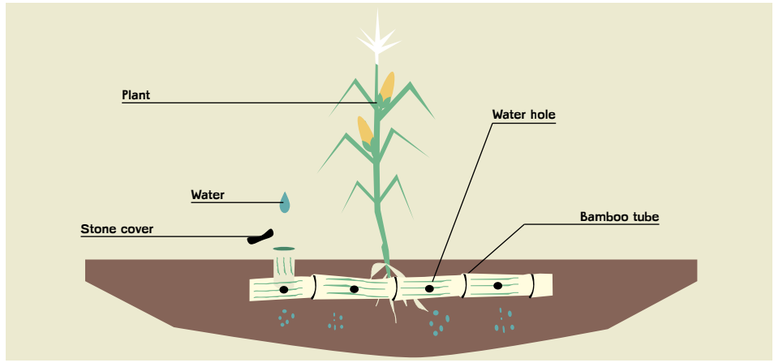


Illustration: Bamboo irrigation

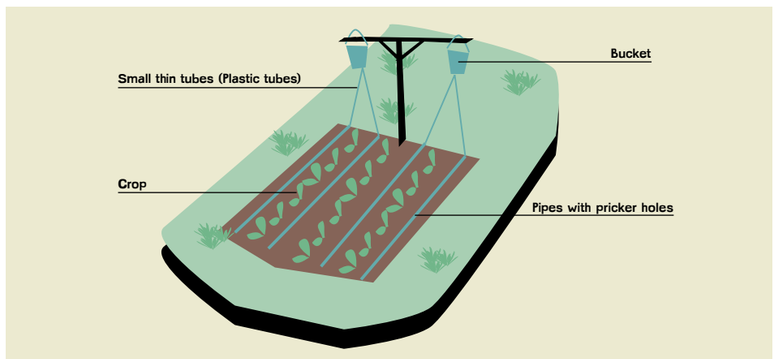


Illustration: Bucket irrigation

EXERCISE

1. **Pull out the drawing of your farm. What soil conservation method would you adopt in your farm?**
2. **List five reasons why this method is good/beneficial for you?**

Think about

River bank protection: **The sides of the river are called river banks. The banks have natural vegetation called riverine which are supposed to be protected. Farmers sometimes destroy the banks of the river by growing crops. Also naturally heavy rainfall, river flooding and landslide erode river banks. When the banks are destroyed the river can flood causing river bank erosion, loss of soil, crops and livestock, as well as depositing sand, silt and boulders on cropland. River banks can be protected using live barriers (plants) and gabion wires. The river sides twice the river include banks are supposed to be protected and not be cultivated by farmers for riverine vegetation and biodiversity. Farmers can rehabilitate the damaged river banks by not cultivating, allowing natural regeneration, planting trees, napier, sugarcane, and/or banana.**

4.2 Rainwater harvesting techniques

Rainwater harvesting is the slowing down, collection and concentration of runoff water for productive purposes such as growing crops, fodder, pasture or trees, and to supply livestock or/and for domestic water supply, especially in arid and semi-arid regions. The purpose is to mitigate the effects of temporal rain shortages, some of which can be attributed to climate change.

There are three (3) major rainwater harvesting techniques:

1. Roof catchment.
2. Ground surfaces and rocks.
3. Irregular surfaces (road, railways, footpaths, hillsides).

4.2.1 Roof catchment

A roof catchment is a system with gutters in the roof that drain water into a suitable storage system such as a tank or a water pan. It is especially used in roofs made of galvanised iron or clay tiles.

4.2.2 Ground surfaces and rocks

The runoff water that collects on the ground and around rocks is channeled to farms or stored in ponds, tanks and dams for future use. Gutters can be used to channel the water.

4.2.3 Irregular surfaces (roads, railways, footpaths and hillsides)

Runoff water from areas such as roads, homesteads and railways lines is caught and channeled into fields or stored in systems such as tanks, dams and ponds for future use. Gutters can be used to channel the water.

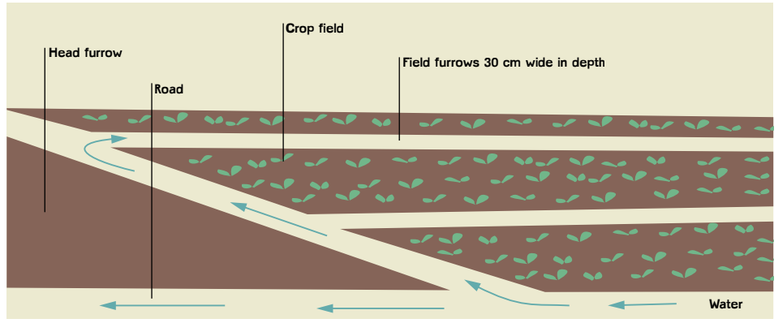


Illustration: Road catchments

EXERCISE

1. **Pull out the drawing of your farm. Which water conservation method would you adopt in your farm?**
2. **List five reasons why this method is good/beneficial for you?**

4.3 Water storage approaches

Water storage approaches are practical ways of storing and conserving water, especially during dry season. The water is mainly used for household consumption, but can also be used for agricultural purposes, e.g. water harvesting tanks can provide water for drip irrigation. There are different approaches, such as tanks, ponds and dams.

4.3.1 Tanks

Tanks can be placed above the ground (surface tanks) or underground (sub-surface tanks) and used to harvest rainwater from large rock catchments and roofs (clay tiles and galvanised iron roofs). The water can be used at home, schools and hospitals. Unless ground gradient permits gravity outlets, pumps are required to lift the water to the surface whenever there is need.

4.3.2 Birkas

Birkas are rectangular underground cisterns lined with concrete on impermeable clay tiles.

4.3.3 Excavated pans and ponds

Ponds are reservoirs with a water volume less than 5,000 m^3. Excavated pans are shallow depressions (1 m to 3 m deep) constructed to collect and hold runoff water from various surfaces including from hillsides, roads, rocky areas and open rangelands. When properly designed and with good sedimentation basins, the water collected can be used for livestock watering or to supplement the irrigation of crops.

4.3.4 Water dams

a. Charco dams

Charco dams are small excavated pits or ponds, about 3 m deep, constructed at well-selected sites on a relatively flat topography for livestock watering.[1] For high efficiency in water collection, the pond is situated at the lowest point of the topography. The right site may be selected using contour maps of the area or by observing where water collects naturally.

b. Small earthen dams

When larger quantities of water are desired, earthen dams are preferred. An earthen dam is constructed either on-stream or off-stream, where there is a source of large quantities of channel flow. The dam wall is 2 - 5 m high and has a clay core and stone aprons and spillways to discharge excess runoff. Volume of water ranges from hundreds to tens of thousands of cubic meters. Due to the high costs of construction, earthen dams are usually constructed through cooperatives and farmers' organisations. Earth dams can provide adequate water for irrigation projects as well as for livestock watering. Sediment traps and delivery wells may help to improve water quality but, as with water from earthen dams, it is usually not suitable for drinking without being subject to treatment.

c. Sand and subsurface dams

Many seasonal rivers in the semi-arid areas of East Africa have sand, hence the term sand river. Dry for most part of the year these rivers are subject to flooding during the rainy season.

A sand dam is a wall constructed across the stream to restrict surface flow. The height of the dam wall is increased by 0.3 m after floods have deposited sand to the level of the spillway. Sand dams are similar to subsurface dams but the top of the dam wall exceeds the level of the riverbed.

A subsurface dam is where the wall embankment, sometimes made of compacted clay, is below the ground. Sometimes the structure is integrated with a drift for river crossing purposes, reducing costs.

Subsurface and sand dams should be built slowly in stages because if built too high, silt settles in the dam instead of sand. It should go down to the impervious layer below the sand. The water in the sand dam can be reserved for a long time due to low evaporative losses.

The most convenient way to harvest water in a sand river is by either

sand or subsurface dams. Local materials for construction are usually available and the only extra cost is that of cement and labour.

Sand river storage is a socially acceptable water source, and because the water is stored under the sand it is protected from significant evaporation losses and is also less liable to be contaminated.

4.3.5 Wells, boreholes

In regions without notable surface water resources it is necessary to obtain water from underground sources (ground water near the surface or deep geological layers). A borehole-well is a borehole connected to a well (generally modern); the borehole feeds the well, which is used as a water reservoir.

Note: Farmers or organisations abstracting water from a river, using dams or bore holes must carry out feasibility, design, Environmental Impact Assessment (EIA) and annual Environmental Audits (EA), consult communities and obtain water permits or licenses. Dams and related infrastructure may impact the local environment, have impact on land use, and cause re-settlement of people or start community conflicts.

4.4 Sustainable sanitation systems

4.4.1 Ecological sanitation

Farmers can use Ecological Sanitation (EcoSan) toilets to collect human waste and urine to use as manure for improving crop productivity. The EcoSan toilets are permanent, you do not need to dig pit latrines. In this system, human waste does not mix with urine.

Urine is collected and diluted with water to use as fertilizers for vegetables, grass, crops or trees (1 part urine, 3 parts water.)

Human waste is decomposed and mixed with ash and top soil, then used as manure for crops. The ash helps to increase decomposition, remove germs and reduces the smell.

How to use manure:

1. Construct and use the EcoSan toilet.
2. Add 1 handful of ash in the hole for human waste every day to reduce smell and kill germs.
3. Collect urine when needed and dilute with water to use as fertilizer.
4. Remove the human waste and mix with top soil to provide essential bacteria that enables decomposition and turns the human waste into soil. (Mix 1 part human waste with 1 part top soil.)
5. Let it decompose for 3 weeks under a tree to provide shade.
6. When ready, turn the manure to make a fine mix. Add the manure to the soil in your field.

Note: Do not apply the EcoSan manure directly on crops or plants, only mix into soil. This is an act of precaution, not to spread germs.

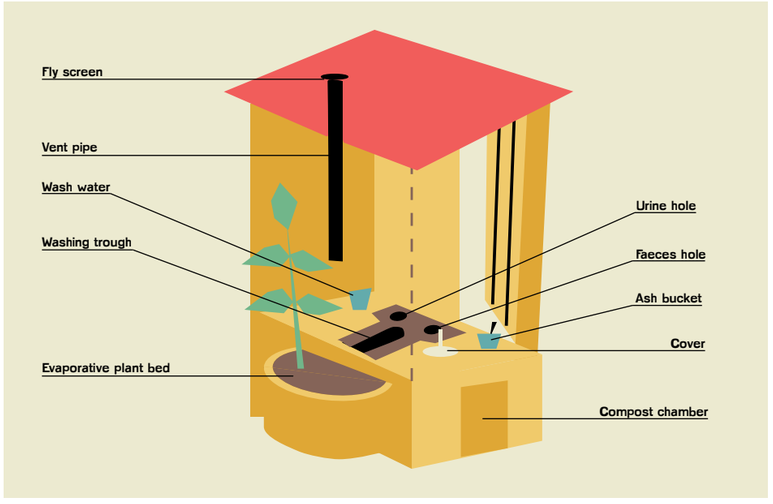


Illustration: Ecosan toilet

4.4.2 Kitchen water

Water that has been used in the kitchen or from showers can be treated and used for irrigating gardens. Leave the water in the basin in the sun to kill germs. Let it cool before applying it to your kitchen garden or trees, otherwise it will destroy the plants.

5. Agronomic practices

Introduction

By the end of this session you will know how to choose the crops best suited for your farm, the most suitable ways to plant different crops in your farm to increase produce, as well as how to adapt to the negative impacts of climate change.

Time required: 4 hours

5.1 What are agronomic practices?

Agronomic practices are designed to manage crops on croplands to increase yields, productivity, adapt to climate change and increase the resilience of the crop land. Some of the recommended practices are listed below.

AGRONOMIC PRACTICE	EXAMPLES	BENEFITS
Improved crop varieties	Hybrid maize, grafted mangoes, indigenous vegetable, mosaic resistance cassava, ground nuts, tissue culture banana	The crops are fast maturing, high yielding, and are generally more tolerant to pests and diseases.
Crop rotation	Maize to groundnuts to root crops.	Controlling the build-up of pests, weeds and diseases, and ensuring that root systems explore the soil to different depths. Recycling nutrients.
Intercropping	Mix maize-beans, maize-groundnuts, maize-potatoes	Nitrogen-fixation, intensification, and increased yields of two crops.
Alley cropping	Trees such as *Sesbania sesban* or *Calliandra* in hedges in maize fields.	Stabilising soils.
Relay cropping	When the main crop, e.g. maize, is a few weeks from the harvesting stage, introduce a cover crop e.g. bean or green gram to succeed the maize field.	Ensuring continuous use of land, and availability of organic fertilizers.
Contour strip cropping	Grass strips.	Reducing soil loss.
Cover crops and green manure	Lab lab beans.	Conserving soil, nitrogen-fixation.
Fodder banks	Place Napier grass, trees such as *calliandra*, or *sesbania sesban* as fodder banks.	Manure availability (both the animals that feed on the fodder, plus the fodder are sources of manure), livestock diet improved.
Integrated Pest Management	Combination of biological, physical and chemical pest and disease control.	The expected reduction in number of pests reduces the need for pesticides.
Cover crops and green manure – See chapter 3 Fodder banks – See chapter 6 Alley cropping – See chapter 6 Integrated Pest Management – See chapter 11		

Table: Agronomic practices

5.2 Improved crop varieties

Improved crop varieties are crops that have been researched on, bred and tested to have special qualities e.g. of fast-maturing, dry spell tolerant, high-yielding, high quality, and pest and disease tolerant. Some particular crops can also withstand the effects of climate change and increase organic carbon or residues that can be managed to store carbon in the soil for a long period of time.

Think about

Examples of crops include hybrid maize, millet, sorghum, pulses and legumes (beans), rice, grafted mangoes, indigenous vegetables, mosaic-resistant cassava, groundnut and tissue culture bananas.

High-yielding crops also provide more biomass or residues can be returned back to the soil. However, certain improved crop varieties need to be used with caution; not all are suitable for all climates and soils.

Note: Please consult with an agricultural extension officer before purchasing and planting the seeds.

The adaptation measures of planting improved crop varieties include:

- Timely planting
- Staggered plantation or succession
- Crop diversification
- Crop rotation

5.3 Crop rotation

Crop rotation is the repetitive planting of a sequence of crops in the same field following a defined order in a year or years of cropping. The practice is necessary in order to avoid the built-up of pests, weeds or diseases, and chemicals, and to ensure that root systems explore the soil to different depths.

Think about

Suitable crops for use in rotations include legumes (nitrogen-fixing), cereals (high feeders), root crops (cover crops) and grasses (which also help to maintain the fertility).

The main practices involve planting cereals (high feeders) first, followed by legumes (nitrogen-fixing) and finally plant root crops (cover crops). Examples of crops used in a crop rotation system include planting maize first, then beans (intercrops and pure stands), and finally cassava or potatoes.

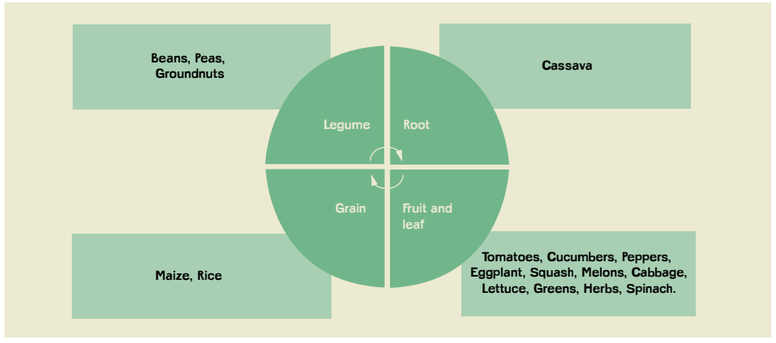


Illustration: Crop rotation

5.4 Intercropping

Intercropping is the planting of two or more crops in the same field at the same time such as maize and beans, maize and groundnuts or maize and potatoes. Intercropping, also known as interplanting, provides additional income, food and shade, fixes nitrogen, and controls weeds and soil erosion. It also provides a lot of biomass to form residues to be returned as organic inputs to the soil in form of mulch and compost.

Think about

The major plants used in intercropping include beans, soya beans, cowpeas, pigeon peas, onions and other vegetables.

Care should be taken when intercropping as some plants host pests and can transmit diseases to the main crop. For example yam, pumpkin, watermelon and cucumber should not be intercropped with banana as these serve as alternate hosts for the infectious chlorosis virus that affects banana.

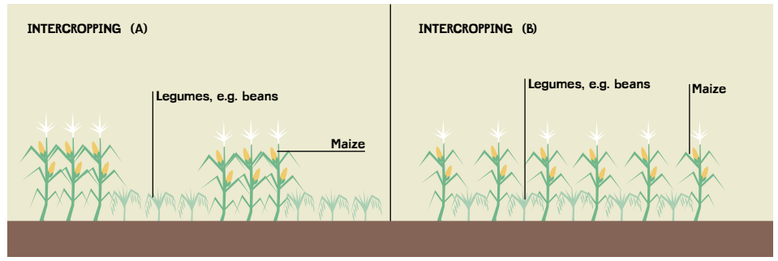


Illustration: Intercropping

5.5 Relay cropping

Relay cropping is the planting of temporary crops within the main crop before the main crop is harvested. Relay cropping ensures the land is used continuously. It also reduces the cost of subsequent cultivation while ensuring the availability of organic matter for the new crop, stabilises nitrogen, and controls weeds and diseases.

Illustration: Relay Cropping

5.6 Contour strip cropping

Contour strip-cropping is the planting alternative strips (15 - 45 m wide) of grasses or grain with other crops along a contour on gentle slopes to conserve moisture and reduce erosion.

EXERCISE

1. **Go back to your drawing and answer the following questions:**
   a. **Verify which of the above-mentioned practices do you have on your land? If you are missing some, are there any practices you wish to implement? Which type of crops do you normally plant in the rotational method?**
   b. **Give five reasons why you carry out rotational cropping system?**
   c. **Do you have different crops and trees on your land for feeding your livestock? If not, why not?**

6. Agroforestry

Introduction

This session introduces the idea of the intentional or deliberate planting of trees in a crop or livestock farm. By the end of this chapter you will know the benefits of agroforestry including climate change mitigation, and some of the common methods used.

Time required: 8 hours.

6.1 What is agroforestry?

Agroforestry is the deliberate growing of woody perennials (trees, shrubs) as agricultural crops alongside other crops and/or livestock in the same land. It improves productivity and mitigates the impacts of climate change (adaptation and mitigation). Existing trees can be protected and managed, or/and new ones planted.

The benefits of trees on the impacts of climate change cannot be overstated. Trees capture and absorb carbon dioxide - a significant factor in the climate change equation - and either use it for photosynthesis or store it in leaves, stems, branches and roots. Trees also release oxygen during photosynthesis. Trees grow faster in tropical regions, absorbing more carbon dioxide than trees that grow in temperate regions. When trees are cut and forests destroyed, the carbon that is trapped is released into the atmosphere, facilitating raises in temperature. Planting trees and maintaining forests is therefore essential for climate change mitigation.

Agroforestry has three major attributes: productivity, sustainability and adoptability. In other words, agroforestry should maintain or increase production (productivity), meet the needs of the present generation without compromising those of future ones (sustainability) and be culturally acceptable and environmentally friendly (adoptability).

Benefits of agroforestry:

CATEGORY	SPECIFIC BENEFITS
Social	Food and nutrition, shelter, medicine, cultural, psychological.
Economic	Sales of timber, fruits, nuts, poles, medicine.
Environmental	Soil fertility, crop and livestock productivity, firewood energy, biodiversity, reduce deforestation, climate change adaptation and mitigation, wind breakers, beauty, landscape.

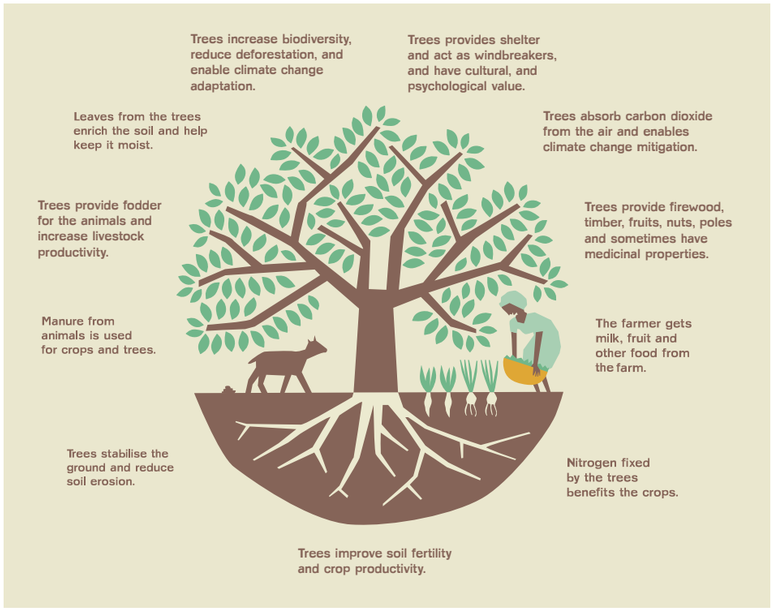


Illustration: Agroforestry - How it works

EXERCISE

1. **What kind of trees do you have on your farm?**
2. **How do you think these benefit your farm?**
3. **How is the tree cover today in your area, compared to 30 years ago? Has any tree species disappeared?**

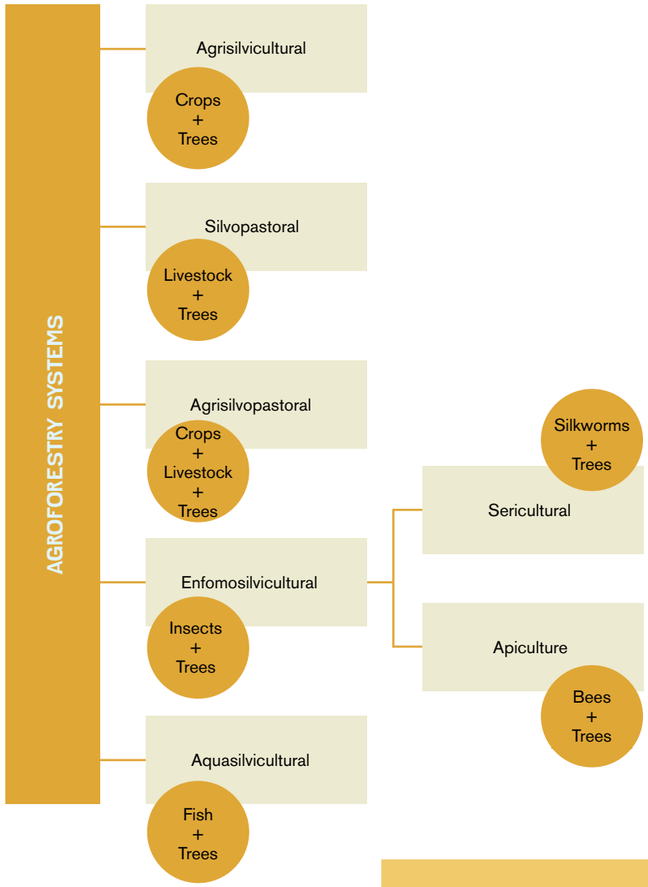
6.2 Agroforestry tree species

BENEFIT	SPECIES	OTHER ATTRIBUTES
Firewood	*Calliandra calothyrsus*	
	Sesbania sesban	
	Cordia africana	Termite resistant
	Gliricidia sepium	Termite resistant, drought resistant
Soil erosion control	*Calliandra calothyrsus*	
	Gliricidia sepium	Termite resistant, drought resistant
	Sesbania sesban	
	Morus alba	
	Tephrosia vogelli	
Soil fertility improvement	*Sesbania sesban*	
	Calliandra calothyrsus	
	Cajanus cajan	
	Gliricidia sepium	Termite resistant, drought resistant
	Tephrosia vogelli	
	Albizia chinensis	Termite resistant
	Trema orientalis	
Shade trees in crop land	*Ficus natalensis*	Termite resistant
	Albizia chinnensis	Termite resistant
	Polyscias fulva	
	Cordia africana	Termite resistant
	Maesopsis eminii	Termite resistant
	Trema orientalis	
	Croton macrostachyus	
Fodder trees	*Calliandra calothyrsus*	
	Albizia chinnensis	
	Morus alba	
	Sesbania sesban	
	Gliricidia sepium	Termite resistant, drought resistant
	Moringa oleifera	Drought resistant
Timber	*Khaya anthotheca*	Termite resistant, competitive
	Milicia excelsa	
	Podocarpus falcatus	Termite resistant, competitive
	Maesopsis eminii	Termite resistant
	Grevillea Robusta	
Timber	*Albizia lebbeck*	Termite resistant, drought resistant
	Markhamia lutea	Termite resistant
	Cederella odorata	Drought resistant
Land rehabilitation	*Acacia mearnsii*	Termite resistant, drought resistant
	Terminalia brownii	Termite resistant, drought resistant
	Terminalia superba	Termite resistant, drought resistant
Poles	*Markhamia lutea*	Termite resistant
	Acacia mearnsii	Termite resistant, drought resistant
	Grevillea Robusta	
Medicine	*Azadirachta indica*	Termite resistant, drought resistant
	Melia azedarach	Termite resistant
	Callistemon citrinus	
	Spathodea nilotica	
	Combretum molle	Termite resistant, drought resistant
	Terminalia brownii	Termite resistant, drought resistant
	Moringa oleifera	Drought resistant
Wind break	*Markhamia lutea*	Termite resistant
	Grevillea Robusta	
	Casuarina equisetifolia	Competitive
Ornamentals compound	*Terminalia brownii*	Termite resistant, drought resistant
	Callistemon citrinus	
	Casuarina equisetifolia	Competitive
	Terminalia mantally	
	Spathodia nilotica	
Bee forage	*Markhamia lutea*	Termite resistant
	Callistemon citrinus	
	Calliandra calothyrsus	
	Albizia chinensis	
	Cordia africana	Termite resistant
Live fences	*Dovyalis caffra*	
	Calliandra calothyrsus	
	Gliricidia sepium	Termite resistant, drought resistant

Table: Some of the agroforestry tree species in East Africa.

6.3 Common agroforestry systems

An agroforestry system is a distinct use of different agroforestry practices in different location and over a certain period of time. The most common systems are discussed below.



Trees can be planted in different ways. Four land use agroforestry practices are:

- Woodlot
- Fruit orchard
- Dispersed interplanting
- Boundary planting

Different practices can be used in the agricultural systems:

- Alley cropping/hedgerow in cropland
- Trees and perennial crops
- Wind trees
- Contour tree
- Fodder banks
- Home and tree garden
- Shade tree systems
- Improved fallows

Illustration: Agroforestry - systems, land use and practices

6.3.1 Planting trees among crops - agrisilviculture

Planting trees among crops is known as agrisilviculture. Examples of practices are dispersed interplanting (see 6.2.3), trees with perennial crops and alley cropping.

a. Alley cropping (hedgerows in cropland)

Alley cropping is the growing of annual crops or forage between rows of trees or shrubs to form hedgerows. This practice improves soil characteristics and fertility. Alley cropping can be done in areas with flat to gently rolling terrain.

Think about

Examples of shrubs to be planted within crop land include *Sesbania Sesban, Gliricidia Sepium* or *Calliandra* species.

The benefits of alley cropping include:

- Controls soil erosion
- Trees shelter crops from wind damage
- Trees sequester carbon dioxide

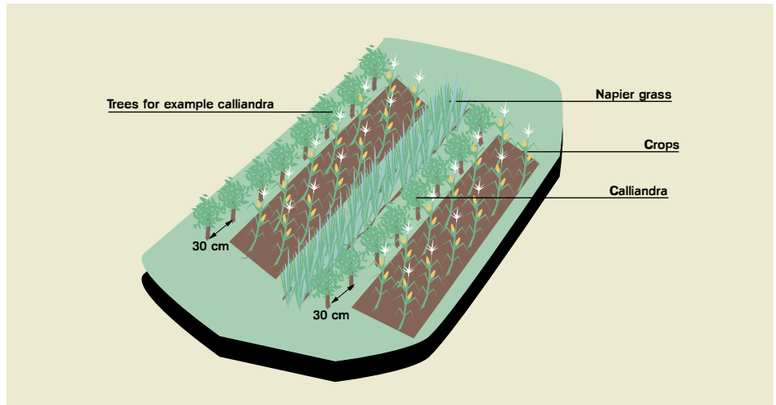


Illustration: Alley cropping

b. Trees with perennial crops

Trees can be grown in combination with other perennial crops such as coffee, sugarcane and tea. This system provides land use with strong build-up soil, organic matter, multiple or intercropping, mulch and extended rotation. Because crops are permanent there is little re-planting. Hence there is minimal disturbance of soil and thereby, more carbon is sequestered in the soil.

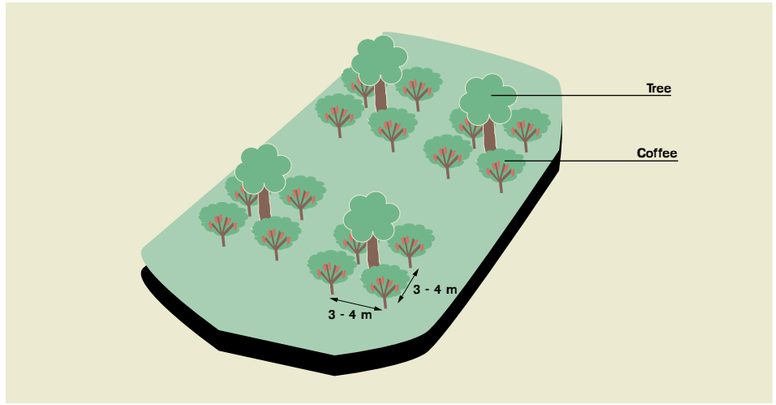


Illustration: Trees with perennial crops

c. Wind trees

Wind trees, also known as wind breaks or shelter, are planted to slow down wind speed. The trees should be of different heights, and should be planted alongside bushes and grasses. Wind trees should not have gaps as wind can be channelled through the gaps creating a destructive tunnel of high winds.

Note: Especially fruit trees, coffee plants and maize need to be sheltered from heavy wind. Wind that damage trees and crops tend to come from specific direction – study your farm and consider the wind directions.

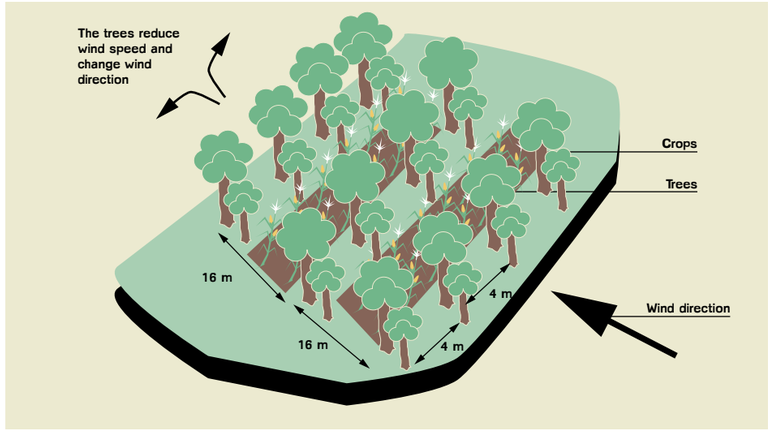


Illustration: Wind trees

d. Contour trees

Contour trees are planted on sloping land for the purpose of soil and water conservation. The trees reduce runoff speed, increase infiltration, increase vegetation cover, control soil erosion and largely sequester carbon into soil.

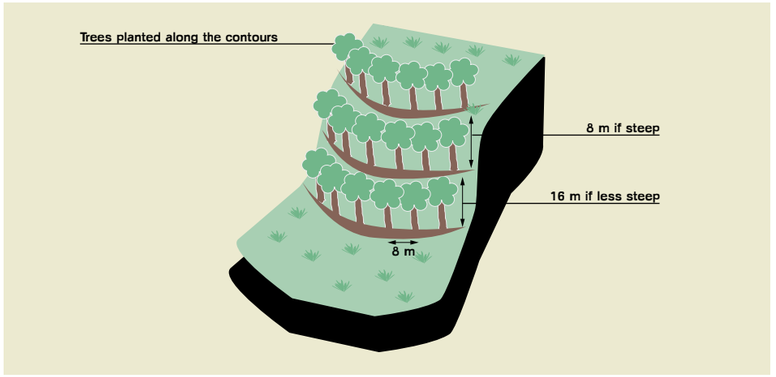


Illustration: Contour trees

e. Home gardens

A home garden is a tree field with various trees (fruit, fodder, timber and medicinal trees) and crops planted together. It is located either close to the homestead or a nearby cropland to provide different plant and animal products. The trees sequester carbon, provide shelter, provide products, and improve soil fertility.

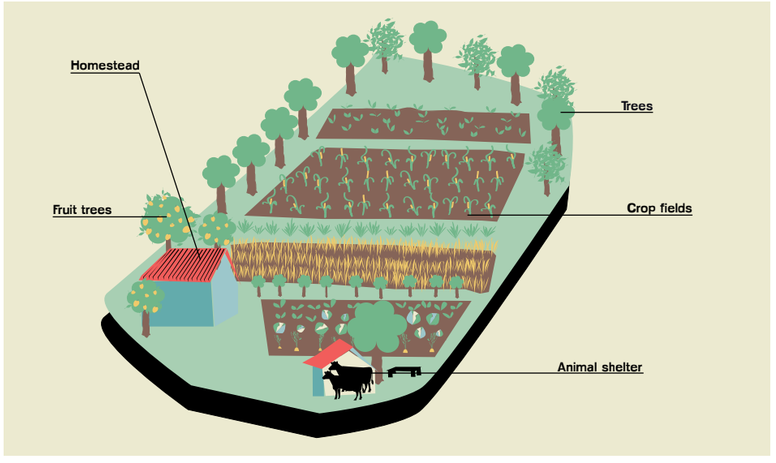


Illustration: Home garden

f. Shade trees

A shade tree system uses selected trees with good canopies to provide shade for livestock, compound and delicate crops against sun scorches. Mostly coffee, fruit trees and bananas require some trees for shade. Example of tree species are *Markamia lutea*, Mango, *Albicia, Acacia xanthophloa.*

g. Improved fallows

Improved fallows is the targeted use of a fast-growing tree species to obtain the benefits of a natural fallow. Nitrogen-fixing trees and shrubs are planted with the main aim of improving nutrient input into soil, by fixing nitrogen and adding organic matter to the soil. The practice is common where land is regularly fallowed especially in semi-arid areas. The trees are planted for 1-3 years, then harvested and the field is planted with high value crops.

6.3.2 Trees with pastures/livestock - silvopastures

Trees with pastures or livestock is a practice concerned mainly with the management of trees, forage and livestock. It is also known as the parkland system or silvopasture.

Silvopastures can be established where the land can support both trees and forage growth at the same time. The trees can be evenly distributed throughout the land to optimize space and light for both trees and forage, or grouped into rows or clusters to open up space for pasture and concentrate shade and root effects.

The animals within this system can be allowed to graze freely or zero-grazed (cut-and-carry system). If managed in a sustainable way, grazing of fallows can particularly enhance soil fertility regeneration.

Silvopasture provides relatively constant income from livestock and livestock products, plus a variety of fruit, tree and timber products.

a. Fodder banks

Fodder bank is a crop field with a variety of suitable and highly nutritious grasses, leguminous crops, trees and shrubs planted in a systematic way to feed livestock such as dairy cows throughout for high quality milk. It is a fodder agroforestry system that involves establishing trees into hedges, blocks or strip cropping, napier grass planting, vines, grass and paddocking (for zero grazing). Established trees provide feeds and manure, litter, humus, fix nitrogen into the soil, improve soil structure and fertility, and control erosion.

Some trees can provide essential feeds and improve the diet of livestock, which if well managed can increase livestock productivity e.g. milk production, as a result of feeding on improved fodder, i.e. increased protein and water intake through the plants as well as manage the agricultural GHG emissions (especially methane) produced by livestock. The ability of some legumes to fix atmospheric nitrogen makes them protein-rich feeds. Improved breeds are encouraged to reduce the number of livestock owned and manage livestock with minimal expenditures and increased productivity.

The relatively deep roots of the woody perennials allow the trees to reach soil nutrients and moisture not available to grasses and herbaceous plants. This characteristic enables the grasses and plants to retain fresh foliage into the dry season.

Fodder banks can be established through direct seeding or cuttings.

Think about

The commonly used fodder bank plants and trees/shrubs include: *Calliandra spp, Sesbania sesban, Gliricidia sepium, Moringa oleifera, Leucaena leucocephala* and *Cajanus Cajan*, and grasses such as napier grass and/or legume crops such as *desmodium, lucern*.

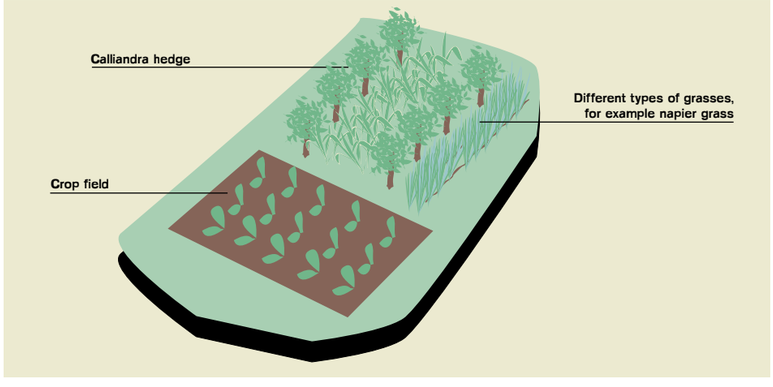


Illustration: Fodder bank

6.3.3 Trees with a mix of crops and livestock - agrisilvopastoral

Trees with a mix of crops and livestock is called mixed farming or agrisilvopastoral.

The trees provide shade for crops and livestock, and absorb carbon dioxide produced by the crops and livestock. The trees also act as wind breaks, preventing crop damage.

The livestock provide manure for both the trees and crops. The livestock can feed on some of the crops. The crops can provide compost and mulch.

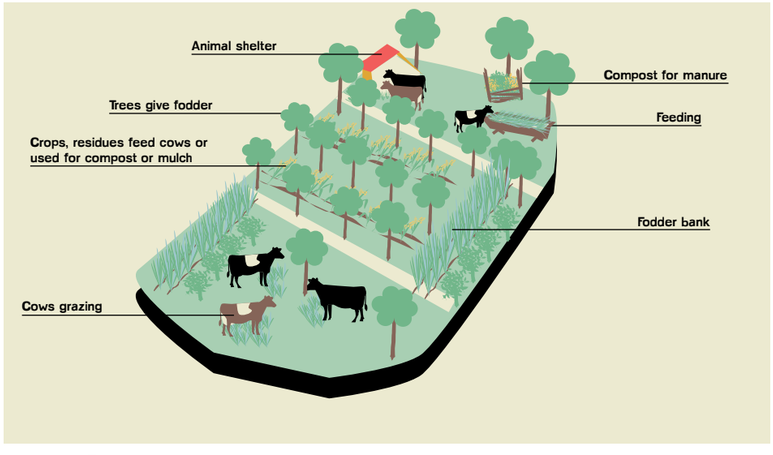


Illustration: Trees with a mix of crops and livestock

6.3.4 Trees and insects - apiculture and sericulture

Trees and insects together is also known as entomosilviculture. Two common forms are apiculture and sericulture.

a. Bee-keeping (apiculture)

Apiculture is the rearing of bees for honey products, using trees for shade and bee-forage. It can be a source of income from selling the honey produced, and honey is also a source of nutrition.

The benefits of bee-keeping include:

- Hive products such as medicine from propolis, wax, honey, royal jelly, venom (poison from the bee to be used for organic pesticides).
- Source of income.
- Pollination, which boosts plant production.
- Not very labour intensive.
- Not very demanding enterprise.
- Requires little capital.
- Few materials/inputs needed.

Factors to consider in bee-keeping:

- Permanent water supply.
- Presence of trees for shade and forage (such as *Gliricidia*, *Calliandra*, *Markhamia lutea, Grevillea Robusta*, mango).
- Area free from noise, wind and pollution.

If you are interested in bee-keeping, you can buy or build a bee-hive.

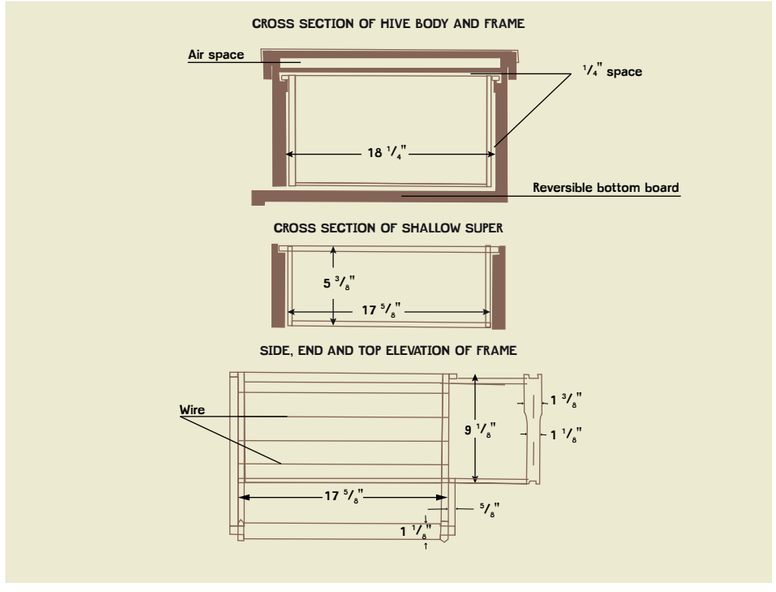


Illustration: How to build a langstroth bee-hive - Part 1

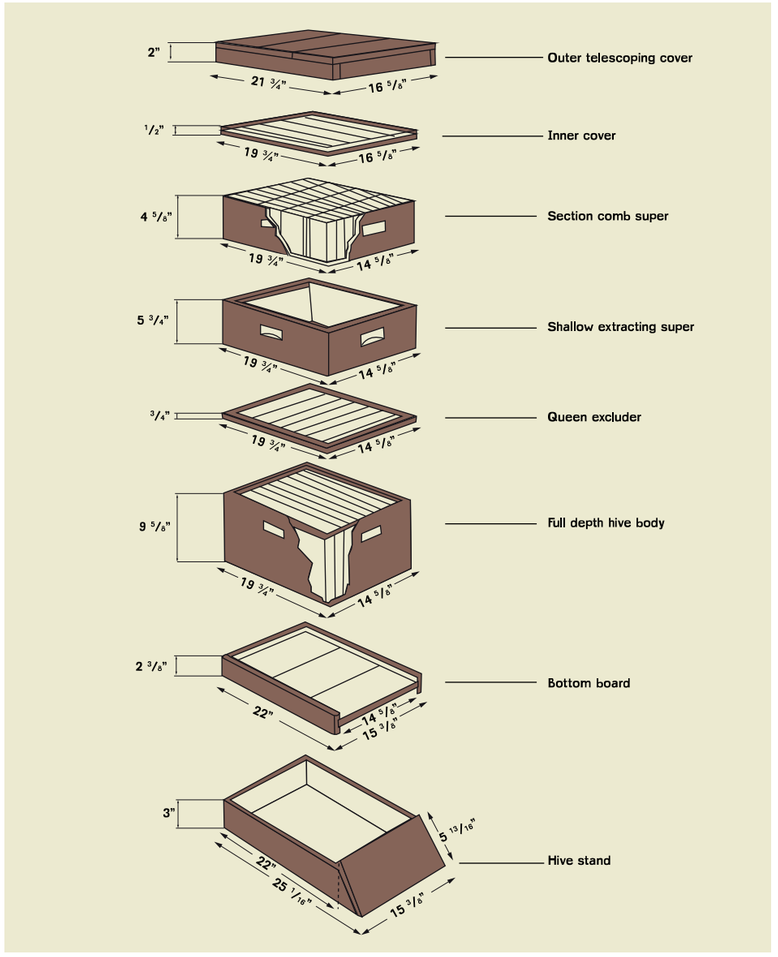


Illustration: How to build a langstroth bee-hive

b. Silkworms (sericulture)

Sericulture is the production of raw silk fiber by rearing the larvae of domesticated silkworms (*Bombyx mori*). The silk is used for making clothes. Silk production involves two processes:

1. Caring for silkworms from the egg stage to the completion of the larvae stage (when cocoon is completely formed).
2. The growing and maintaining of mulberry trees. The silkworm feeds on the leaves of this tree.

Silk production provides alternative income for the farmer.

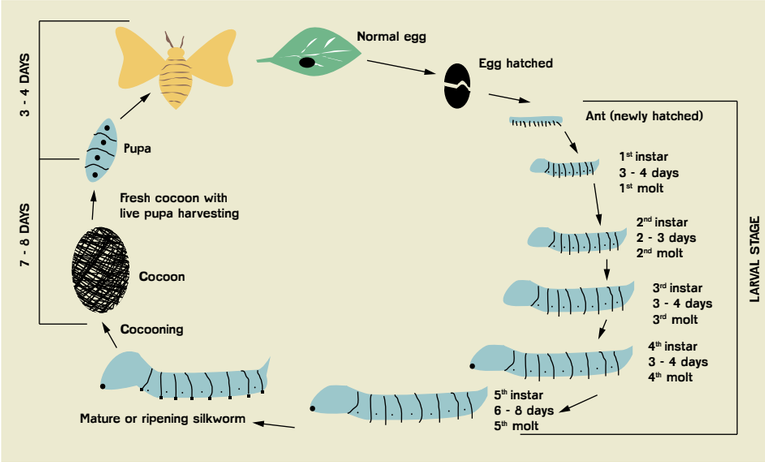


Illustration: Silk production

6.3.5 Trees and water animals - aquasilviculture

Aquasilviculture is an agroforestry system that combines trees and water animals. It involves planting and/or maintaining belts of trees and shrubs in areas bordering lakes, streams, rivers and wetlands containing fish. For example, selected tree species are planted to interact with fish ponds. The trees provide leaves to feed the fish and manure for the pond to generate plants that fish can feed on.

Think about

Example of trees to be planted: *Calliandra, Sesbania sesban, Gliricidia sepium.*

The benefits of aquasilviculture include:

- Alternative livelihood to fishing communities. Fish farmers can harvest fish and mud crabs, and at the same time get fruits from trees.
- Conservation of ecosystems at coastal areas and rivers, and related wildlife.
- Protection of water and river resources.

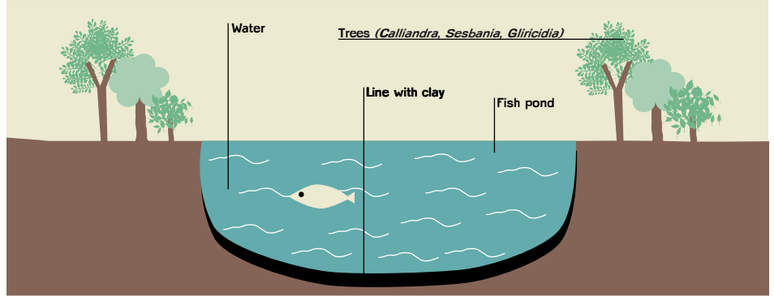


Illustration: Fish farming

6.4 Common agroforestry land use

There are four major land use practices within agroforestry. In this context, land use refers to how you choose to plant the trees and how they interact with the crops.

Tree species

The following table summarises the main tree species in various major lands use agroforestry systems in East Africa.

WOODLOTS	FRUIT ORCHARD	DISPERSED PLANTING	BOUNDARY PLANTING
Casuarina equisetifolia	*Mangifera indica*	*Grevillea Robusta*	*Markhamia lutea*
Albirzia lebbeck	*Citrus limon*	*Albirzia coriara*	*Casuarina equisetifolia*
Markhamia lutea	*Persea Americana*	*Albirzia lebbeck*	*Acacia xanthophloea*
Cedrela odorata	*Artocarpus heterophyllus*	*Acrocarpus fraxinifolius*	*Maesopsis emnii*
Acacia nilotica	*Psiduim quajava*	*Podocarpus falcatus*	*Grevillea Robusta*
Acacia xanthophloea	*Syzygium cumnii*	*Prunus Africana*	*Leucaena leucocephala/ Calliandra calothyrsus*
Acacia polyacantha	*Pasiflora edulis*	*Cordia Africana*	*Senna siamea*
Maesopsis emnii	*Eriobotrya japonica*		

Table: Tree species for different land uses

Factors to consider when selecting tree species for agroforestry:

CHARACTERISTICS	BENEFITS
Multi-purpose	Provide products such as firewood, fodder, poles, green leaf manure, medicine.
Growing	Fast growing, increased production of biomass.
Rooting system	Deep-rooted so that they do not affect other crops.
Competition	Non-competitive for plant space, nutrients, air, light and water.
Re-growth	Grows back after cutting.
Nutritious and tasty	Fodder for livestock, non-poisonous, soft leaves.
Canopy	Light can penetrate but still give shade.
Nitrogen	Nitrogen-fixing, improve soil fertility.
Economic	Produce saleable products (fruits, timber, firewood).
Environmental	Do not overtake other species, indigenous, promote biodiversity, adaptable, compatible with the landscape.

Table: Agroforestry trees and characteristics

6.4.1 Woodlots

Woodlot refers to a cluster of trees grown together to produce timber, poles, or fuel wood (firewood and charcoal) and support other systems like bee-keeping, livestock and crop production. Woodlots are grown on agricultural land.

Woodlots form high carbon pools (made of tree stems, roots, litter and organic matter). It is advisable to plant a variety of indigenous tree species for high carbon sequestration and to conserve biodiversity. As a complement, you can also plant exotic agroforestry trees if they are adaptive to the local setting.

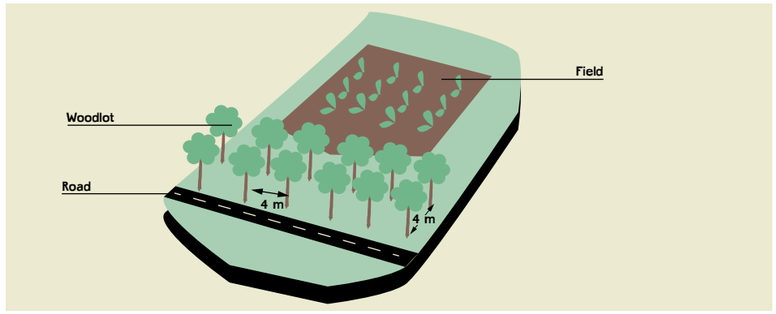


Illustration: Woodlot

6.4.2 Fruit orchards

Fruit trees can be planted as orchards (cluster of fruit trees) or scattered in the farm for home use or for selling. The leaves, seeds, fruits, nuts of fruit trees provide food with high nutrition value, medicine and other products. Choose trees that grows well in your area.

6.4.3 Dispersed inter-planting

In dispersed inter-planting, trees are grown in a systematic way in fields alongside crops to provide food, fuel wood, building poles, fodder or gum. The trees also provide nutrients and organic matter for the soil, and shade for crops and livestock.

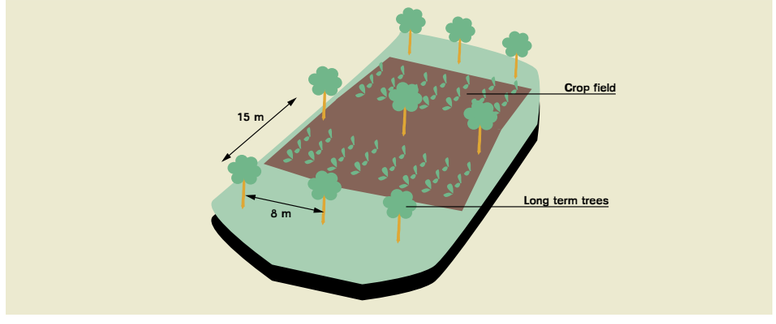


Illustration: Dispersed inter-planting

6.4.4 Boundary planting

Boundary planting involves planting selected trees along field boundaries, hedges, borders and roadsides. The trees can create micro-climate for crops, create windbreaks, stabilise the soil, and sequester significant amounts of carbon.

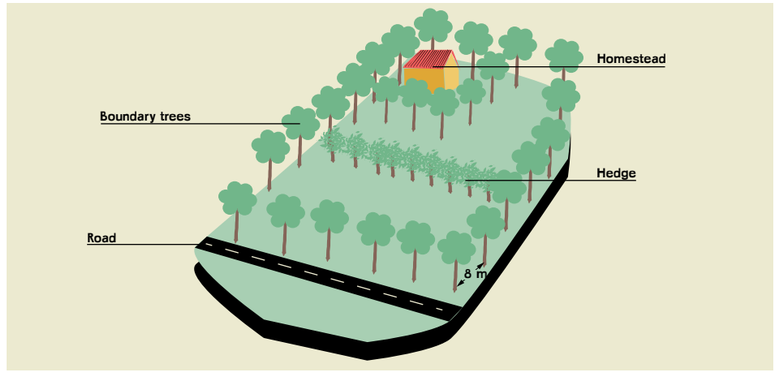


Illustration: Boundary planting

EXERCISE

1. **Describe the agroforestry practices you are currently having on your farm.**
2. **What benefits do you derive from your farm?**

6.5 Nursery and seed management

A tree nursery is a place, on the farm or away from it, where tree seedlings are bred and grown to a desired, usable size. The plants can be used on your farm or sold to others, providing extra income for the family. Nurseries offer ready access to new tree seedlings at a low cost. Seedlings grown in a nursery, are more likely to survive, than seeds sown directly. This is because the seedlings are already established.

6.5.1 Benefits of on-farm nurseries

- You can grow the desired tree species and number of seedlings.
- Income generation opportunities from selling seedlings.
- Cost efficient - cheap to establish and manage.
- Availability of seedlings throughout the year.
- Possibility of using locally available materials for planting.
- Nurseries can be used as teaching material for schools and groups.

6.5.2 Location of tree nursery

The following factors determine the location of a nursery on a farm:

- Reliable water supply.
- Accessibility and near the farm.
- Availability of good soils.
- Protection from strong wind, direct sunlight (shade) and livestock.
- Gentle slope for water drainage.
- Area free for expansion.

6.5.3 Soil preparation

Nursery soil should be fertile and well-drained. It should also be collected, preferably, from some identified part of the farm such as under some trees or along the fence since it is here that most of the core soil nutrients are stored. Before digging topsoil for nursery use, clear the surface to remove all plants and litter. Dig using a hoe and then sieve the soil to remove undesirable materials such as stones and sticks. Mix two portions of the sieved soil with one portion of sand and one portion of manure. This is the soil to use for the next step, potting.

6.5.4 Potting

Potting is the process of putting soils into the containers or bags for the purpose of raising and protecting seedlings to maturity. Locally available materials e.g. milk packets, used tins, calabashes and clay can also be used as containers. You can also buy ready-made potting material such as special black polythene bags.

Instructions:

1. Take the soil mixture and moisten it by sprinkling some water on it. Ensure that the soil is neither too dry nor too wet.
2. Put the moist soil into the containers in such a way that lower part (¾) of the container is slightly pressed while the soil in the upper quarter is loose. Remember, heavy compaction at the top makes seed sowing difficult and inhibits root penetration.
3. Ensure the containers are open at both ends or have holes at the bottom to allow movement of water and healthy root development.

6.5.5 Sources of tree seeds

Seeds can be collected from healthy trees, from other farmers or acquired from relevant institutions such as the Kenya Forestry Research Institute (KEFRI), Country Forest Services (Departments), non-governmental organisations, community-based organisations, and authorised seed vendors.

How to collect seeds:

1. Find a good example of the tree that looks healthy, without diseases.
2. Pick seeds that are not rotten or damaged (neither the pods or the seeds).
3. Process the seeds (see table)
4. Pre-treat the seeds (see table)
5. Now the seeds are ready for sowing.

TREE SEEDS SPECIES	METHOD OF PROCESSING THE SEED	PRE-TREATMENT METHOD	GERMINATION PERIOD	PLANTING METHOD
Terminalia mantally	Drying under the shade	Soak in boiled hot water overnight	7 - 20 days	Direct sowing/ nursery
Terminalia superba	Drying under the shade	Remove wings and soak seeds overnight in boiled hot water	21 - 40 days	Direct sowing/ nursery
Toona ciliata	Drying in the sun	Not necessary	5 - 7 days	Nursery and put in pots 3 - 6 months
Acacia nilotica	Drying in the sun and crushing the pods	Soak in boiled hot water overnight	5 - 7 days	Direct sowing/ nursery
Acacia polyacantha	Drying in the sun and crushing the pods	Soak in boiled hot water overnight	5 - 7 days	Direct sowing/ nursery
Acrocarpus flaxinifolius	Drying in the sun and crushing the pods	Soak in boiled hot water overnight	7 - 20 days	Direct sowing/ nursery
Albizia chinensis	Drying in the sun and crushing the pods	Soak in boiled hot water overnight	8 - 30 days	Direct sowing/ nursery
Albizia coriaria	Drying in the sun and crushing the pods	Soak in cold water overnight	8 - 30 days	Direct sowing/ nursery
Albizia gummifera	Drying in the sun and crushing the pods	Not necessary	7 - 15 days	Direct sowing
Albizia lebbeck	Drying in the sun and crushing the pods	Soak in boiled hot water overnight	5 – 7 days	Direct sowing/ nursery
Alnus acuminata	Drying in the sun and crushing the pods	Plant immediately after harvest	6-15 days	Nursery

Table: From seed to tree - 1

TREE SEEDS SPECIES	METHOD OF PROCESSING THE SEED	PRE-TREATMENT METHOD	GERMINATION PERIOD	PLANTING METHOD
Azadirachta indica	Drying in the sun and crushing the pods	Soak in cold water for 48 hrs	8 - 28 days	Direct sowing/ nursery
Cajanus Cajan	Drying in the sun and crushing the pods	Not necessary	5 – 7 days	Direct sowing
Calliandra callothyrsus	Drying in the sun and crushing the pods	Soak in boiled hot water for 12 hrs	4 - 10 days	Direct sowing
Callistemon citrinus	Drying in the sun and crushing the pods	Not necessary	20 - 28 days	Nursery
Carica papaya	Cut the fruit and expose the seeds	Soak in cold water for 12 hrs	7 days	Direct sowing/ nursery
Casuarina equisetifolia	Cones are sundried and turned regularly to release seeds	Not necessary	10 - 15 days	Nursery
Cedrela odorata	Drying in the sun and crushing the pods	Not necessary	5 - 7 days	Direct sowing/ nursery
Chlorophora excelsa	Drying under shade	Not necessary	21 - 60 days	Nursery
Citrus reticulata	Softening in cold water for 12 hours and then drying in the sun	Not necessary	10 - 15 days	Potting
Citrus sinensis	Seeds must not be more than 3-4 weeks old	Soak in boiled hot water overnight	3 weeks	Direct sowing
Citrus sinensis	Softening in cold water for 12 hours and then drying in the sun	Not necessary	10 - 15 days	Nursery and put in pots 3 - 6 months
Cordia africana	Drying in the sun	Soak in cold water for 12-24 hours	30 - 60 days	Direct sowing/ nursery
Croton megalocarpus	Crush the pods and sort them	Not necessary	6 - 60 days	Direct sowing
Cyphomandra betacea	Wash and dry in the shade	Soak in boiled hot water overnight	4 - 6 days	Nursery

Table: From tree to seed - 2

TREE SEEDS SPECIES	METHOD OF PROCESSING THE SEED	PRE-TREATMENT METHOD	GERMINATION PERIOD	PLANTING METHOD
Grevillea Robusta	Drying in the sun and crushing the pods	Soak in boiled hot water for 24 hrs	8 - 30 days	Nursery
Grilicidia sepium	Drying in the sun and crushing the pods	Soak in boiled hot water overnight	7 -10 days	Direct sowing. (If you do not plant by seed, you can plant a cutting with bud directly).
Hibiscus sabdariffa	Drying in the sun and crushing the pods	Not necessary	4 - 7 days	Direct sowing
Khaya anthotheca	Drying in the sun	Not necessary	7 - 30 days	Direct sowing/ nursery
Leucaena diversifolia	Drying in the sun and crushing the pods	Soak in boiled hot water for 4 hrs		Direct sowing
Leucaena leucocephala	Drying in the sun and crushing the pods	Soak in boiled hot water	4 - 15 days	Direct sowing
Maesopsis eminii	Depulping (removing flesh)	Soak in cold water for 12-72 hours	24 - 90 days	Direct sowing/ nursery
Markhamia lutea	Mature capsules are dried in the sun to extract the seeds	Not necessary	4 - 20days	Direct sowing
Moringa oleifera	Capsules are dried in the sun and seeds ex-tracted manually	Not necessary	9 - 30 days	Direct sowing
Persea americana	Using fresh seeds	Disinfection with hot water	4 - 6 weeks	Direct sowing, grafting, nursery
Podocarpus usambarensis	Depulping (removing flesh)	Crack seeds	23 - 100 days	Direct sowing/ nursery
Prunus africana	Depulping (removing flesh)	Soak in cold water overnight	10 - 30 days	Direct sowing/ nursery
Psidium guajava	Softening in water and drying in the sun	Not necessary	5 - 7 days	Direct sowing/ nursery

Table: From tree to seed - 3

TREE SEEDS SPECIES	METHOD OF PROCESSING THE SEED	PRE-TREATMENT METHOD	GERMINATION PERIOD	PLANTING METHOD
Senna siamea	Drying in the sun and crushing the pods	Soak in cold water overnight	8 - 30 days	Nursery
Sesbania sesban	Drying in the sun and crushing the pods	Soak in cold water overnight	7 days	Direct sowing
Tephrosia vogelii	Drying in the sun and crushing the pods	Soak in cold water overnight	8 - 10 days	Direct sowing
Tephrosia vogelii	Drying in the sun and crushing the pods	Not necessary	4 - 4 days	Direct sowing
Terminalia brownii	Drying under the shade	Remove wings and soak seeds in cold water overnight	10 - 90 days	Direct sowing/ nursery
Terminalia catapa	Sorting and drying	Soak in boiled hot water overnight	20 - 30 days	Direct sowing/ nursery

Table: From tree to seed - 4

6.5.6 Seed sowing

The time for sowing a specific type of seed depends on the time it takes to attain plantable size, this takes normally 1-3 months depending on tree species. It is important that seeds are sown in time to attain plantable sizes 20-30 cm by the onset of the rainy season.

Seed can either be sown directly into potting material or in transplant beds (for example in a sunken bed). Big seeds such as mango, avocado, neem, *Syzgium, Sesbania sesban* and kei apple can be sown directly into the field. They do not have to be potted first and bred in the nursery. Fine and light seeds such as *Casuarina, Grevillea Robusta, Markhamia lutea, Prunus africana* are sown in transplant beds and later pricked out into potting containers after germination. It is important that fine seeds are mixed with sand and uniformly spread on the seed bed to avoid overcrowding as overcrowding leads to diseases. Do not sow the seed too deep in the soil as this is likely to affect seed germination.

6.5.7 Seed germination bed preparation

A seed germination bed is a place where seed are sown for purposes of germination. There are several types of beds: sunken beds, raised beds, and other containers.

a. Sunken beds

A sunken bed is a basin like excavation, 1 m wide and 5 cm deep, in which seeds are planted. Such a structure holds the seedlings together, and help to conserve moisture. Sunken beds are commonly used in dry areas.

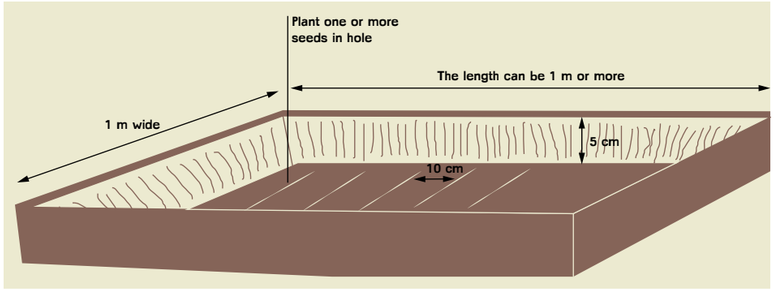


Illustration: Sunken beds

b. Raised beds

A raised bed is a structure of soil in which the soil is held in place using materials like banana stems. The width of a raised bed is 1m, the height 10 cm. A raised bed is most preferable in high rainfall areas. The bed enables you to manage the roots so that they don't grow too deep.

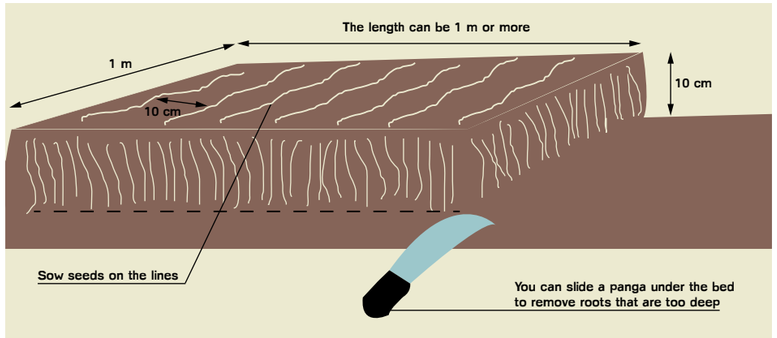


Illustration: Raised beds

6.5.8 Pricking out

Pricking out is the process of transferring young and tender seedlings from seedbeds into potting containers following this sequence of activities:

1. Water the seedbed properly before pricking out.
2. Take an empty basin and fill with water to ¾ level.
3. Hold the leaves of the seedlings and insert a sharp tool (pencil or small stick) underneath the root system to loosen the soil.
4. Pull out the seedlings gently and immediately put them in to the basin with water.
5. Water the pots before transplanting the seedlings.

6. Make a hole at the center of the pot using sharp tool (pencil or small stick).
7. If the roots are too long clip off the tip, insert the root system gently in the hole while holding the seedlings by the leaves. Do not hold the stem of the seedling because they are tender and feeble – this may injure the seedlings.
8. Hold the sharp tool (pencil or small stick) in the tilling position and insert it in the soil about one centimeter away from the seedling to the same depth as the hole.
9. Push the soil towards the seedling to hold it tightly. This ensures that all the air pockets around the roots are closed; using your fingers cover the hole you made; water the pots properly and shade the seedlings.

6.5.9 Shading and watering

Both during germination period and raising the seedling, shading is necessary. Use locally available materials such as grass, mats, or banana fibres for shade construction.

Water seeds and seedlings twice a day, early in the morning and evening, when the sun is not hot. Watering may be done once or skipped altogether during the rainy season. Take care not to under-water or over- water the plants. Use adequate amount of water, i.e. 20 litres for 1,000 seedlings. Use a watering can which doesn't damage the seedlings. Avoid the direct use of hosepipes while watering the seedlings as this may wash away the soil.

6.5.10 Weeding

Weeds are a threat to healthy seedlings development as they compete with seedlings for nutrients, water and light. Weeds also cause diseases to the seedlings. Control weeds by gentle pulling out of the unwanted growth (rouging) whenever the weeds are observed sprouting from the pots. You can also use your fingers to weed by gently disturbing the soil, or a small stick.

6.5.11 Root pruning

Root pruning is the cutting of the roots to control the root system development beyond the container. It is done when the roots become longer than the depth of the pots. Roots that are not pruned will penetrate into the ground and develop a root system.

Water the seedlings properly before root pruning. Use a sharp knife or wire to cut the long roots underneath the container. You can also uplift the pots (wrenching) to cut overgrown roots. Water the seedlings well after root pruning to help the plant withstand moisture stress. Root pruning should be done regularly preferably every 2 - 3 weeks.

6.5.12 Hardening off

Hardening off is the gradual preparation of seedlings for field conditions. Hardening-off should be done 2 - 3 weeks before transplanting. It involves the reduction in watering intensity, frequency and exposure to more sunshine. Good preparation for transplanting results in good field survival.

6.5.13 How to plant a tree

For most trees, the right time to plant is during the long rainy season. Get a note book to record every detail of the tree and make sure you have all the materials and requirements available before planting.

1. **Choose a suitable species** for the area. Select healthy seedlings.
2. **Choose the agroforestry system/practice** you want have on your farm, for example woodlot, dispersed interplanting, boundary etc. Demarcate the areas with right measurements and mark with sticks where to plant the trees.
3. **Prepare the holes:**
   - For soft soils, dig a round hole: 20 cm diameter wide and 30 cm deep.
   - For hard soils, dig a rectangular hole, to let roots penetrate through the corners: 50 cm width, 50 cm deep.

     Note: If you plant a seed (spot planting), dig a small rectangular hole (30 deep and 20 cm wide). If you plant a cutting with a bud (for example for hedges), dig 30 cm deep. Follow the instructions below regarding soil preparations.

   - Separate top soils (10 cm depth) from sub soils.
   - Leave the holes to stay for 7 days – 3 months depending on tree species.
4. **Prepare the soil and manure:**
   - Mix top soil and subsoil (ratio 2:1), make a fine mix by crushing crumbs.
   - Mix the soil mixture with well composted manure or compost (ratio 1:2).
   - Fill the hole completely with the mixture.
   - Leave the filled hole 1 – 3 days.
5. **Plant the seedling:**
   - Time the rains onset well, plant 1 - 7 days before raining.
   - Water the hole with slow flow of water (20 l) in the morning or evening.
   - Open a hole depending on the size of the seedling and species.
   - If your seedling is in a black polyethylene bag, cut of the bottom if closed. Be careful not destroying the roots.
   - Place the seedling gently in the hole, half down the stem.

     Note: Plant seeds 5-10 cm deep. Plant cuttings 30 cm apart and 10 cm deep.

   - Return the soil to cover the hole and flatten.
   - Water the seedling until it is saturated.
6. **Managing the growing planted tree:**
   - Spread compost/manure around the plant.
   - Mulch with dried residues.
   - Shade the plant against the sun.
   - Weed the plant regularly.
   - Prune if necessary.
   - Water twice a day if rain is not falling.
   - Spread ash around to scare away ants and termites.

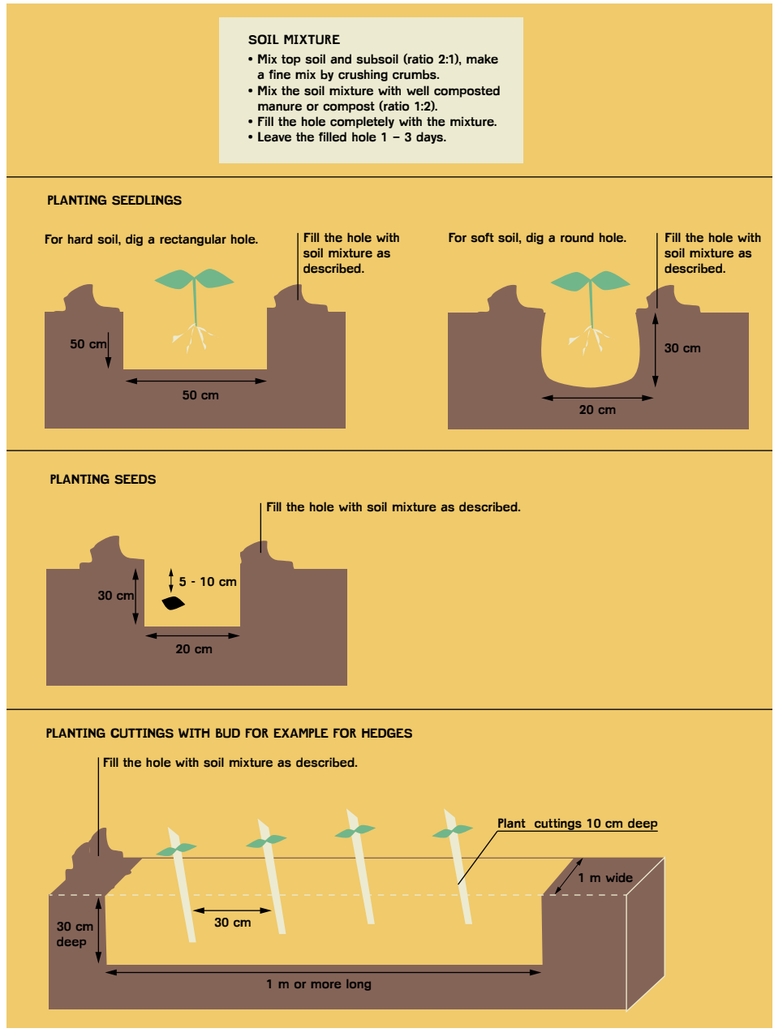


Illustration: How to plant a tree: seedlings, seeds and cuttings with buds.

EXERCISE

1. **Have you ever had a nursery on your farm? If so, where on the farm did you place it? Why did you establish it? Pull out the map of your farm and draw where you would like to put the tree nursery.**
2. **What are some of the benefits that you have had since you started your nursery?**

7. Tillage and residue management

Introduction

This chapter demonstrates how the integration of residue management and reduced tillage can sustainably manage agricultural lands to increase productivity, resilience to effects of climate change and increase soil organic matter. As a farmer you have significant amount of crop residues and litter from trees that you can use to mulch the farm. By the end of this chapter you will understand different tillage operations as well as the importance of residues in supporting tillage.

Time required: 4 hours

7.1 Conservation agriculture

Conservation agriculture is the way in which crops can be grown in a sustainable way while conserving the environment. Conservation agriculture is based on three core principles:

1. Permanent soil cover with mulch or crops residues (residue management), to protect the soil.
2. Minimal soil disturbance during tillage.
3. Crop rotation.

Think about

CROP RESIDUE MANAGEMENT AND CORRECT TILLAGE CAN:

- **Increase crop productivity.**
- **Reduce weeds.**
- **Reduce cost of production.**
- **Improve soil conditions such as structure and nutrients.**
- **Enhance soil moisture retention and infiltration.**
- **Reduce soil disturbance and hence reduce soil erosion.**
- **Increase climate resilience.**
- **Increase soil organic matter (carbon sequestration).**

7.2 Residue management

Residue management refers to the sound handling and utilisation of plant and crop residues that combines mulching, composting, integrative manure and livestock management. Plant residues are a major source of carbon in soil. The residue should be distributed uniformly over the soil surface. The residues can be used as trash lines or mulch (see also chapter 3 and 4). But residues can also be used for feeding livestock. Manure from the livestock can then be collected and used on the farm.