Sustainable Agriculture Land Management

Amos Wekesa and Madeleine Jönsson

Vi Agroforestry

VI AGROFORESTRY

Vi Agroforestry is a Swedish development organization, fighting poverty and improving the environment through tree planting. We do this together with farmers and farmers' organisations in the Lake Victoria basin in East Africa. The foundation of Vi Agroforestry's work is agroforestry – planting trees and crops together. It provides increased access to food, more income and protection against the negative effects of climate change. Since its inception in 1983, the organization has helped to plant 100 million trees and improved the lives of 1.8 million people.

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We Effect (formerly Swedish Cooperative Centre) is a development cooperation organisation that has acted and worked with a long-term approach since 1958 in order to effect change. Help to self-help is our guiding principle – in 25 countries on four continents. Our areas of focus include Rural development, Housing, Gender equality and Access to land. We Effect works in partnership with member-based cooperative organisations, other democratic associations or informal groups working to achieve common goals.

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Originally written by: Amos Wekesa (Vi Agroforestry), Madeleine Jönsson (We Effect).
Project coordinator: Linda Andersson (Vi Agroforestry).
Compiled by: Roselyne Omondi (Independent Editorial Professional).
Illustrations, design and layout by: Avocado Design Studio Ltd.
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Foreword

CLIMATE CHANGE with uncertain weather conditions constitute one of the main challenges for small-holder farmers in the East African region. Vi Agroforestry works with farmers and farmers' organisations to increase their environmental awareness, helping farmers to adapt to climate change, increasing the use of sustainable energy and prevent and reduce the effects of natural disasters caused by climate change.

Sustainable Agriculture Land Management (SALM) is a methodology for farmers to adapt to the impacts of climate change or to reduce such risks upon farmers' productivity. The practices can be used in different climate or agro-ecological zones. Certain SALM practices can also be adopted in urban areas, e.g. green gardening, agronomic practices, renewable energy solutions, and water and waste management. This material includes practices that farmers can use to take small realistic steps to ensure productivity and profitability.

The purpose of the manual is to guide farmers to adopt the practices in their crop and livestock management systems. This manual includes modules on SALM practices, such as agroforestry, nutrient management, integrated livestock management as well as soil and water conservation. Each module contains an overview of the topic, descriptions on how to implement the specific techniques, and suggested exercises.

This SALM training manual has been developed by Vi Agroforestry and We Effect. Madeleine Jönsson, We Effect and Amos Wekesa, Vi Agroforestry are appreciated for the process of developing this guide. We would also like to thank Linda Andersson and Roselyne Omondi for their work on this publication.

We hope the manual will improve the ability of farmers and farmers' organisations to implement SALM practices and ultimately achieve our goal *"A sustainable environment that enables people in poverty to improve their lives."*

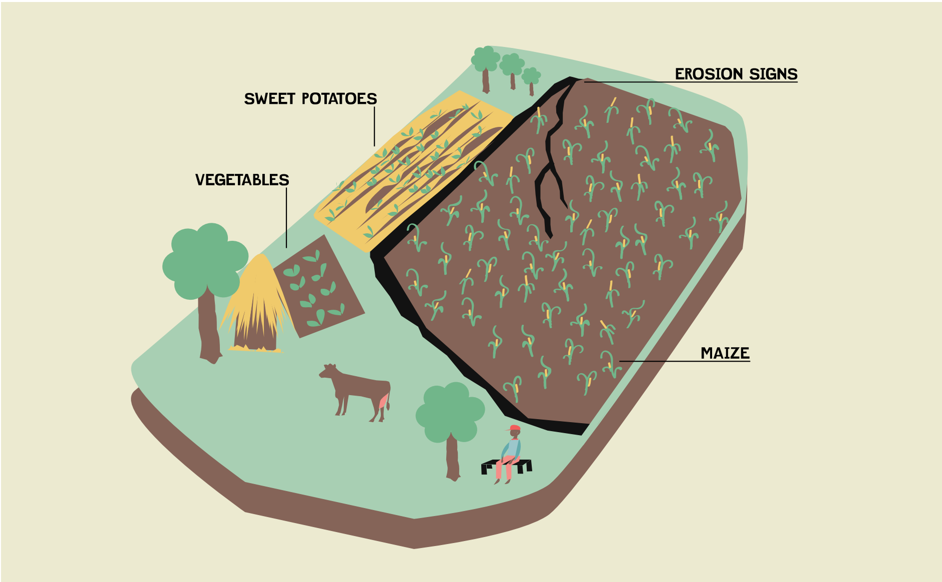
Arne Andersson
Regional Director
Vi Agroforestry, Regional Office East Africa

Table of Content

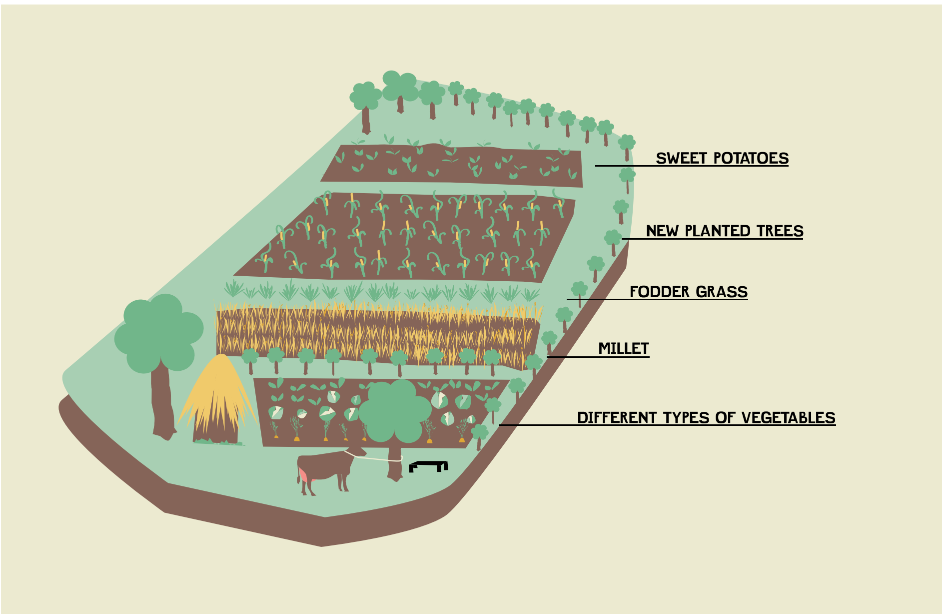
Table of Content

Farm development over time

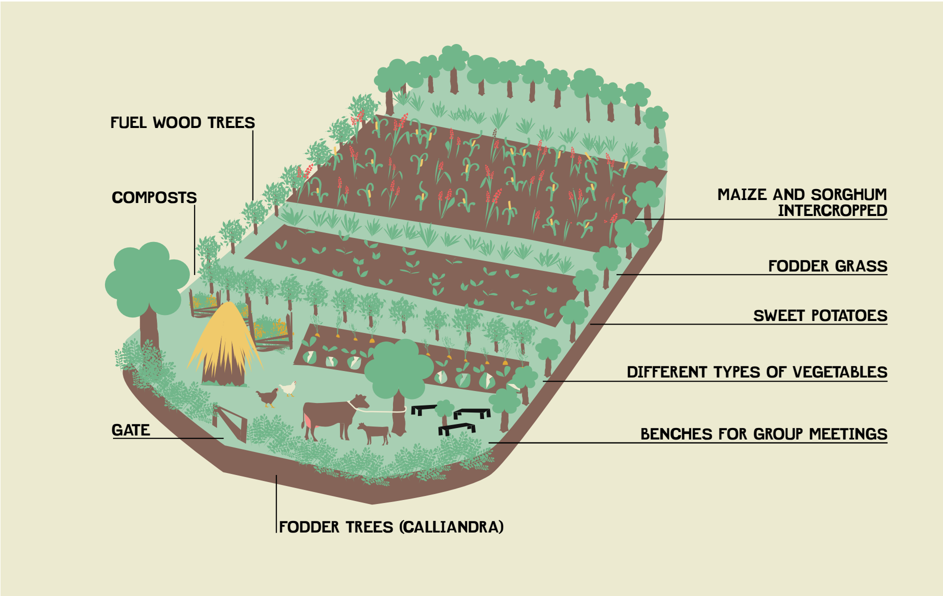
Before Sustainable Agriculture Land Management



After 1 year



After 2 years



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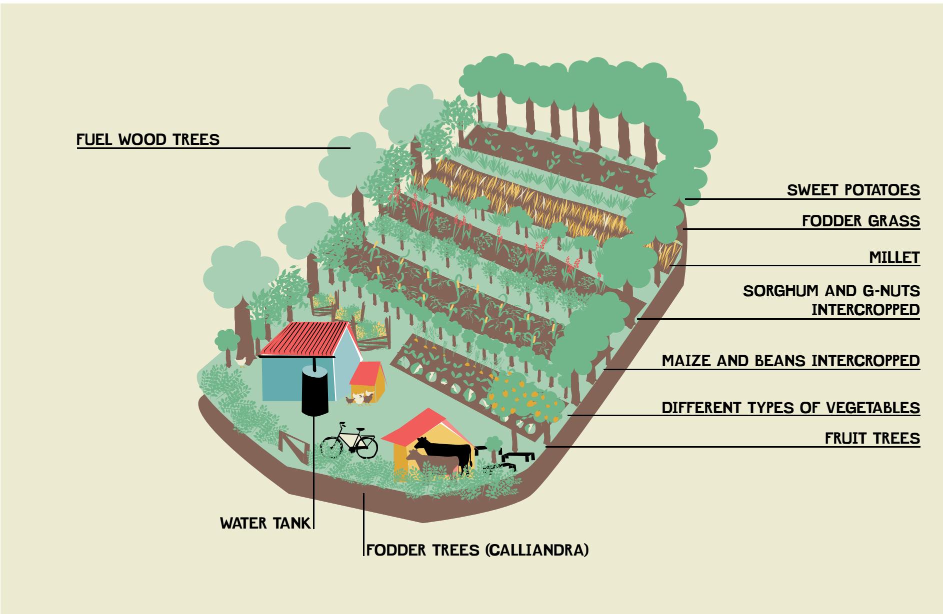


1. Climate change adaptation and mitigation

Introduction

Climate change is one of the factors that affect agricultural production. By the end of this session, you will have better understanding of the concept of climate change, and some of the activities that you can do to reduce its impact on your livelihood.

Time required: 2 hours

1.1 What is climate change?

Climate change refers to a broad array of alterations in climatic and weather conditions. It is characterised by shifts in average conditions and in the frequency and severity of extreme conditions that have occurred over a long period of time, generally over a period of 30 to 35 years. The conditions that are altered include rainfall, temperature, winds, humidity, snow, and seasons. Simply put, climate change refers to changes in long-term weather patterns.

1.2 What are the causes of climate change?

Climate change is predominantly caused, directly or indirectly, by both natural processes and human activities that lead to the accumulation of greenhouse gases (GHGs) in the atmosphere (see 1.3). These natural and human activities include: industrialisation, deforestation, destruction of ecosystems (wetlands, oceans, lakes, wildlife), agriculture and livestock production, transport, energy production, waste, urbanisation, building, and changes in land use.

The increased concentration of greenhouse gases makes our atmosphere store more heat from the sun thereby increasing the temperature on earth. This results in global warming. The higher the temperature, the more severe the weather conditions become.

The impacts of climate change in agriculture are associated mostly with high or low temperatures, shifting of seasons, drought, storms and flooding as well as damages caused by frost and wind.

Affected component	Impact
Water	Decreased or increased availability of water.
Agricultural land	Land degradation (soil erosion, leaching of nutrients, water-logging).
Food systems and supply	Decrease in cereal production, food rotting and high prices.
Eco systems	Loss of biodiversity, deforestation and loss of wetlands.

Affected component	Impact
Farmer health	Increased malnutrition diseases, hunger and starvation cases.
Crops and livestock	Proliferation of pests and diseases, high inputs required, crop failure.
Infrastructure and markets	Damaged roads, irrigation, markets and storage facilities.
Energy supply	Fluctuations in electricity supply in agri-processing industry.

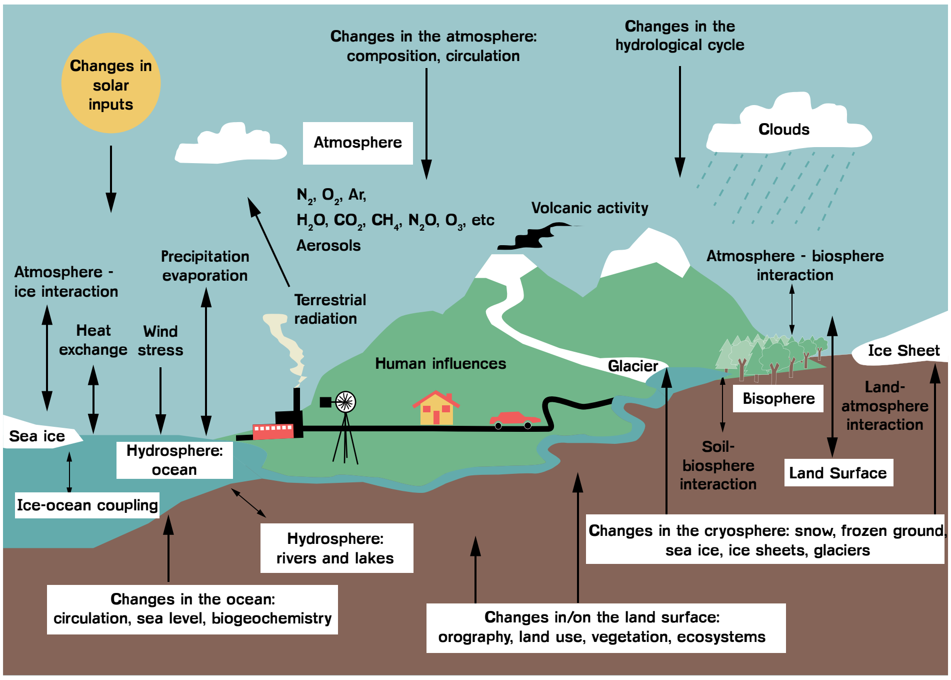


Illustration: Climate change (Illustrator: Elijah Njenga)

1.3 What are greenhouse gases?

Greenhouse gases are gases that occur naturally in the atmosphere. These gases absorb infrared radiation and release heat that warms up the atmosphere.

The most common greenhouse gases are:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous Oxide (N_2O)
- Hydroflourocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulfur hexafluoride (SF_6)

1.4 What is the greenhouse effect?

Greenhouses gases have chemical characteristics that allow these gases to capture, absorb and store heat energy for a long time. The greenhouse effect is therefore the process by which greenhouse gases absorb reflected long wave radiation (background radiation), and raise atmospheric temperature.

1.5 What are the major sources of greenhouse gases?

Greenhouse gases are a result of a combination of natural and human activities; the main ones are summarised in the following chart. Notably, 68% of all greenhouse gases result from the processing (combustion) of fossil fuels to provide energy for production.

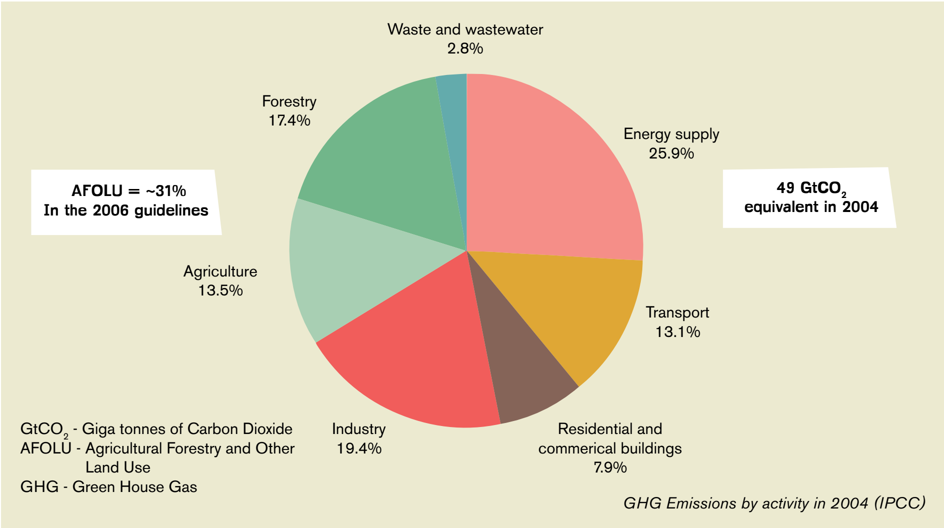


Illustration: Contribution per sector to climate change

The following illustration shows the GHGs that are emitted as a result of agricultural activities as well as those that are absorbed via sustainable agricultural activities.

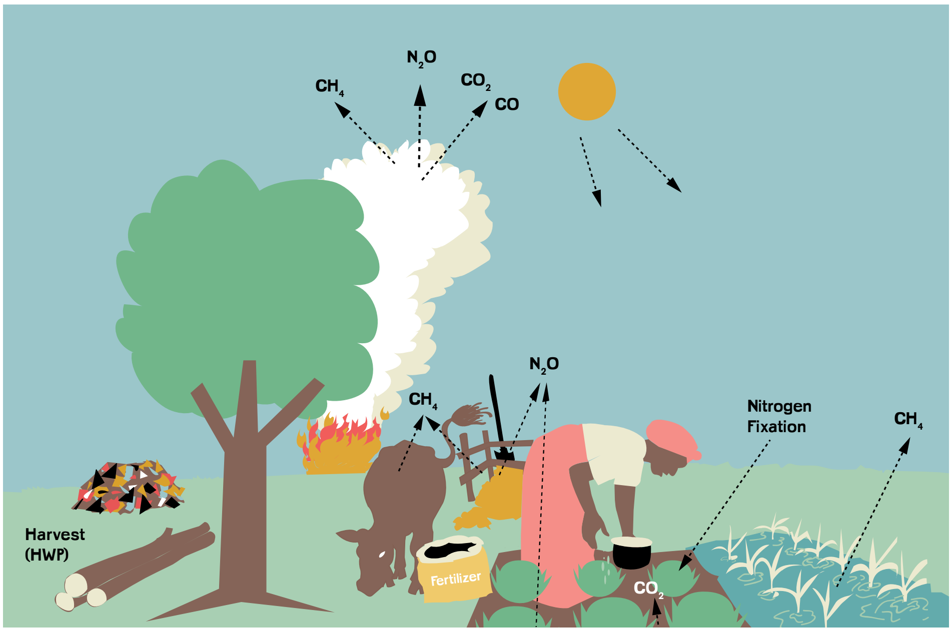


Illustration: Greenhouse gases emitted and/or stored from agricultural activities (Illustrator: Elijah Njenga)

1.6 Climate change adaptation and mitigation

Agriculturalists around the world have been struggling with the impacts of changing climatic conditions on their animals and/or plants. In order to ensure food security and sustain livelihoods it is becoming increasingly important for farmers and other stakeholders to find ways of adapting to and/or reducing the negative impacts of changing climates, and improving their farming practices through Sustainable Agriculture Land Management (SALM) activities (see chapter 2).

APPROACHES TO CLIMATE CHANGE

There are two approaches to climate change: adaptation and mitigation. Climate change adaptation refers to activities to managing the social, environmental and economic impacts of climate change, whereas climate change mitigation involves activities implemented to reduce the emission of greenhouse gases.

Think about

The strategies that can be used in climate change adaptation for small-holder agriculture may be divided into nine (9) categories (see chapter 2). These strategies will be discussed in more detail in chapters three to eleven (3 – 11).

Illustration: Impacts of climate change and how you can adapt a sustainable way (Illustrator: E.Njenga)

EXERCISE

1. Discuss the illustration. On what side of the picture would you like to be?
2. Map out:
   a. The negative impacts of climate change.
   b. What the farmer can do to adapt to climate change.
3. How do you think the weather has changed in the past 10 – 30 years (e.g. increased drought or floods, unreliable rainfall)? How is this affecting your farm?
4. How do you contribute to climate change?
5. Draw a seasonal calendar for your home area or area of work comparing five years ago and now.
6. What is the difference between climate change adaptation and mitigation? What do you think is the most relevant to you, to try and adapt to the impacts of climate change, or to try and mitigate?
7. Do you have plans to adapt to the impacts of climate change? If yes, what plans? If no, why not?

2. Sustainable Agriculture Land Management (SALM)

Introduction

By the end of this section, you will have better understanding of Sustainable Agriculture Land Management (SALM), identify some of the common SALM practices, and explain the importance of these practices. You will also be able to make the link between climate change and SALM practices.

Time required: 1 hour

2.1 What is SALM?

Sustainable Agriculture Land Management (SALM) is a methodology for farmers to adapt to the impacts of climate change and achieve increased environmental resilience in different climate or agro-ecological zones.

SALM practices can be divided into nine (9) categories:

1. Nutrient management
2. Soil and water conservation
3. Agronomic practices
4. Agroforestry
5. Tillage and residue management
6. Restoration and rehabilitation
7. Integrated livestock management
8. Sustainable energy
9. Integrated pest management

EXERCISE

1. **Identify which zone or zones your farm belongs to.**
2. **Make a drawing of your farm.**

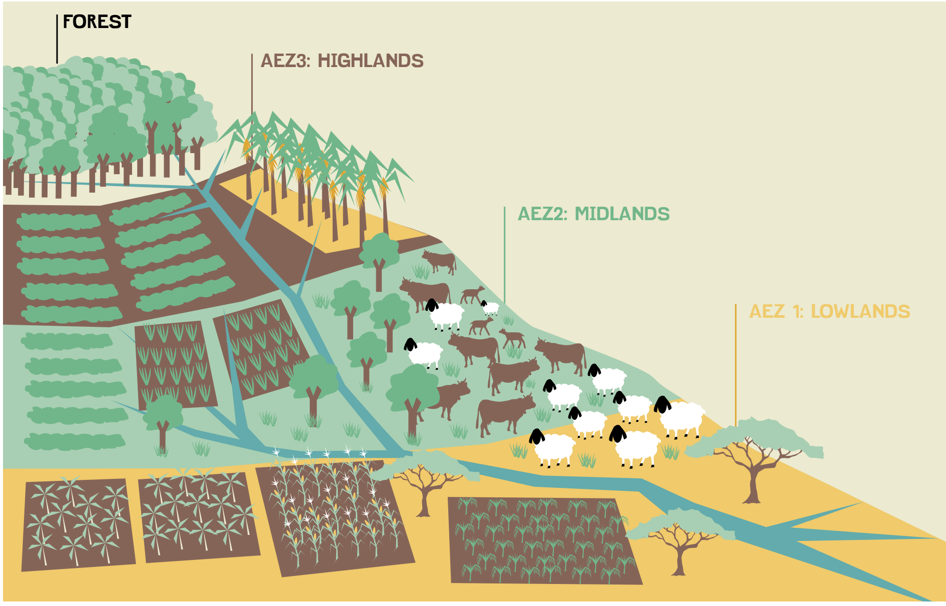


Illustration: Common agro-ecological zones

	AEZ3: HIGHLANDS	AEZ2: MIDLANDS	AEZ1: LOWLANDS
Agriculture	Coffee/banana belt, livestock	Livestock, food crops, some coffee	E.g. maize, beans, lablab, cassava and sheep keeping
Climate	The higher the altitude the colder the climate	Mid altitude, cold, humid	Low altitude, semi arid and arid
Annual rain	1200 – 2000 mm	800 – 1600 mm	500 – 850 mm
Altitude	1200 – 2000 m	800 – 1200 m	700 – 800 m
Soils	Humic ferralitic soils, humic ferrasoils, volcanic and basement complex rocks.	Humic ferrasoils of moderate base status, entrophic brown soils, soils on volcanic rocks in humid areas.	Entrophic brown soils, brown calcareus soils, ferruginous tropical soils developed on volcanic rocks.
SALM	• Soil and water management (e.g bench terraces, retention ditches) • Agroforestry • Intergrated Pest Management • Nutrients management (e.g composting, mulching, application of animal manure)	• Soil and water management (e.g bench terraces with napier grass, intercropping with cover crops) • Nutrient management • Agroforestry • Livestock management (e.g zero grazing) • Integrated pest management • Tillage and residue management	• Integrated livestock management • Agroforestry • Integrated pest management (semi-zero grazing, free range grazing)

2.2 Why are SALM practices important?

SALM activities are essential for:

- Ensuring agricultural productivity in the short-and-long-term.
- Preserving and enhancing productive capacity of cropland, forest land and grazing land, including uplands, lands on slopes, flat lands and bottom lands.
- Sustaining productive forest areas and potentially commercial and non-commercial forest reserves.
- Upholding the integrity of watersheds for water supply and hydro-power, generation needs and water conservation zones.
- Maintaining the ability of aquifers to serve the requirements of farms and other related productive activities.
- The potential to reverse land degradation.

2.3 Common SALM practices

NUTRIENT MANAGEMENT — CHAPTER 3

- Mulching
- Composting
- Cover/nitrogen-fixing crops
- Manure
- Restricted chemical fertilizers and chemical management

SOIL & WATER CONSERVATION — CHAPTER 4

- 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
- Roof catchment
- Ground surfaces and rocks
- Irregular surfaces
- Tanks
- Birkas
- Pans
- Ponds
- Dams
- Wells and boreholes
- Ecological sanitation
- Kitchen water

AGRONOMIC PRACTICES — CHAPTER 5

- Crop rotation
- Intercropping
- Green manure
- Contour strip cropping
- Relay cropping
- Use of improved crop varieties

AGROFORESTRY — CHAPTER 6

- Plant trees amongst crops
- Trees and livestock
- Trees, crops and livestock
- Trees and insects
- Trees and water animals
- Woodlots
- Boundary planting
- Dispersed interplanting
- Fruit orchards

TILLAGE AND RESIDUE MANAGEMENT — CHAPTER 7

- No-tillage/zero-tillage
- Reduced tillage
- Pitting systems
- Stubble and residue mulch tillage
- Dibble stick planting
- Strip and spot tillage
- Ripping
- Ridge and furrow tillage
- Residue management

LAND RESTORATION AND REHABILITATION — CHAPTER 8

- Natural regeneration
- Assisted natural regeneration
- Enrichment planting
- Fire management
- Agroforestry

INTEGRATED LIVESTOCK MANAGEMENT — CHAPTER 9

- Improved feeding and watering
- Housing, stall management systems
- Improved waste management
- Pest and disease control
- Improved breeding practices

SUSTAINABLE ENERGY — CHAPTER 10

- Biomass
- Biogas
- Farm residues
- Energy-efficient stoves
- Sustainable charcoal production

INTEGRATED PEST MANAGEMENT — CHAPTER 11

- Biological pest control
- Use of crop-resistant varieties
- Alternative agricultural practices (spraying, use of fertilizers, pruning)
- Mechanical pest control
- Pesticides
- Cultural methods
- Pest management plan

Note: Not all SALM practices are appropriate for all areas, and care should be taken to avoid generalisations.

EXERCISE

1. Look at the map of the farm that you have drawn and the illustration of the different agro-ecological zones.

a. In what zone(s) is your farm placed (can be in multiple zones)? Try and map out the differences in climate per zone and what type of practices you are currently using in respective zone, e.g. bench terraces, contour farming and/or rain water harvesting? Make use of the table.

b. Do you experience any problems with your land (e.g. soil erosion) that you do not yet have a solution for? If you have found a solution please share it with the group.

2. What farming methods are you now doing differently to ensure good produce every season?

3. Nutrient Management

Introduction

The goal of this session is to introduce some of the common soil nutrients, explain the importance of these nutrients, and discover ways through which you can increase and/or maintain the nutrients in the soil for food production. The careful application of inorganic fertilizers will also be discussed.

Time required: 4 hours

3.1 What are nutrients?

Plants need nutrients to grow and reproduce. Without sufficient nutrients plants can become stunted, struggle to flower and produce fruit, become discoloured, or simply wither and die.

Examples of nutrients are:

- Potassium (K)
- Magnesium (Mg)
- Nitrogen (N)
- Phosphorous (P)
- Carbon (C)
- Calcium (Ca)
- Sulphur (S)
- Iron (Fe)
- Zinc (Zn)

EXERCISE

1. **List five abnormal changes you have observed in your crops.**
2. **Do you remember when or why your crops were looking or behaving strangely (growing at a slower rate, for example)?**

3.2 What is nutrient management?

Soil is fertile when it can supply different forms and amounts of nutrients to plants in a balanced way. Nutrient management is the process of maintaining and/or enhancing soil fertility, and it is done through the use of the nutrients already in the soil or adding nutrients through organic fertilizers (application of compost). The purpose of nutrient management is to increase soil and crop productivity, and increase climate resilience.

When chemical fertilizers are used inefficiently or overused, soils get depleted, toxic, acidic and generate GHG emissions.

Think about

Soil nutrients or minerals contribute significantly to: soil fertility characteristics, crop productivity, climate change adaptation, enhanced environmental resilience, and potentially reduce greenhouse gas (GHG) emissions.

Examples of nutrient management are: use of manure, application of fertilizers and composting.

3.2.1 Use of animal manure

Animal manure is obtained from different animals on the farm, but it can also be bought from other farmers or at the market. Animal manure is used as an organic fertilizer, on different crops and trees.

Think about

THE DIFFERENT FORMS OF ANIMAL MANURE ARE:

1. **Chicken manure – chicken excreta.**
2. **Cow manure – cow excreta.**
3. **Horse manure – horse excreta.**
4. **Goat manure – goat excreta.**
5. **Human waste and urine.**

Instructions

- You can mix the different types of manure. Sometimes it might be even better!
- Dry the manure and mix it with residues (from the compost) before applying it to the soil where crops are to be grown. Wet manure can burn the crops and create more damage than good for your crops.

Application

- **Per tree:** Apply 2 wheel barrows per tree. Place the manure one meter around the tree. If it is a seedling, place it around the root stems.
- **For crops:** Apply 2 tonnes of the manure per acre.

The quality of manure differs because of:

- Type of livestock.
- Number of livestock.
- Grazing/stall management.
- Feeding (diet).
- Collection.
- Composting.
- Storage (to avoid evaporation of nutrients or volatilisation, and nutrient leaching.

3.2.2 Use of green manure

Green manure refers to plants (i.e. cover crops, see section 3.2.3) that are grown to improve or protect the soil. These plants tend to grow fast, cover the ground, and have deep roots, but are not left to flower or harvested for food. The deep roots bring – to the surface – nutrients that the plants with shallow roots cannot reach. Some of these plants also take nitrogen from the atmosphere and deposit this in the soil. By covering the ground, these plants also prevent the growth or spread of weeds, and can be used to break disease cycles; some have beneficial microbes. The plants can also be cut and placed on the compost heap. Whichever way, green manure increases the levels of organic matter in the soil.

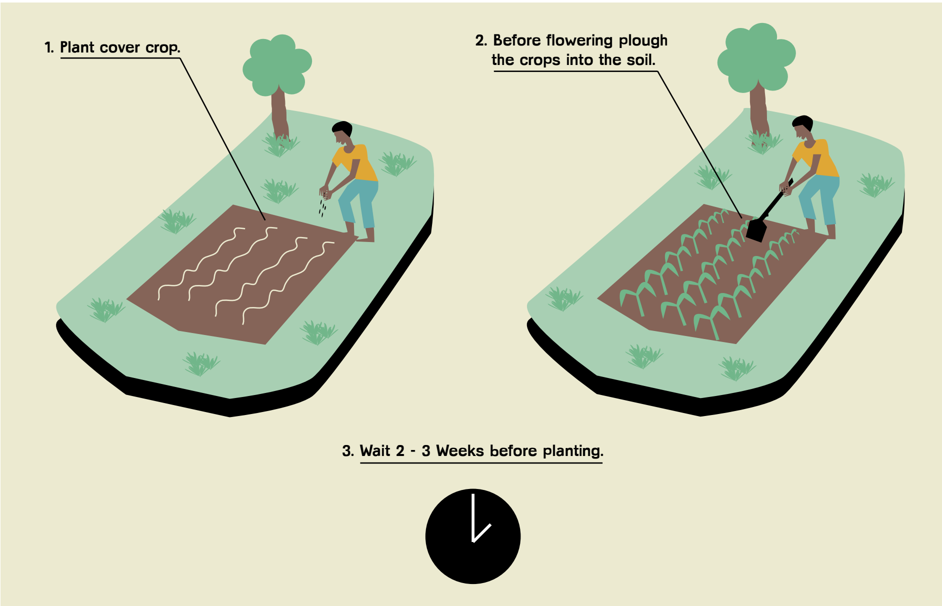


Illustration: Planting green manure

3.2.3 Cover crops

Cover crops, sometimes referred to as nitrogen-fixing crops, are either leguminous or non-leguminous crops with green manure properties that are able to absorb atmospheric nitrogen and fix it organically into the soil to increase nutrients and conserve soil. For example, mucuna sowed when maize is at the dough stage can be used to get rid of the striga weed on the farm.

Note: Cover crops should be ploughed or removed at the flowering stage, to prevent the crops from using the nitrogen that has already been fixed.

Think about

SOME OF THE COMMON COVER CROPS ARE:

- Alfalfa
- Beans
- Butternut
- Cowpeas
- Desmodium
- Lablab
- Lentil
- Lucern
- Lupin
- Mucuna
- Peanuts
- Peas
- Pumpkin
- Pigeon peas
- Soybean
- Squash
- Sweet clover
- Sweet potato
- Vetch

How to plant mucuna in a maize field

1. Plant maize in rows. Make sure that you have 80 cm between rows and 40 cm within rows. The process is easier with ropes and poles.
2. Place two (2) maize seeds per planting hole.
3. Weed the maize field once before planting mucuna (for example weed by using biological control e.g. mulch, see also integrated pest management chapter).
4. Sow mucuna when the maize has grown for approximately 60 days (dough stage, i.e. when it is ready to harvest and eat).
5. Serve 60 kg of mucuna seed per hectare.
6. Drop two seeds of mucuna per hill between the maize rows with 40 cm of distance from each other.
7. The mucuna plant will keep on growing after the maize harvest until the end of the short rainy season.
8. Keep a layer of mucuna as mulch and let the organic matter decompose.
9. Depending on the amount of weed in the field, some farmers sow maize directly into the mucuna mulch, without ploughing.

If the soils are poor and have a high amount of weeds plant mucuna once per year for three consecutive years. Once the soils are restored, it is recommended to plant mucuna once every second year.

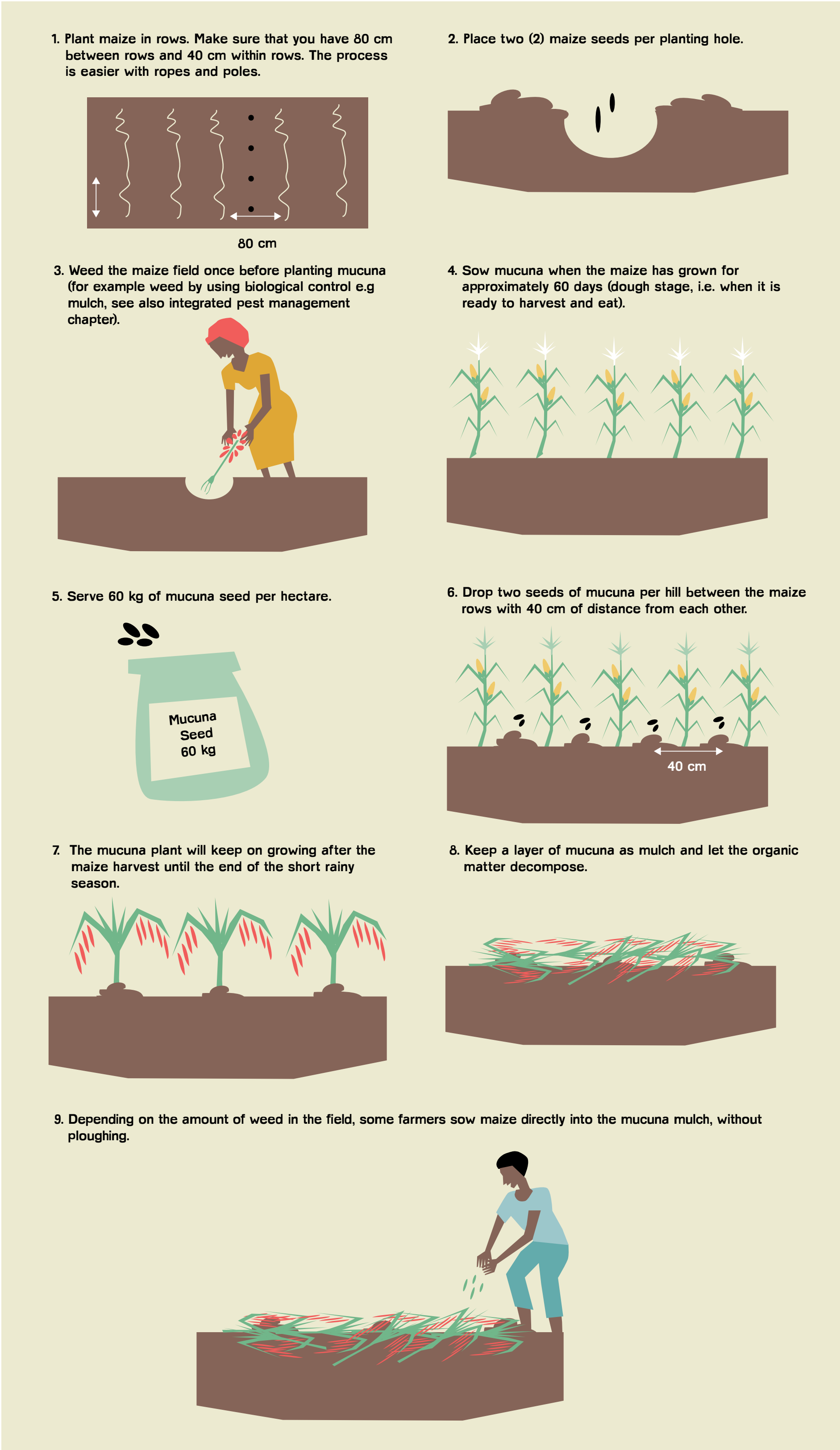


Illustration: How to plant mucuna in a maize field

For a video demonstration on reviving soils with mucuna, visit:
http://www.accessagriculture.org/node/513/en

3.2.4 Mulching

The objective of mulching is to conserve soil moisture, reduce runoff flows, reduce evaporative losses, reduce wind erosion, prevent weed growth, enhance soil structure, and control soil temperature. Common mulches include: cut grass, crop residues, straw and other plant material.

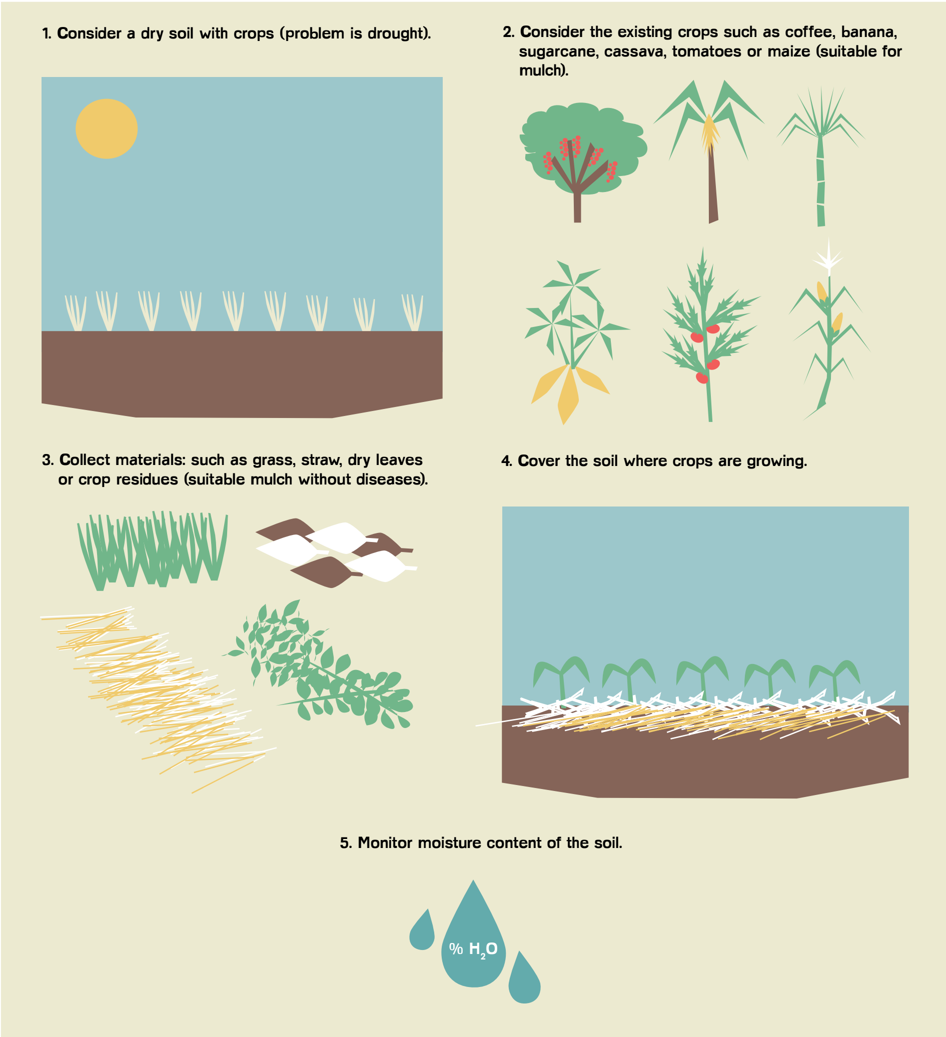


Illustration: Mulching

3.2.5 Liquid manure

Liquid manure is manure from green but mostly leguminous plants, ash and animal dung that has been fermented or diluted as slurry. It can be applied directly to the soil or crops. Plants that are suitable for making liquid manure include Mexican Sunflower (*Tithonia diversifolia*) and *Sesbania Sesban*.

Liquid manure protects crops, prevents pests and diseases, provides nutrients (nitrogen, phosphorous, potassium) and irrigates crops. It is also an alternative to harmful chemicals.

Continuous use of liquid manure provides the following benefits:

- Improves the soil.
- Saves cost.
- Helps farmers to be self-reliant.
- Uses local resources and knowledge.
- Protects beneficial insects.
- Protects the environment.
- Preserves health by reducing the use of harmful chemicals.

How to prepare liquid manure:

1. Chop green sappy leaves and young branches of leguminous plants such as *Sesbania* and *Tithonia*.
2. Put these in a sack e.g. a maize bag.
3. Place the sack or bag in a drum with clean water. Mix thoroughly.
4. Cover drum and let contents stand for 21 days.
5. Dilute by at least 1:2 parts per volume e.g. 1 litre of manure to two litres of water.
6. Apply to soil near the crop. Do not apply directly to the crop as this will burn it.

Illustration: How to prepare liquid manure

3.2.6 Composting

Composting is the natural process of turning organic materials such as crop residues and farmyard manure into plant food or humus. Compost is a cheap and effective organic mulch that can be used as an alternative to commercial fertilizers to improve the soil. Humus is the organic matter component of soil that is being destroyed and eroded throughout much of the world.

How to build a compost pit

1. Place the compost pit in a shaded place or under a tree.
2. Dig the pit. It should be 1.5 m wide and 0.5 m – 1 m deep.
3. Loosen the soil at the bottom of the pit (30 cm deep loose soil). Pour water over the soil.
4. Start piling ingredients into the pit:
   - **First layer:** Put 30 cm of rough material at the bottom layer, e.g. maize stalks.
   - **Second layer:** Put 15 cm of dry grass.
   - **Third layer:** Put 15 cm of green leaves from, e.g. high protein legumes, trees, shrubs.
   - **Fourth layer:** Put 10 cm of animal/bird waste.
   - **Fifth layer:** Sprinkle top soil and if possible, wood ashes.
5. Water the compost before repeating the same process three times.
6. Place a stick in the compost in an angle of 45 degrees in order to check if the pile is too dry or too wet.
7. Cover the compost with top soil and grass in order to avoid evapotranspiration.
8. Keep the compost for 21 days before applying it into the field.

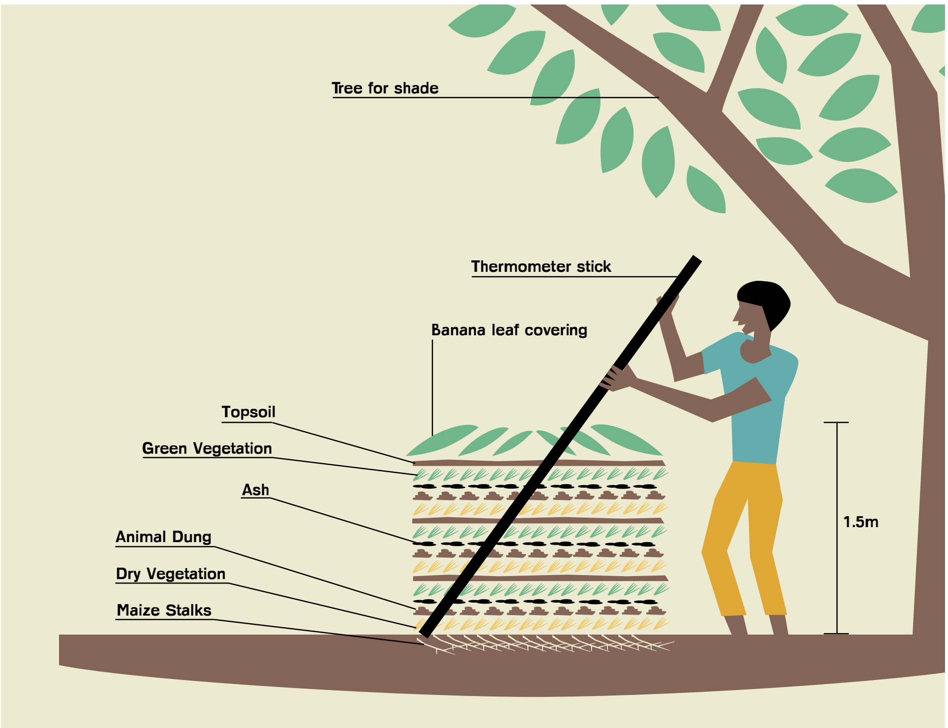


Illustration: How to make a heap compost

3.2.7 Use of mineral fertilizers

One way to increase soil fertility when soils lack adequate levels of phosphorous and nitrogen is the proper use of appropriate type of mineral (inorganic) fertilizers. Inorganic fertilizes are mainly from mineral ores and contain high percentage of nutrient elements that are readily soluble and available to plants. But important to note is that mineral fertilisers alone cannot sustain soil productivity.

Disadvantages of using mineral fertilizers:

- Continuous use of inorganic fertilizers will lead to:
  - decline of soil organic matter (for example after 8 years about 65% of initial organic matter disappears),
  - acidification,
  - compaction of soil (hardpan) and land degradation.
- Expensive.
- Release GHGs (for example nitrous oxide, and during their manufacture and transportation they use fossil fuels hence releasing carbon dioxide).

Overusing inorganic fertilizers will increase the impact of climate change and vulnerability of land to effects of climate change.

Think about

Examples of mineral fertilizers are:

FERTILIZER	COMPOSITION	RECOMMENDED APPLICATION
Di-Ammonium Phosphate (DAP)	18% Nitrogen (NH_4– nitrate) 46% Phosphorous (P_2O_5)	During planting.
Nitrogen, Phosphorous, Potassium (NPK)	21 parts of Nitrogen 17 parts of Phosphorous 17 parts of Potassium	During planting and/or as top dressing.
Calcium of Ammonium Nitrate (CAN)	26% Nitrogen (NH_4+ NO_3) Urea (45 – 46% Nitrogen (NH_4).	As top dressing.
These fertilizers are water soluble and are best applied when the soil is moist.		

Table: Examples of mineral fertilizers

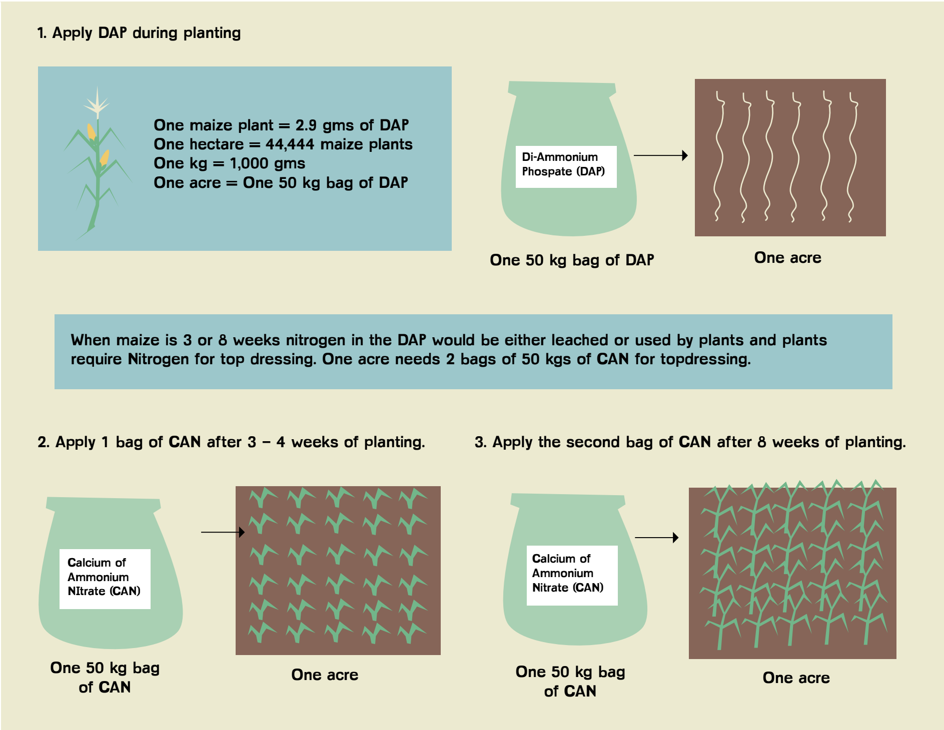


Illustration: How to apply mineral fertilizers

Note: Inorganic fertilizers are best applied to soils with high soil organic matter or high carbon.

3.2.8 Use of agricultural lime

Sometimes soils become acidic due to overuse of fertilizers, mono-cropping and depletion of soil organic matter stocks. One of the most common ways of neutralising soil acidity to achieve the required pH for crop productivity is by lime application. Different crops have different pH requirements. Lime, also known as calcium carbonate ($CaCO_3$), comes from limestone.

How to apply lime

1. The soil acidity that triggers the use of lime in your farm should be of a pH of 4.5 or below.
2. Lime is applied after the soil is ploughed or tilled well.
3. Apply 1 week before planting, or during planting.
4. Apply 2 or 3 tonnes of lime to one acre of land.
5. Repeat every 2 to 5 years depending on the acidity levels in the soil.

After liming, suitable crops to plant are, for example, cereals and grasses.

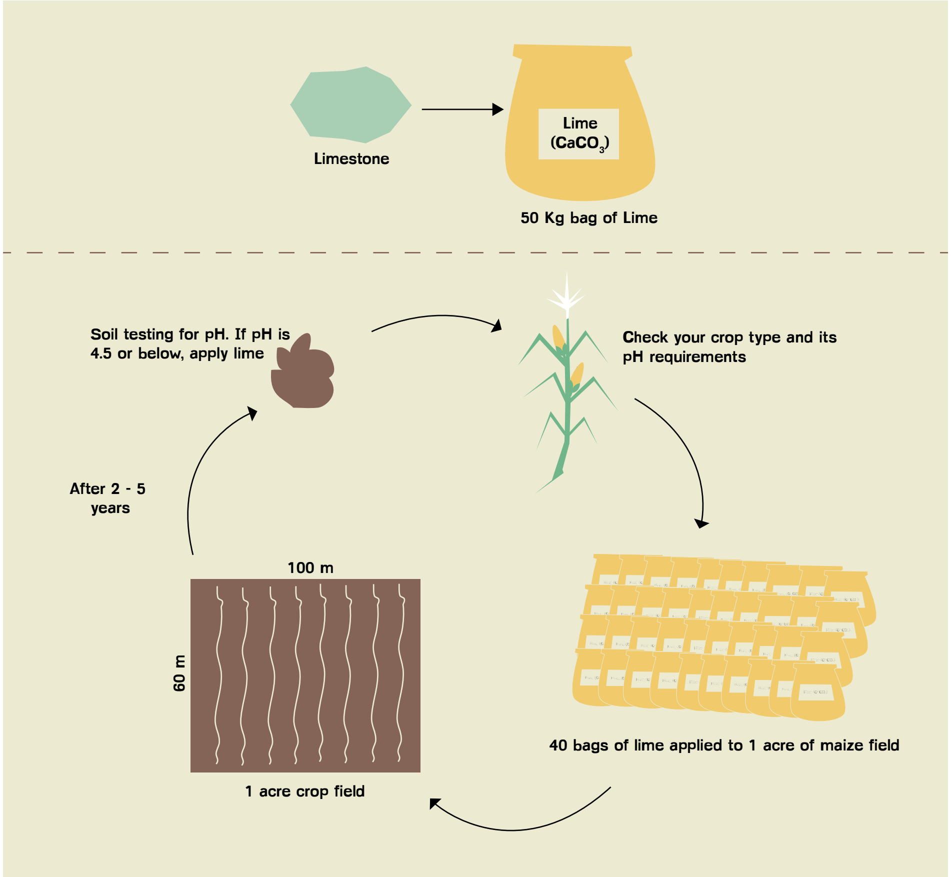


Illustration: Use of lime

Lime is not easily found in the market, and you may need to order what you need through the district or county department of the Ministry of Agriculture.

Note: Lime is expensive and many farmers may not be able to afford the cost of applying lime to one acre of land. Lime should be applied restrictedly.

EXERCISE

1. **Which nutrient deficiencies do you notice in your farm? (This builds on the exercise at beginning of this session.)**
2. **Find your drawing. How would you manage the soil nutrients in your farm (e.g. add compost, mulching, green manure, intercropping with cover crops)?**

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.

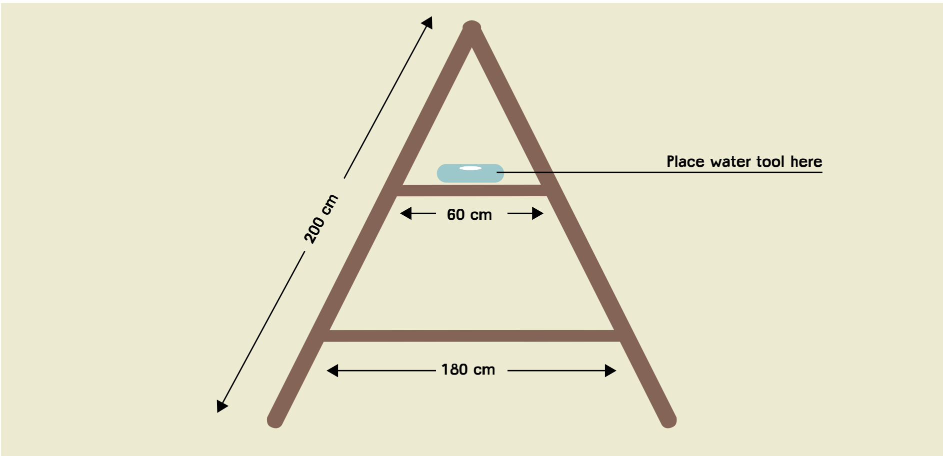


Illustration: A-Frame

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).

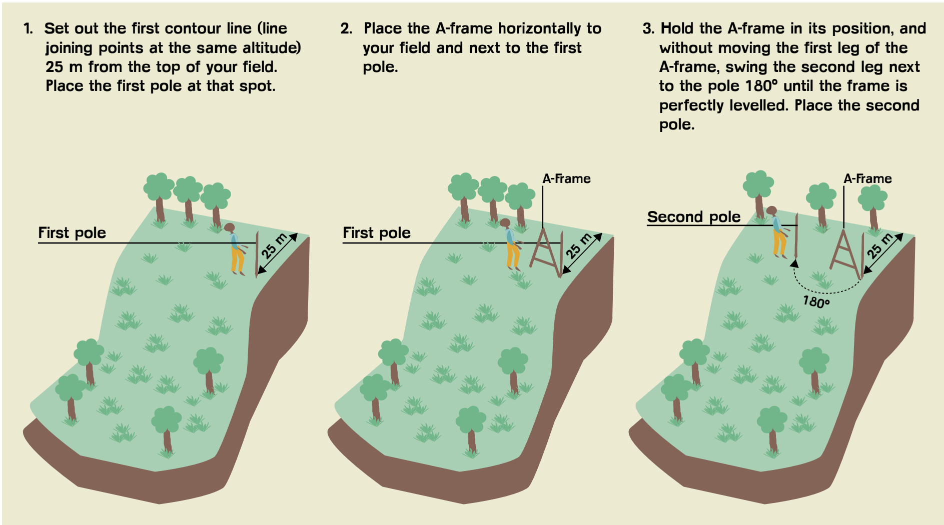


Illustration: How to use the A-frame

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.

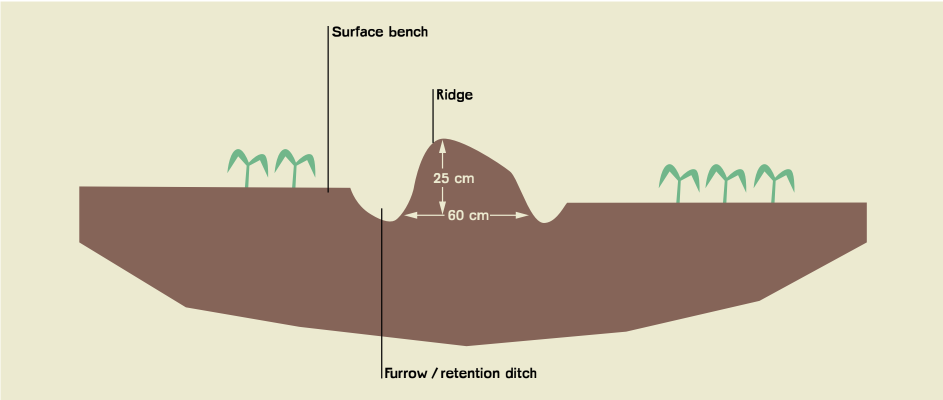


Illustration: How to make a contour bund

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.

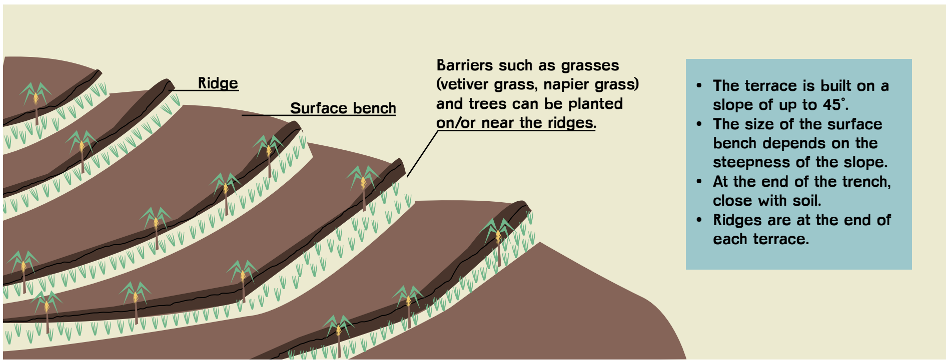


Illustration: How to build bench terraces

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.

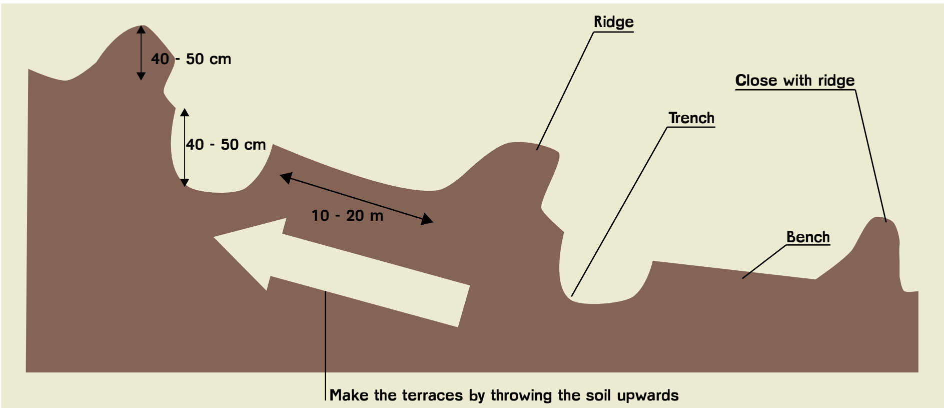


Illustration: How to build fanja juu terraces

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.

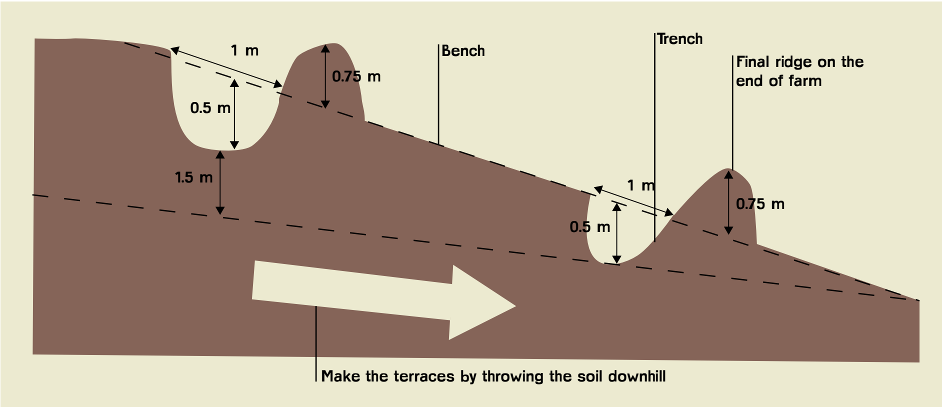


Illustration: How to build fanja chini terraces

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.

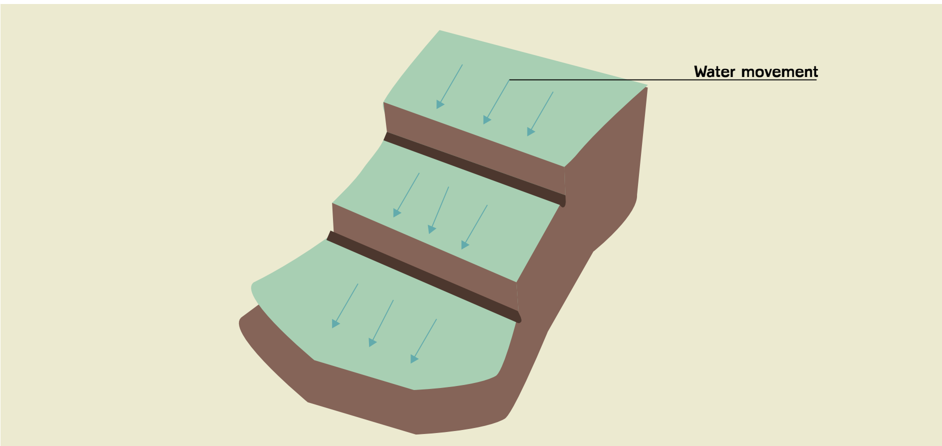


Illustration: How to build water terraces

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.

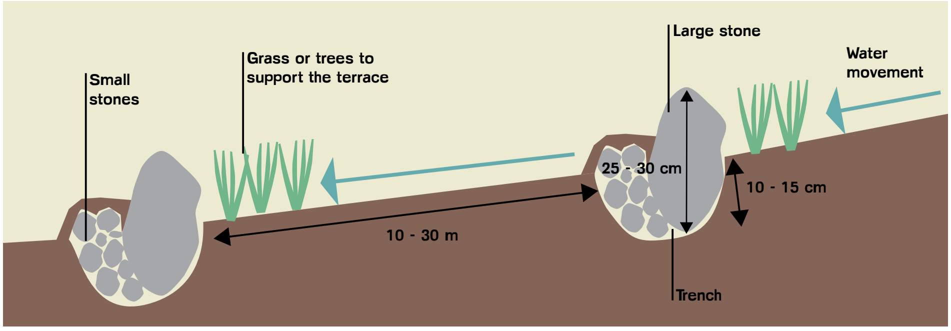


Illustration: How to build stone terraces

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.

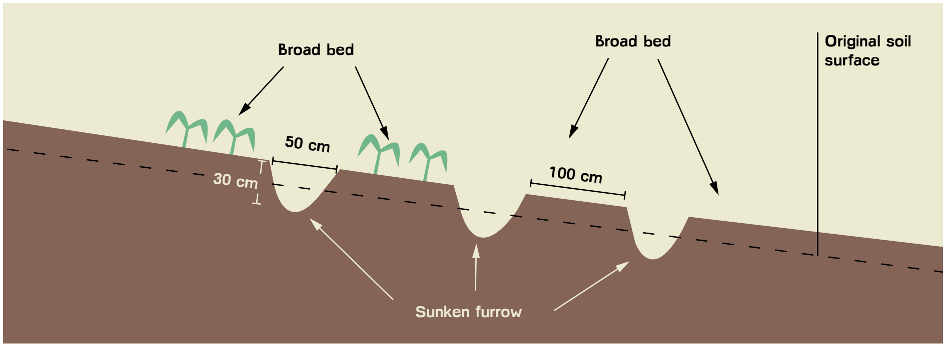


Illustration: How to make broad beds and furrows

4.1.4 Semi-circular bunds

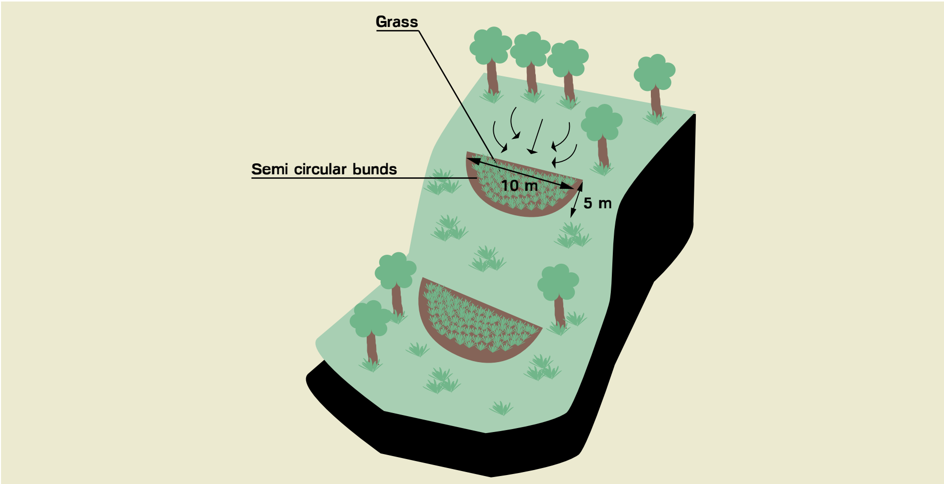
Semi-circular bunds are made by digging holes on the tips of the contours, in the form of half-circles. Semi-circular bunds are used to harvest water, conserve soil and water, and improve soil fertility (when manure or compost is added).

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.



llustration: 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.

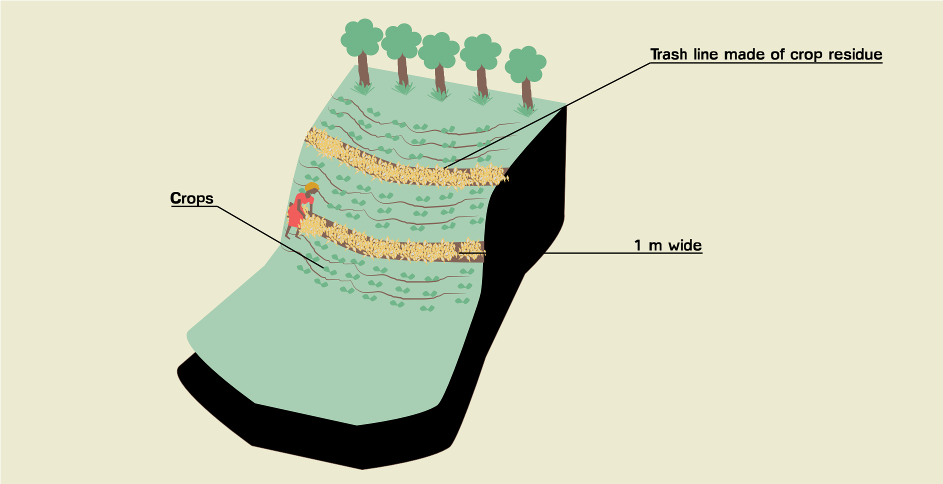


Illustration: How to make trash lines

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.

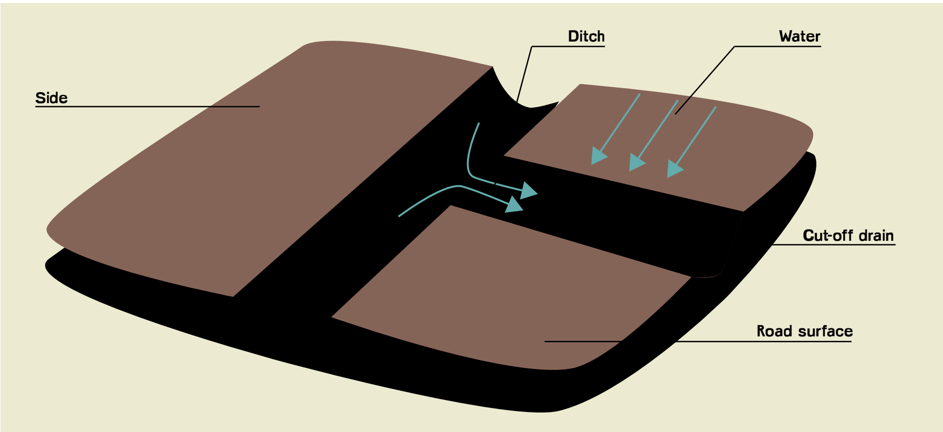


Illustration: How to make cut-off drains

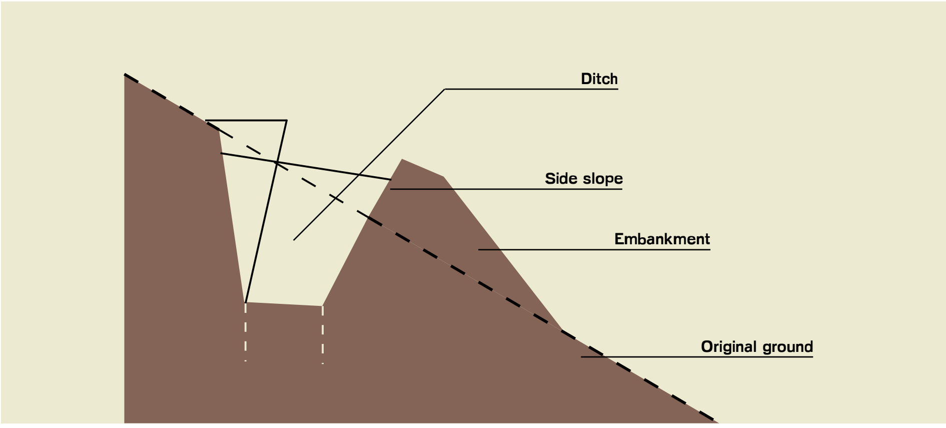


Illustration: How to make a diversion ditch

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.

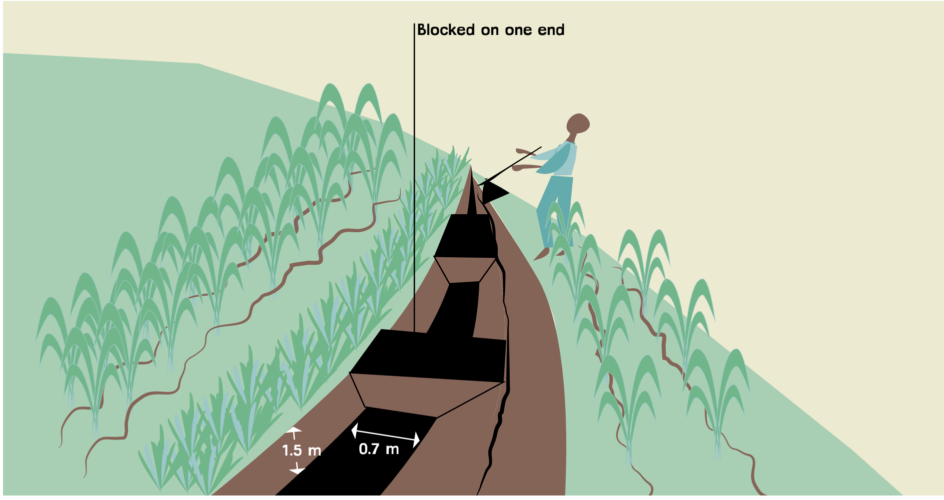


Illustration: Contour infiltration ditch

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.

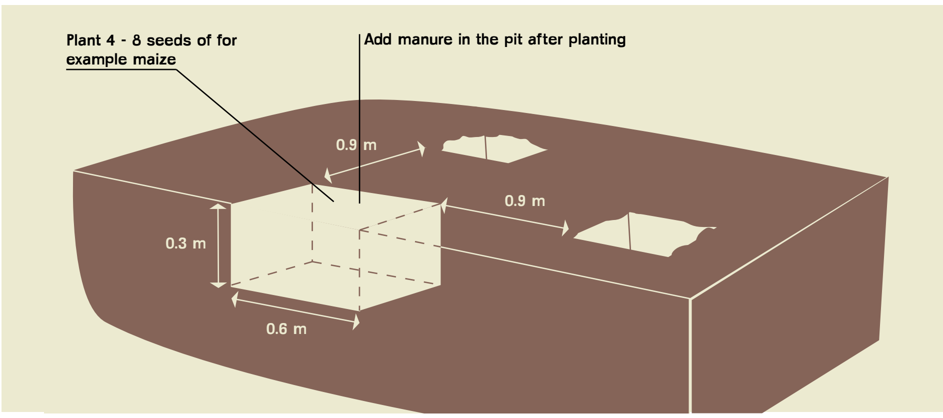


Illustration: How to make a zai pit

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.

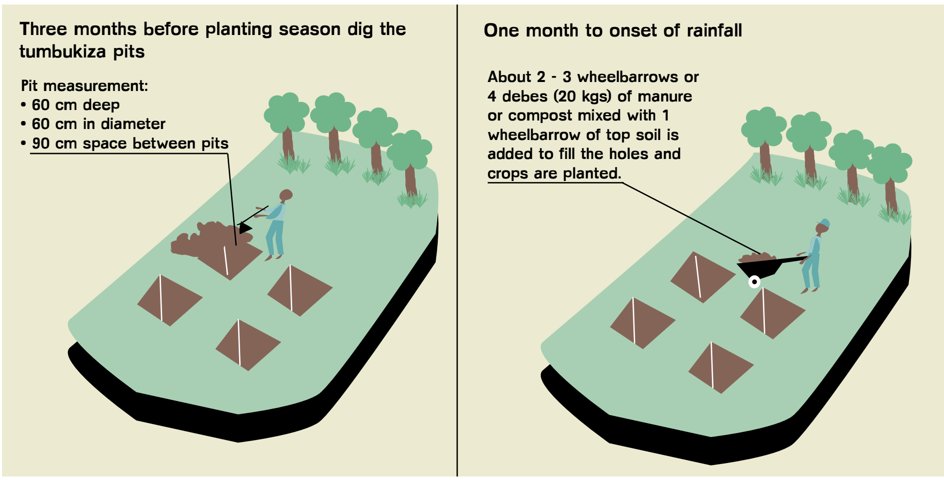


Illustration: How to make tumbukiza pits

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.

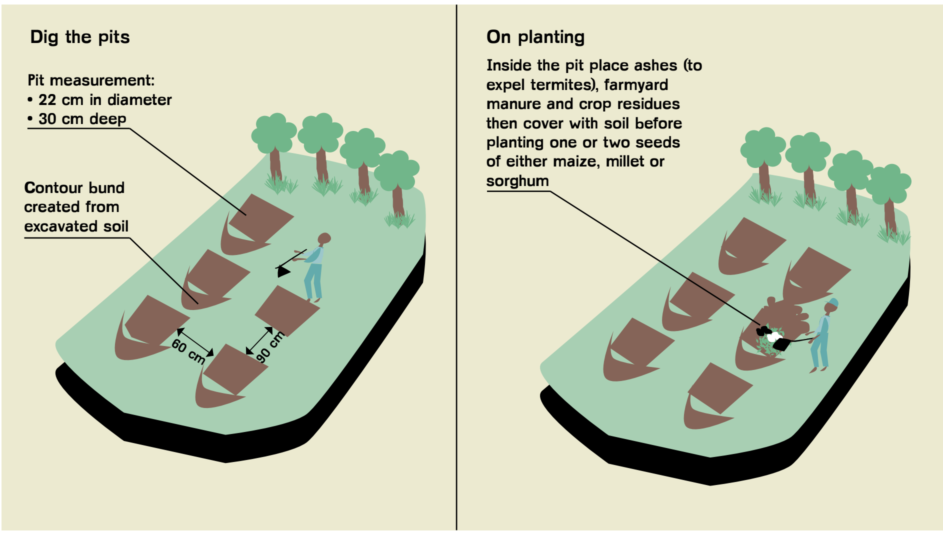


Illustration: How to make chololo and ngolo pits

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.

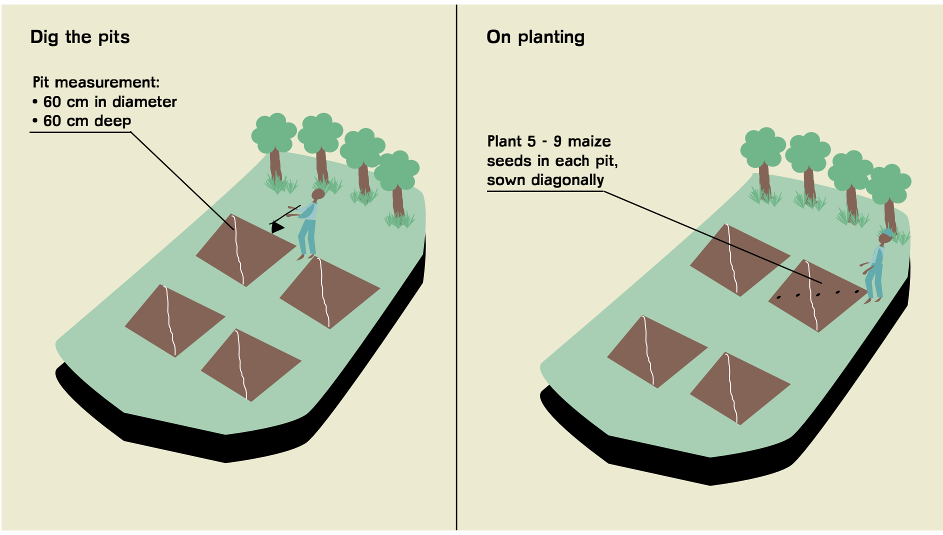


Illustration: Five by nine pits

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.

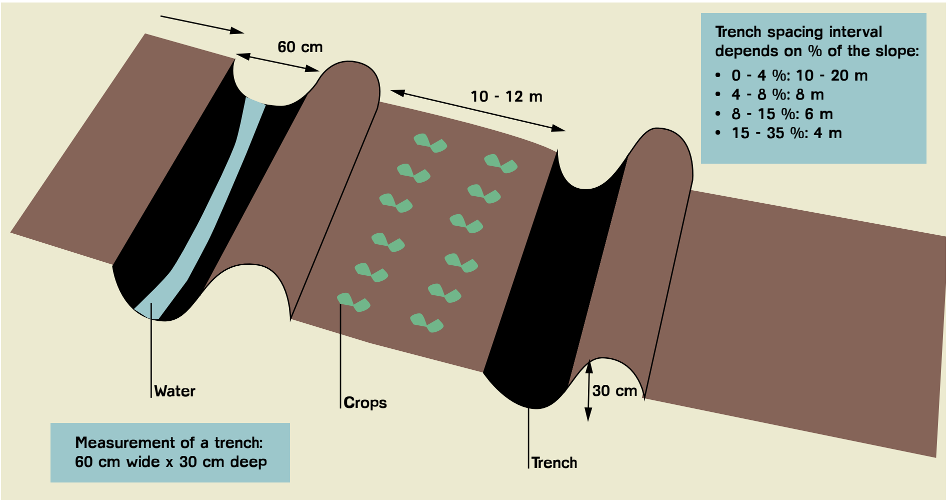


Illustration: How to make a trench

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.

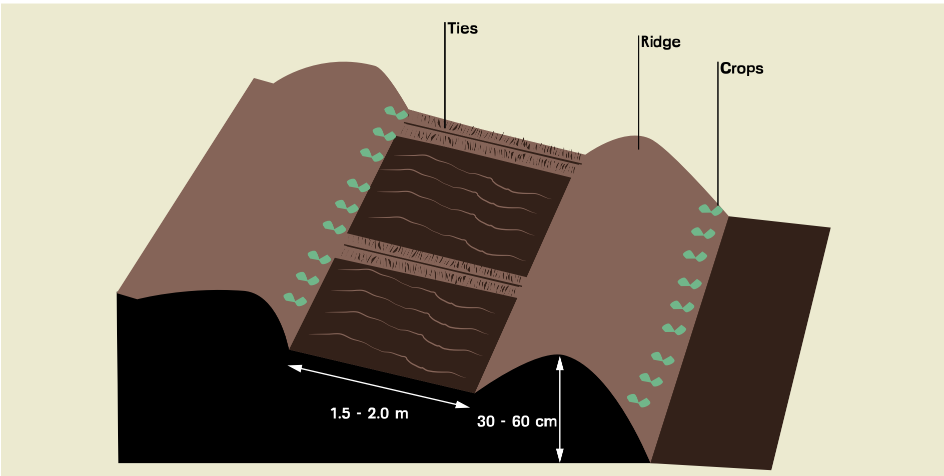


Illustration: How to make tied ridges

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).

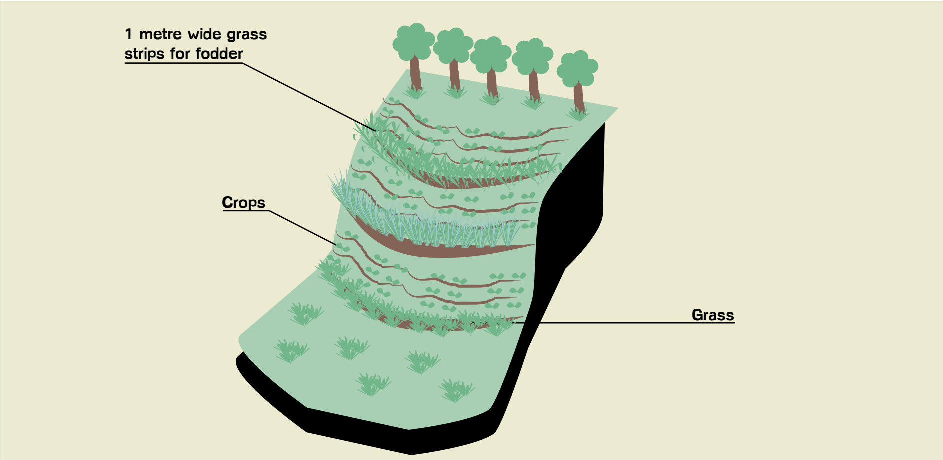


Illustration: How to make grass strips

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.

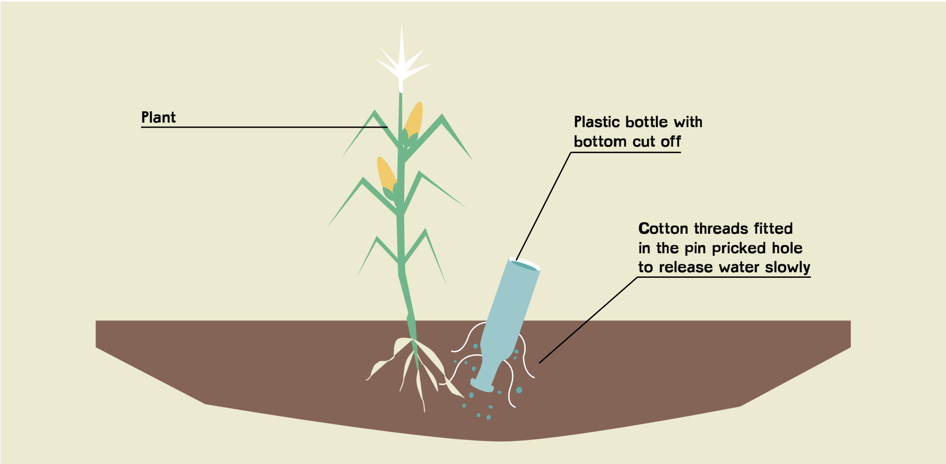


Illustration: Bottle irrigation

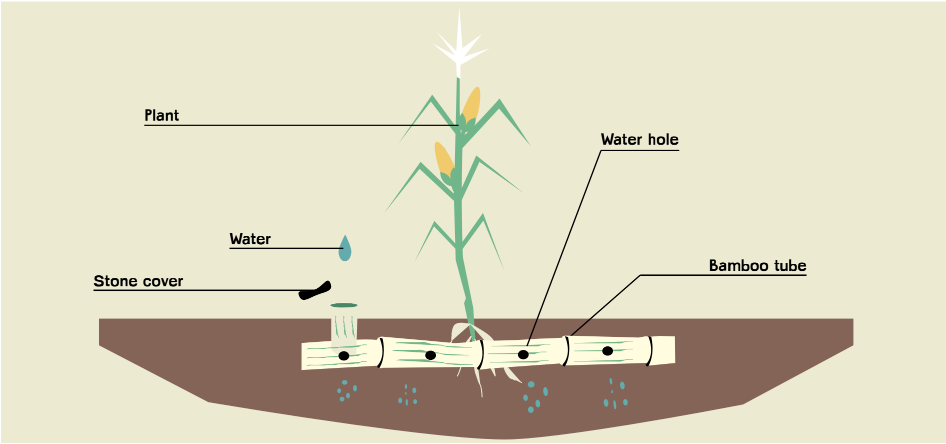


Illustration: Bamboo irrigation

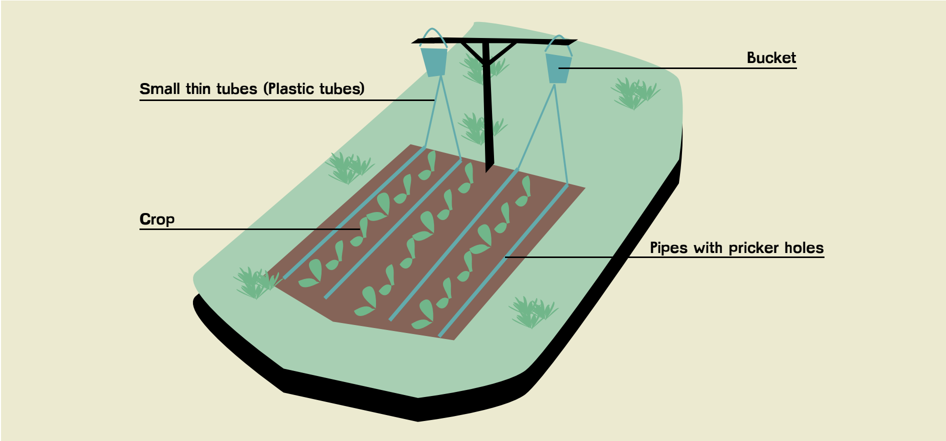


Illustration: Bucket irrigation

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 and/or 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.

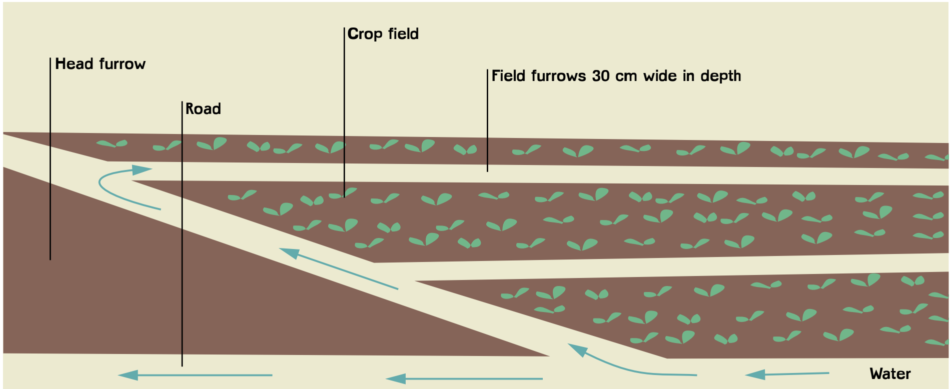


Illustration: Road catchments

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.

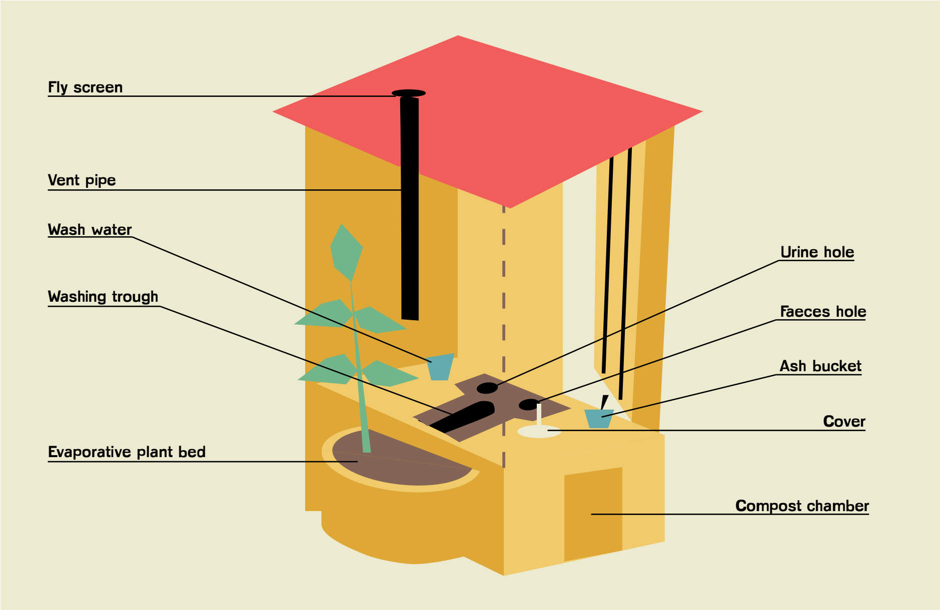


Illustration: Ecosan toilet

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.

Table: Agronomic practices

AGRONOMIC PRACTICE	EXAMPLES	BENEFITS
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.

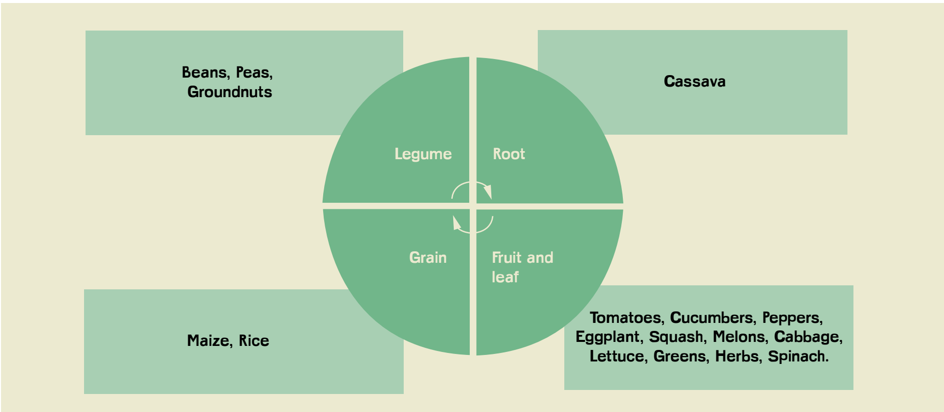


Illustration: Crop rotation

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.

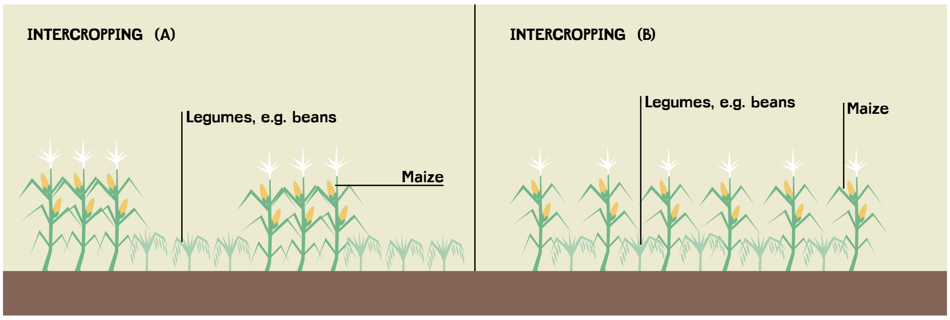


Illustration: Intercropping

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.

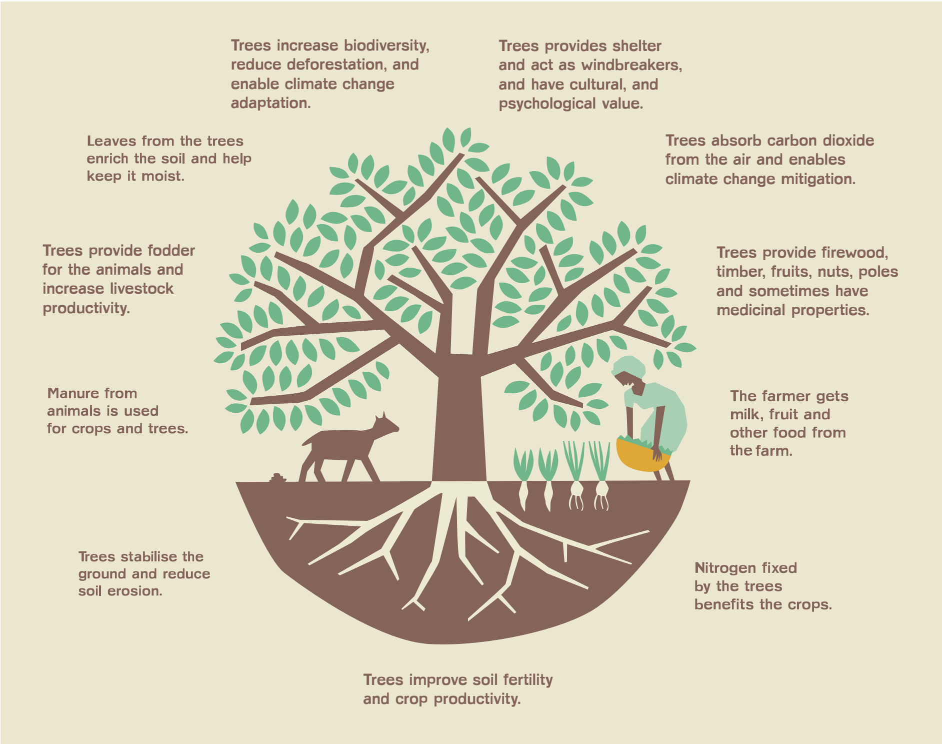


Illustration: Agroforestry – How it works

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 chinensis	Termite resistant
	Polyscias fulva	
	Cordia africana	Termite resistant
	Maesopsis eminii	Termite resistant
	Trema orientalis	
	Croton macrostachyus	
Fodder trees	*Calliandra calothyrsus*	
	Albizia chinensis	
	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	

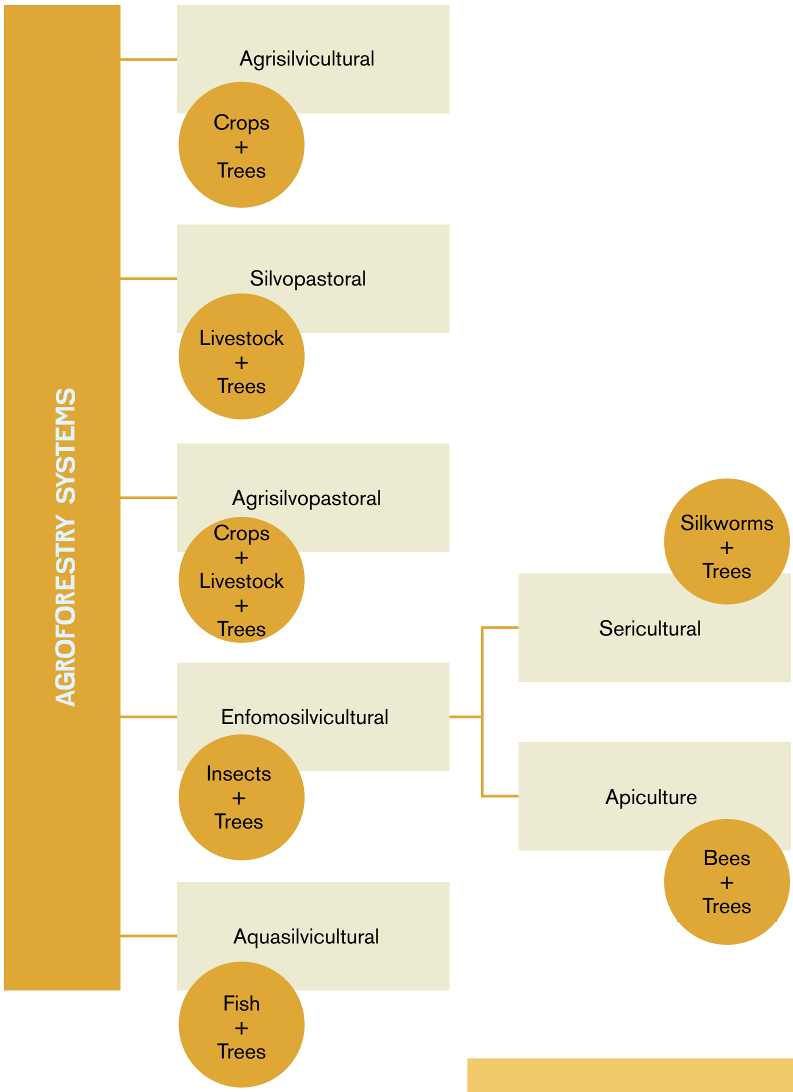
Table: Some of the agroforestry tree species in East Africa – 1

BENEFIT	SPECIES	OTHER ATTRIBUTES
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 – 2

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

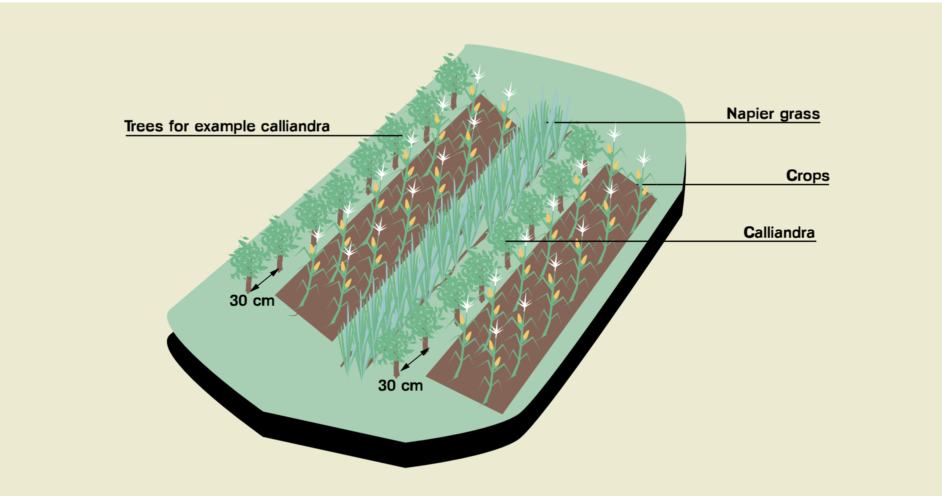


Illustration: Alley cropping

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.

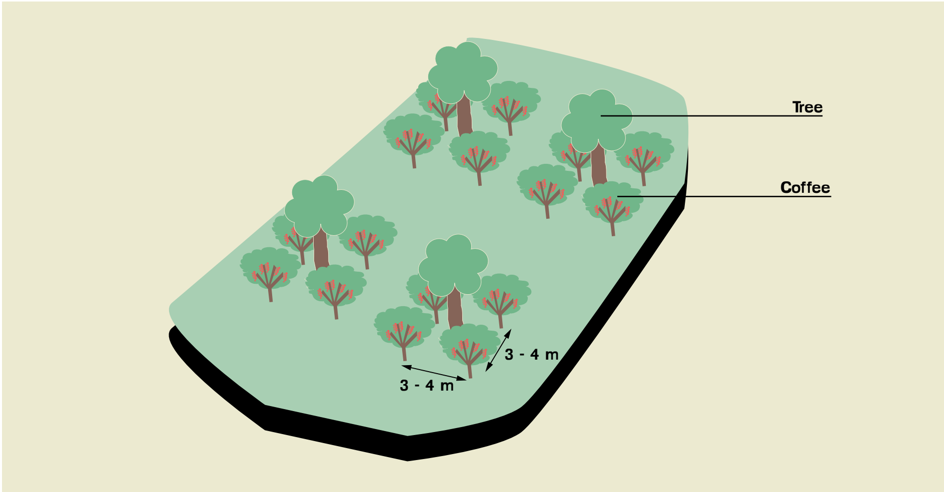


Illustration: Trees with perennial crops

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.

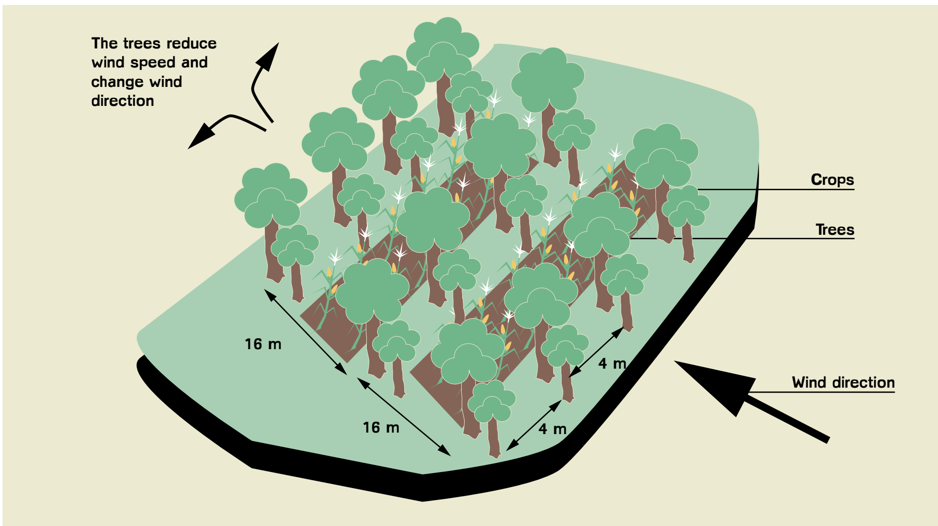


Illustration: Wind trees

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.

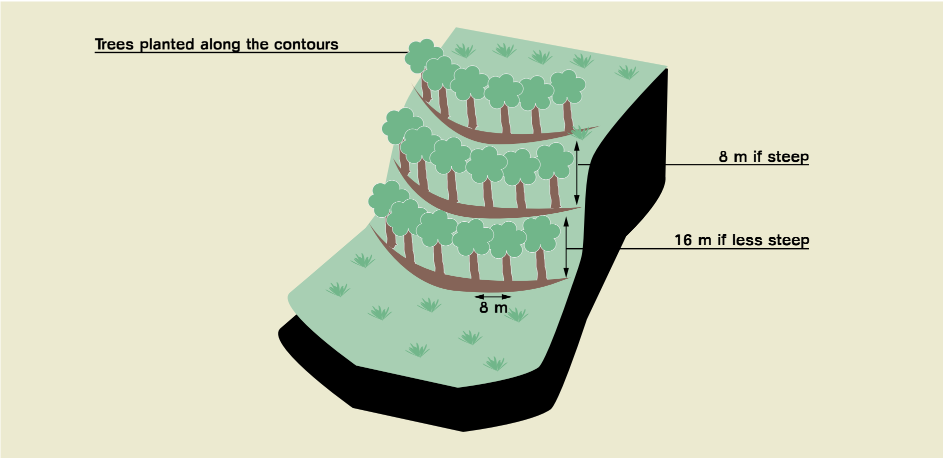


Illustration: Contour trees

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.

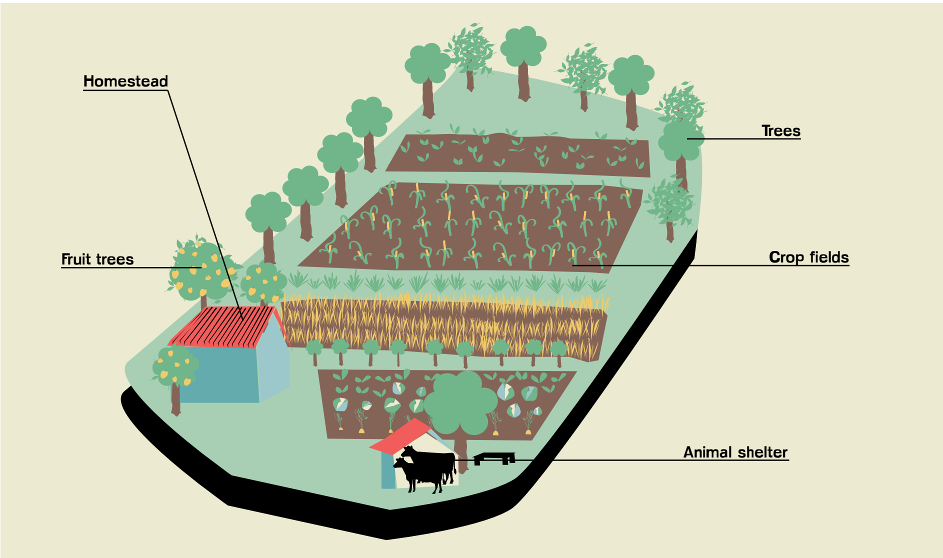


Illustration: Home garden

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 *Markhamia 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*.

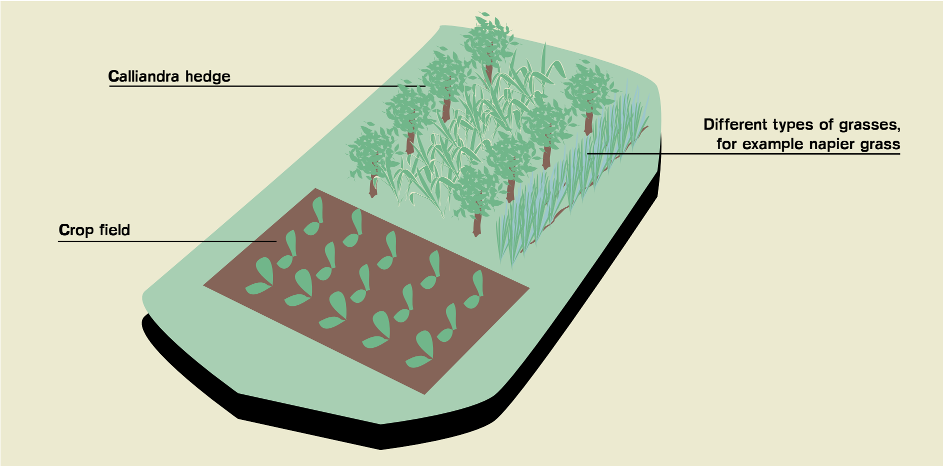


Illustration: Fodder bank

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.

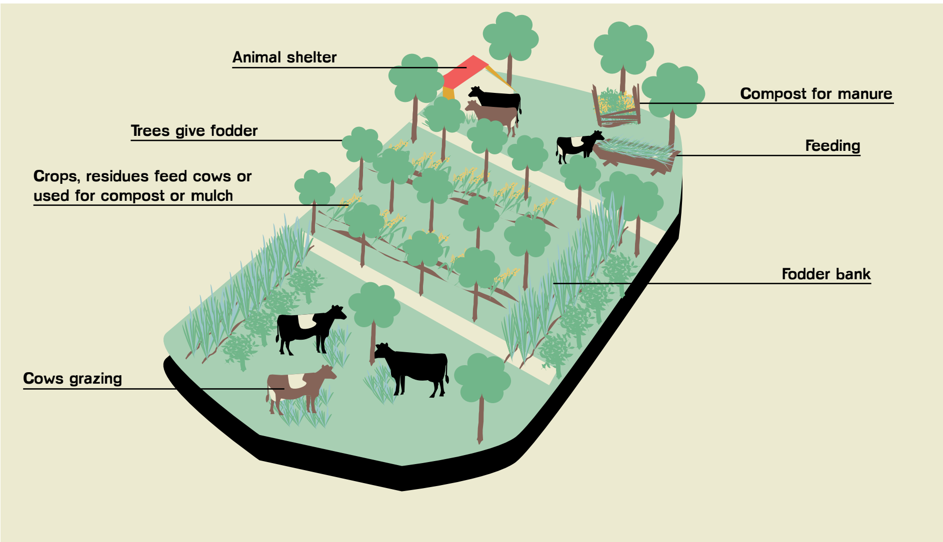


Illustration: Trees with a mix of crops and livestock

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.

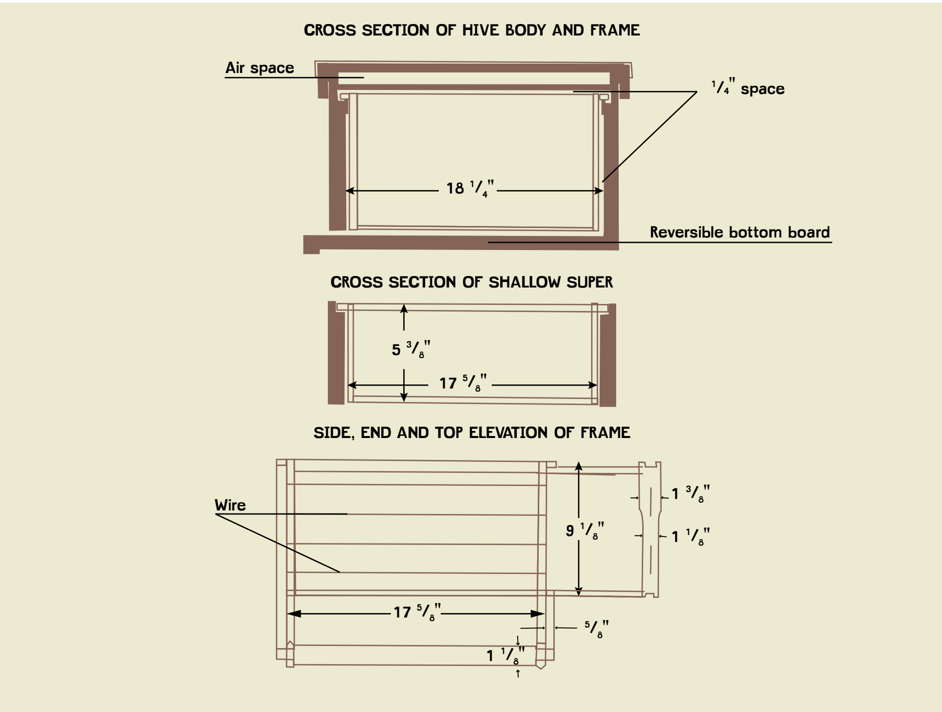


Illustration: How to build a langstroth bee-hive – Part 1

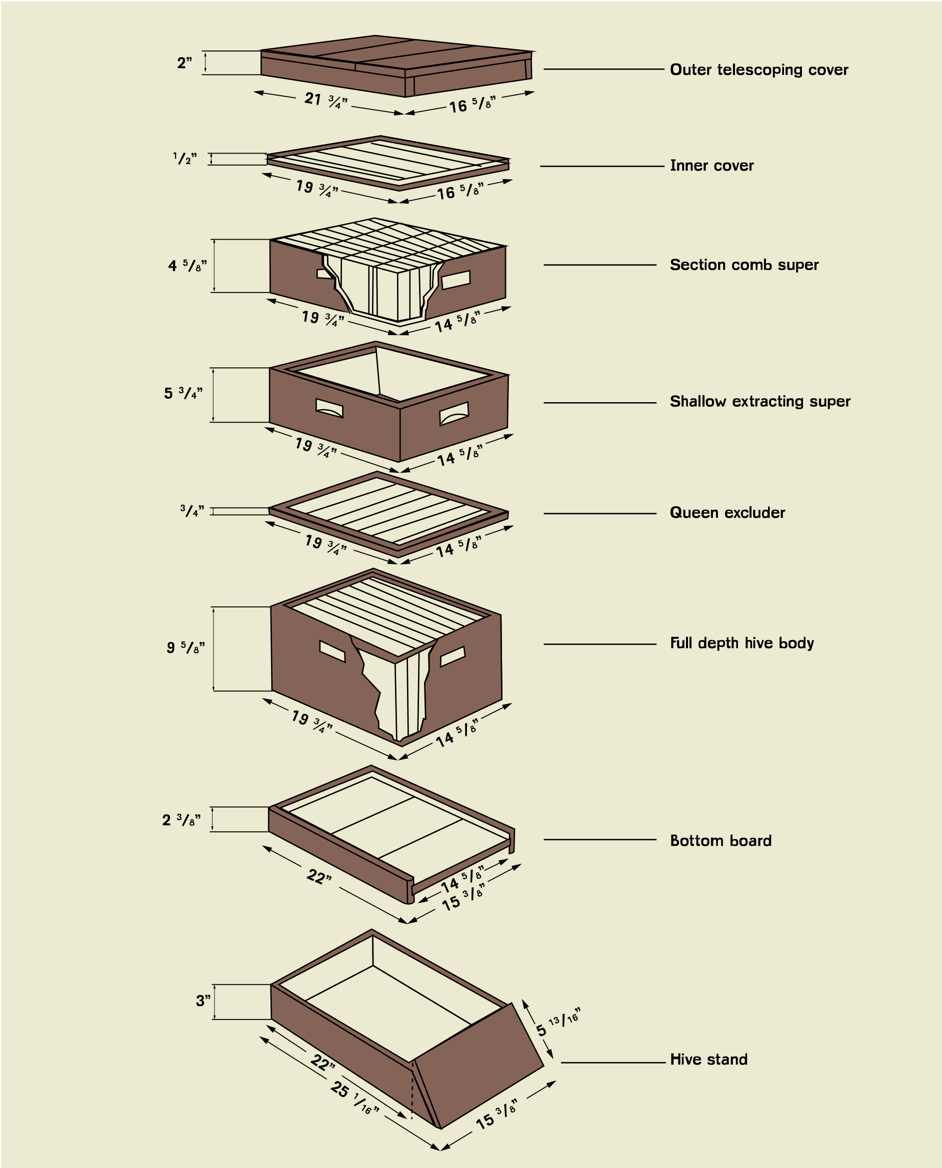


Illustration: How to build a langstroth bee-hive

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.

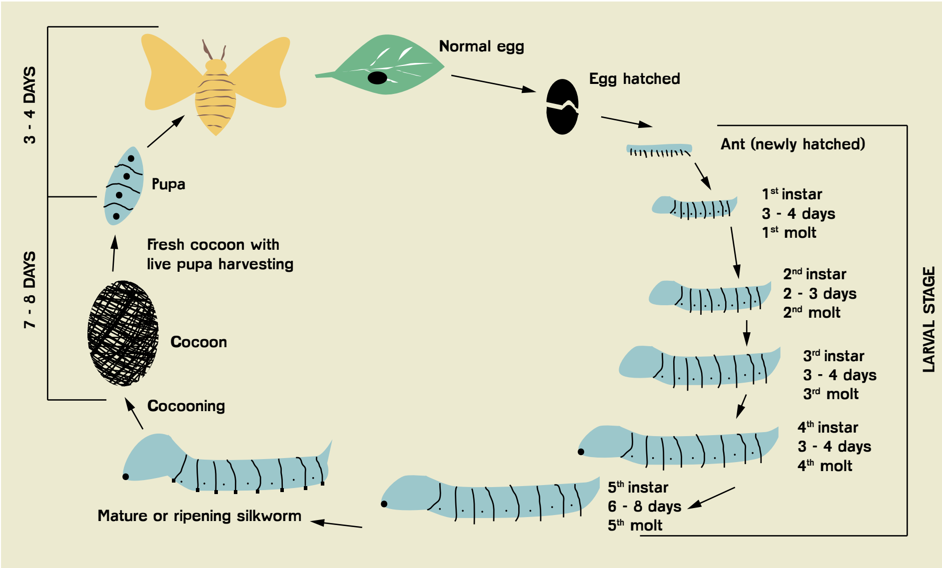


Illustration: Silk production

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.

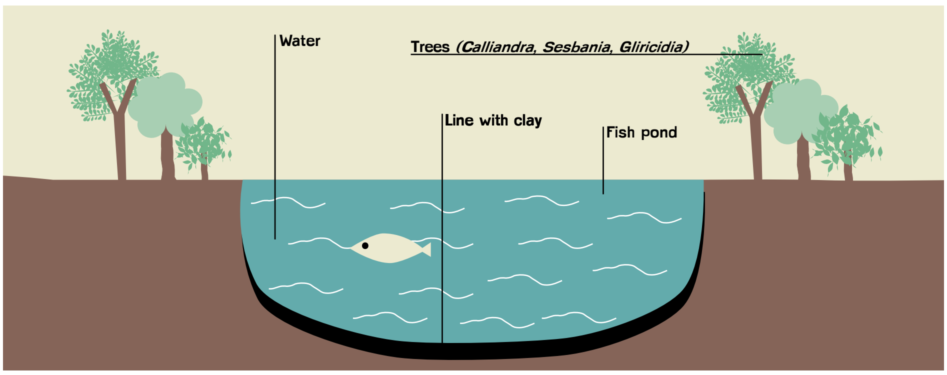


Illustration: Fish farming

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.

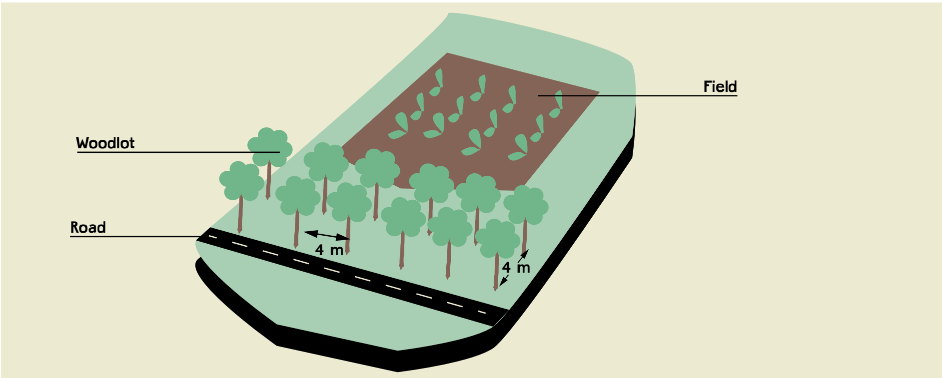


Illustration: Woodlot

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.

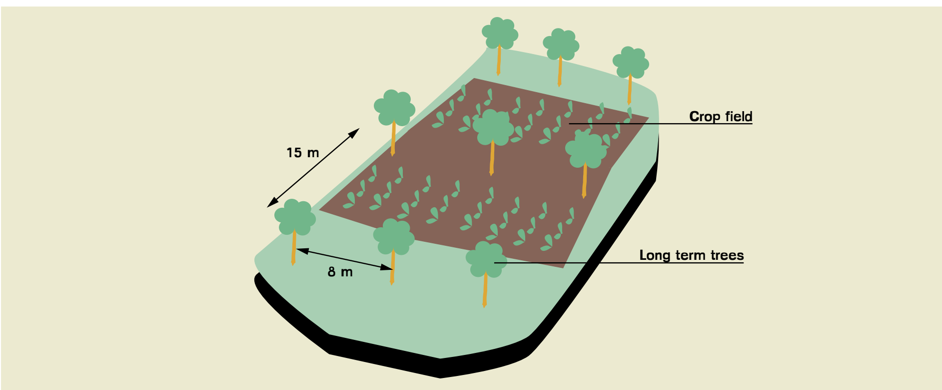


Illustration: Dispersed inter-planting

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.

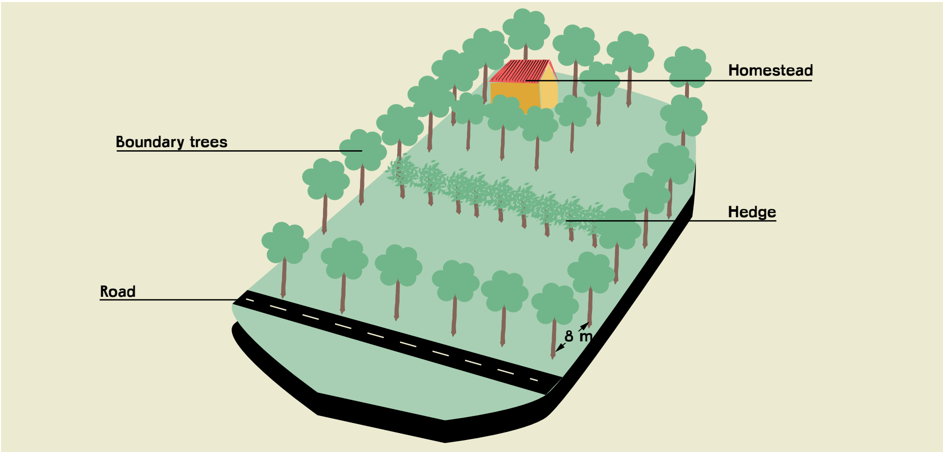


Illustration: Boundary planting

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
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
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

Table: From seed to tree – 1

TREE SEEDS SPECIES	METHOD OF PROCESSING THE SEED	PRE-TREATMENT METHOD	GERMINATION PERIOD	PLANTING METHOD
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. Softening in cold water for 12 hours and then drying in the sun.	Soak in boiled hot water overnight. If seeds are fresh, it is not neccessary to soak them.	10–15 days if seeds are fresh. Otherwise 3 weeks.	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
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

Table: From tree to seed – 2

TREE SEEDS SPECIES	METHOD OF PROCESSING THE SEED	PRE-TREATMENT METHOD	GERMINATION PERIOD	PLANTING METHOD
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 extracted 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
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

Table: From tree to seed – 3

TREE SEEDS SPECIES	METHOD OF PROCESSING THE SEED	PRE-TREATMENT METHOD	GERMINATION PERIOD	PLANTING METHOD
Terminalia catapa	Sorting and drying	Soak in boiled hot water overnight	20 – 30 days	Direct sowing/ nursery
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

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.

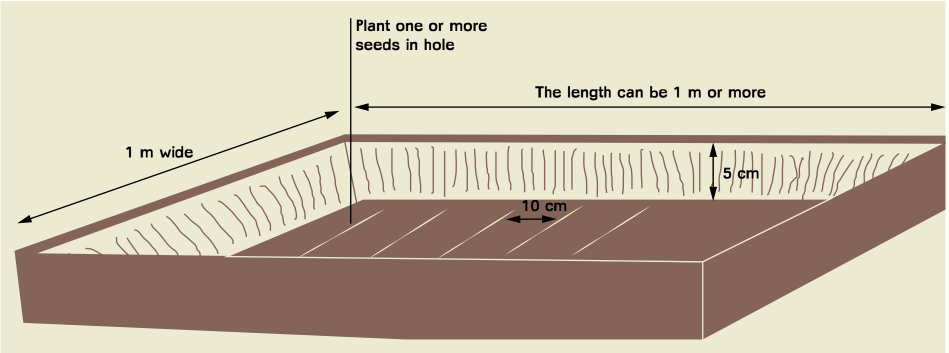


Illustration: Sunken beds

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 1 m, 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.

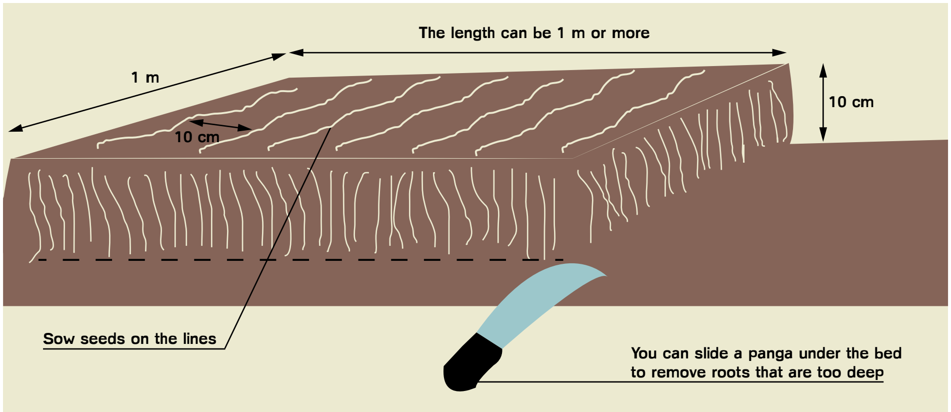


Illustration: Raised beds

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.

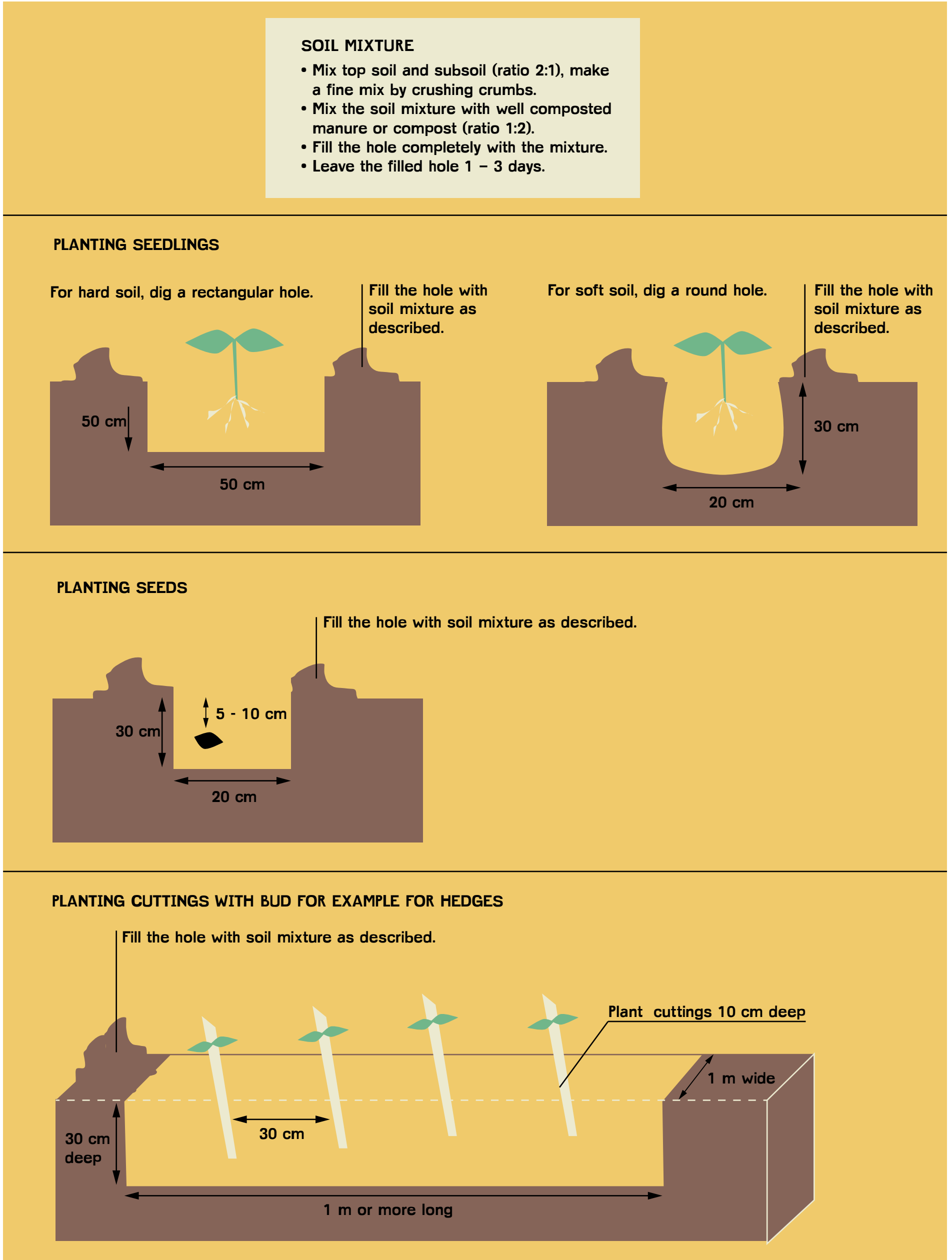


Illustration: How to plant a tree: seedlings, seeds and cuttings with buds.

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.

Think about

BENEFITS OF CROP RESIDUES:

- **Improve soil nutrients.**
- **Improve soil structure and moisture-holding capacity.**
- **Increase soil organic matter.**
- **Control soil erosion.**
- **Control of pests, weeds and diseases.**

Note: Residues can be used without burning. Burning of residues increases the emission of particles (aerosols) and greenhouse gases, and should be avoided. Burning residues also increases soil temperature, depletes nutrients from the cropland and interfere with micro-organisms activities.

7.3 Tillage

Tillage is the preparation of soil conditions by digging, stirring, overturning and/or any other appropriate method to facilitate seed germination, root development, weed eradication, and crop growth. Tillage can be achieved using hand tools, animal drawn-implements or machines such as tractors.

Note: Animal-drawn ploughs reach the depth of about 15 cm, while hand tools dig to a shallower depth less than 10 cm. Tillage is likely to compact the soil and create a hard pan. Therefore, in the initial tillage an animal plough can be used to break the hard pan and bring nutrients from the bottom layer to the top layer where micro-organisms and nutrient cycling takes place. You can also do this by hand; use a jembe to dig 20 cm and then put the soil back (also called double dug). The use of tractors in tillage increases emissions and should be avoided.

There are two main types of tillage systems:

1. Conventional/intensive tillage
2. Conservation tillage

7.3.1 Conventional/intensive tillage

Conventional or intensive tillage is the ploughing done at the beginning of the planting season before crop establishment. It is usually done using: a hand hoe, moldboard plough (ox-drawn or tractor operated), disc plough, rotator or various harrows. However, there are several risks associated with conventional tillage. To avoid these risks, conservation tillage is recommended.

Think about

RISKS OF CONVENTIONAL TILLAGE:

- Leaves less than 15% residue on the soil surface after planting.
- Compresses the soil layer of many soils (to a depth of 15 cm) leaving a fine seedbed that caps easily. This layer can form a hard pan after several seasons of ploughing, preventing water percolating down and increasing water runoff on the surface. This can inhibit root growth deeper than 15 cm.
- Involves a higher degree of soil disturbance, leading to the mixing of top soils and sub soils.

7.3.2 Conservation tillage

Conservation tillage is a planting system that ensures minimal soil disturbance. It leaves at least 30 – 50% of the field surface covered with crop residues such as mulch and stubble after planting has been completed. The top and sub soils are not mixed in the process.

You can leave stalks and leaves of harvested crops on the fields to cover the soil and protect the soil from wind and rain. The cover also mixes with the soil, releasing nutrients and improving soil conditions for plant growth. A chisel plough can be used to mix crop residues into the soil.

In the initial stages of cultivation, farmers often use herbicides for weed control during conservation tillage. Note that mulching also provides cover which can control weeds.

Note: Herbicides are not recommended since these are expensive, destroys micro-organisms, pollute soil and water and can harm the farmer if applied incorrectly.

Think about

BENEFITS OF CONSERVATION TILLAGE:

- Increases productivity.
- Controls weeds.
- Reduces tillage costs.
- Controls soil erosion.
- Increases soil organic matter.
- Conservers soil moisture.
- Reduces water pollution in rivers and lakes.
- The conditions created in the soil form resource capital bases for farmers to adapt to climate risks and hazards.

There are two main systems of conservation tillage:

1. Zero tillage/no-tillage/direct drilling
2. Reduced or minimum tillage

7.3.2.1 Zero tillage

Zero tillage is also known as no-tillage or direct drilling. It is a method where all of last crop's residue is left in the soil after harvest. The new crop is then planted directly into the untilled soil by placing the seeds in the soil through small openings or holes.

7.3.2.2 Reduced or minimum tillage

Reduced tillage involves preparing the soil only to the extent that renders the soil ready for seed germination, seed emergence, water infiltration, aeration, soil temperature regulation, and weed control. It is achieved by opening up a planting line or a hole without disturbing the areas between the rows where crops are planted. Some practices involve a ripper tine or a plough without the mouldboard. If no other tools are available, a hand hoe can be used for opening up planting holes. Seeds are sown in the planting lines and covered with soil.

Reduced tillage leaves 15% – 30% residue.

Think about

REDUCED TILLAGE DIFFERS FROM CONVENTIONAL TILLAGE IN THE FOLLOWING WAYS:

- Involves fewer operations.
- Less soil disturbance.
- Only the seedbed where the seeds are planted is prepared.
- Crop residues are not buried but left on the soil instead.

Think about

Zero tillage and minimum tillage has been criticised for the high number of pests and the difficulty in maintaining untilled land. Weed control can be achieved without the unnecessary use of herbicides through: biological methods (planting crops that inhibit the growth of the weeds), crop rotation (see chapter 11) using mulch or cover crops, or using a combination of cover crops with stubble or mulch.

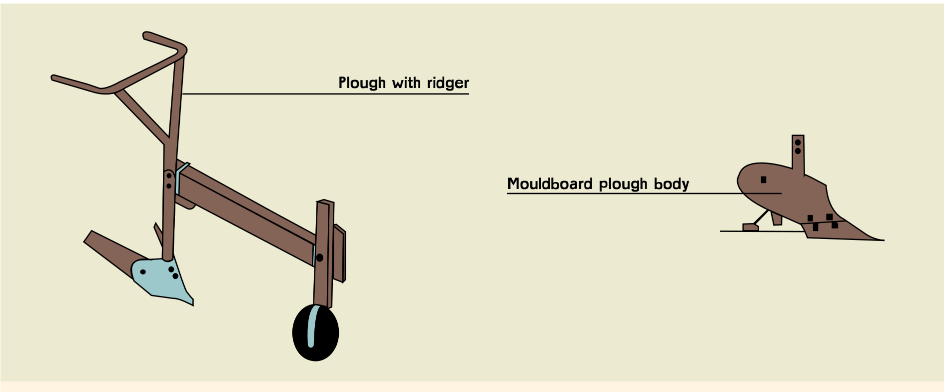


Illustration: Plough with ridger (mouldboard plough body also shown)

Some of the most common used reduced tillage systems are:

- Pitting systems.
- Stubble and residue mulch tillage.
- Ridge and furrow tillage.
- Dibble stick planting.
- Strip and spot tillage.
- Ripping.

a. Pitting systems (see chapter 4)

Pitting system utilise the cropland efficiently by just disturbing the soil at planting sites only. The rest of the areas without pits can be mulched to control soil moisture and runoffs. Only sites of planting are dug to make pits. The pits can be permanent places of planting in the first 5 – 10 years before changed. You should make sure that pits have the same number of plants per acre and this can be achieved by designing pits taking a number of plants required. See chapter 4 for more details on types of pitting.

b. Stubble and residue mulch tillage

Stubble mulch or tine tillage involves chopping 30 – 70% of crop residues and spreading these on the surface or incorporating them during tillage. You can also leave the residue as mulch on the surface to cover the soil and eradicate weeds.

The stubble tillage is done with using a tined implement with blades or sweeps attached to the tines to uproot or undercut the weeds. Implements such as chisel plough, field cultivators or a combination of these tools are used. You can also use a *panga* to chop the residues into the desired sizes.

Note: Equipment used for planting must have special furrow openers to avoid clogging with trash, otherwise residues and mulch materials can block the machine carrying the seed during planting.

c. Ridge and furrow tillage

Ridge tillage involves building ridges 10 – 15 cm high during row cultivation and then scrapping off 2.5 – 5 cm of the ridge during planting. Some farmers use special machines to form soil into ridges and then plant the seeds on top of the ridges. The soil and residue from previous crop between ridges are not disturbed during planting or cultivation. The risk of soil erosion is reduced as plant material and soil material are not broken by the machines.

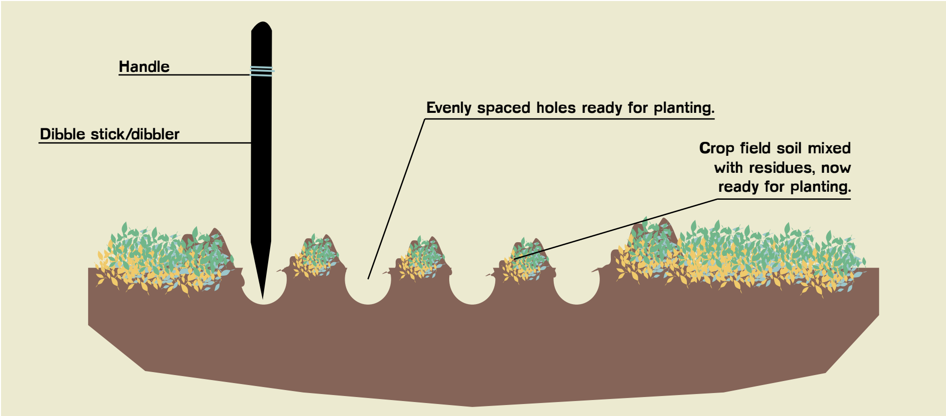
Ridges are made with alternate furrows that run across the field parallel to the contours. Rows of crops are planted on ridge top, in the furrow or along both sides of the ridge. A ridger (tool for making ridges), jembe, hoe or mouldboard plough can be used for cultivation.

Discontinuous furrows may be made through cross-ties to interrupt water flow in the furrow, by these basins or pools can be created to retain water temporarily (tie-ridging).

This system is suitable for gentle slopes in arid semi-arid areas and for growing crops such as sweet potatoes, yams and cassava.

d. Dibble stick planting

A dibble or dibbler is a pointed wooden stick used for making holes in the ground so that seeds, seedlings or small buds can be planted without disturbing the soil too much. The sticks are used in an un-ploughed field that has stubble or crop residue. The holes are made in lines at evenly spaced distances. This makes weeding, and the application of fertilizers or manure easier.



llustration: Dibble stick and how it is used for planting

e. Strip and spot tillage

In strip tillage, seeds are planted in narrow strips leaving soil in between rows untilled. In other words, only those parts of the fields where the seeds and fertiliser are placed is tilled. You can make strips using a mouldboard plough or animal-drawn striper. This conserves crop residues and thus helps to conserve soil moisture.

In spot tillage, only the soil in a narrow strip directly below the row of crop is disturbed. It is effective when used in combination with cover crops as it allows soil to aerate and warm up.

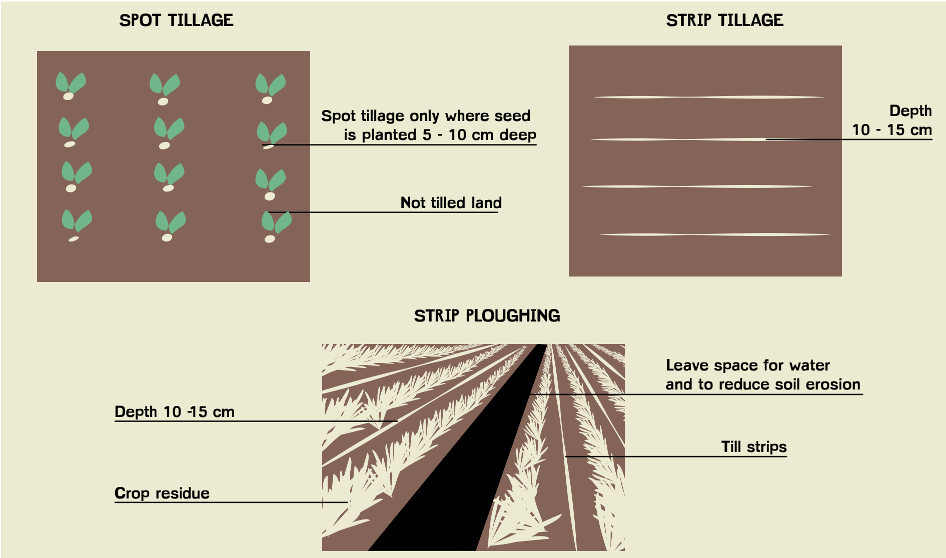


Illustration: Spot tillage, strip tillage, strip ploughing

For a video demonstration on strip tillage, visit:
http://www.accessagriculture.org/node/882/en

f. Ripping

Ripping involves the use of a chisel-shaped implement pulled by at least one animal that is used to break up the surface crusts and open narrow slots in the soil. The slots measure about 5 – 10 cm deep. Ripping can be done on fields that may or may not have crop residues on the soil surface.

EXERCISE

1. **How do you manage residues on your farm? How can you improve your practices?**
2. **How can you reduce tillage operations on your farm?**

8. Land restoration and rehabilitation

Introduction

Land is degraded when it is infertile, saline, acidic, eroded, weedy, and low in organic soil matter. Degraded land can decrease productivity and increase the cost of crop production. By the end of this session you will know how you can restore the land on your farm by returning lost nutrients, improving soil structure, and finding alternative nature-based land uses such as bee-keeping or planting fodder plants.

Time required: 2 hours

8.1 What is land degradation?

The causes of land degradation vary, but it is often a result of population pressure, unsustainable land practices and poor farming practices such as:

- Land clearance.
- Agricultural depletion of soil nutrients.
- Overgrazing.
- Excessive use of inorganic fertilizers and/or agrochemicals.
- Mono cropping.
- Conventional tillage.
- Deforestation.
- Droughts, fire and flooding also cause land degradation.

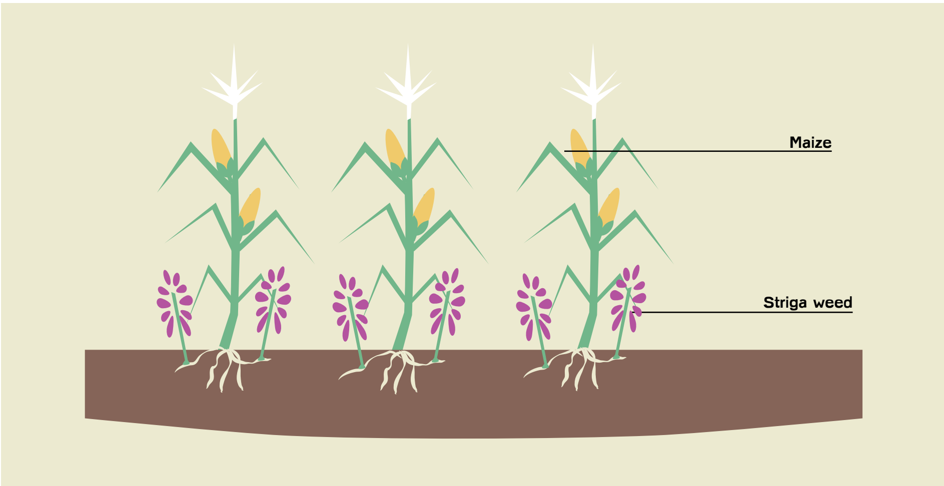


Illustration: Example of degraded land – 1

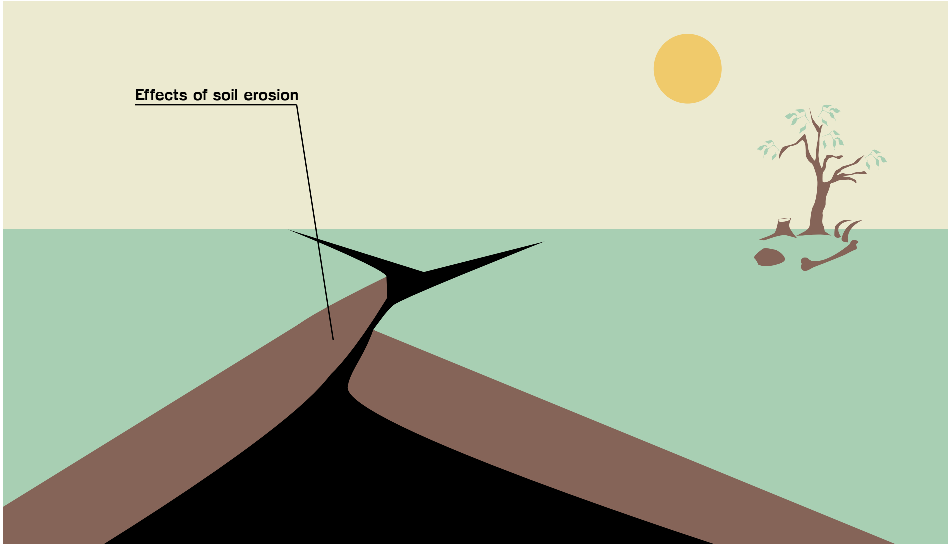


Illustration: Example of degraded land – 2

Land that has become unproductive can be restored and/or rehabilitated using the following methods:

- Natural regeneration
- Assisted natural regeneration
- Enrichment planting
- Fire management

8.2 Natural regeneration

Natural regeneration is the deliberate re-establishment of healthy vegetation and biomass on degraded land by accelerating or enhancing the way the vegetation naturally changes (ecological succession). Bee-keeping, if suitable, can be also introduced. The bees will help to pollinate the crops. Alternatively silt can be poured onto the affected land and tree seedlings planted to create a woodlot. Over time the forest and the land on it will be restored.

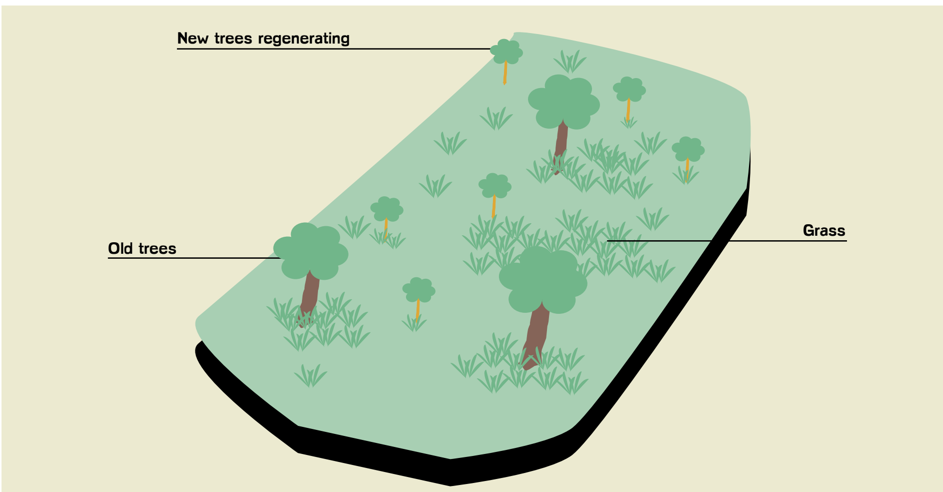


Illustration: Natural regeneration

8.3 Assisted natural regeneration

Assisted natural regeneration involves promoting tree seedlings and favourable species that were once destroyed.

Another way would be to produce fodder banks or produce fodder for livestock. After a while, grass or other fast-growing crops are planted. With time the quality of the soil on this land improves, and the land becomes more productive.

Note: Remember that grazing livestock accelerates land degradation. Instead use fodder banks for fodder-grass and fodder trees.

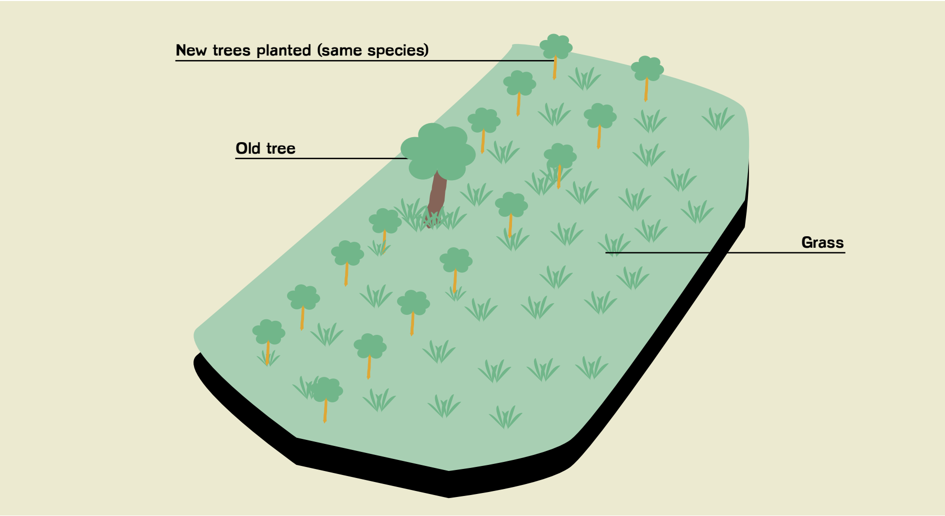


Illustration: Assisted natural regeneration

8.4 Enrichment planting

Enrichment planting is a method used to restore over-exploited forest-dominated ecosystems especially along waterways.

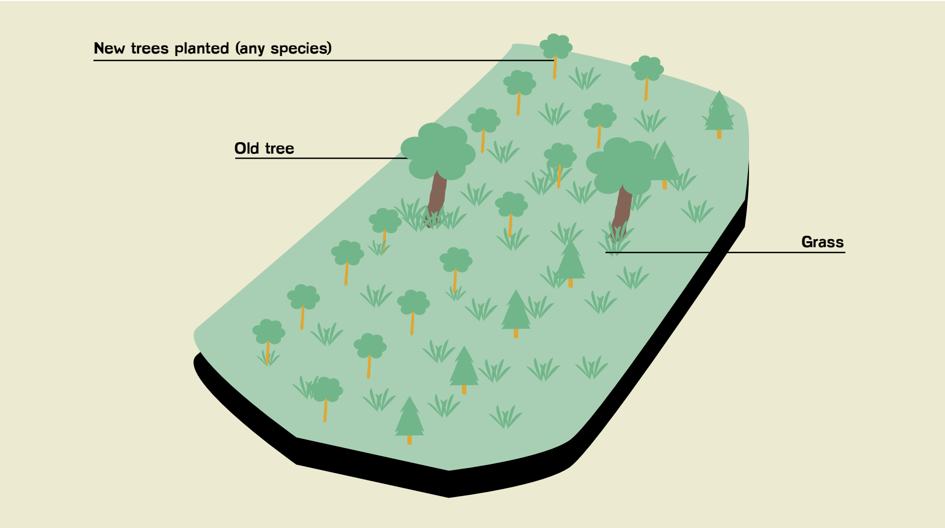


Illustration: Enrichment planting

8.5 Fire management

Fire in agriculture and forestry sectors has caused land and environmental degradation. It is therefore important with fire management to control fires. Reducing the frequency and intensity of fires typically leads to increased tree and shrub cover and increasing the levels of carbon in the soil and biomass.

Note: There are severe dangers with burning, such as the risk of spread of the fire (from controlled to uncontrolled fire), deforestation, damage crops, soils and biodiversity. There is also the human risk of getting burned or hurt by smoke.

EXERCISE

Pull out your map of your farm.

1. What areas are degraded today? Why?
2. What method do you use to restore your land? Why?
3. What new or different methods do you think will be more useful and how would you apply them to your land (use the map of your farm again)?

9. Integrated livestock management

Introduction

The purpose of this session is to help you understand how best to manage and reuse most or all the resources in your farm while rearing the livestock efficiently and sustainably, in a coordinated manner. These practices will also help to adapt to the impacts of climate change and to reduce the greenhouse gas emissions associated with livestock production.

Time required: 2 hours

9.1 What is integrated livestock management?

An integrated livestock system usually consists of different mixed components, for example, livestock with crops, or livestock with bees and crops, or livestock with crops and fish. These components work together in a natural cycle to maximise resource use. The products or by-products of one component (e.g. manure from livestock) are used as a resource for another component (e.g. crops).

Several components: land or soil, water, crops/vegetation, feeds, livestock, manure and waste are considered to achieve efficient livestock production.

Example 1: Integrating bees with crops and livestock

Bees cross-pollinate crops, increasing yields naturally. Bees also provide many useful products such as medicine (propolis), honey, and wax, which can be processed and sold for extra income.

Example 2: Integrating fish with crops and livestock

Fish ponds can be used to irrigate vegetables. The by-products of the vegetables can be used as livestock food (suitable for a variety of animals including pigs, goats and rabbits, and the fish). The livestock provide manure.

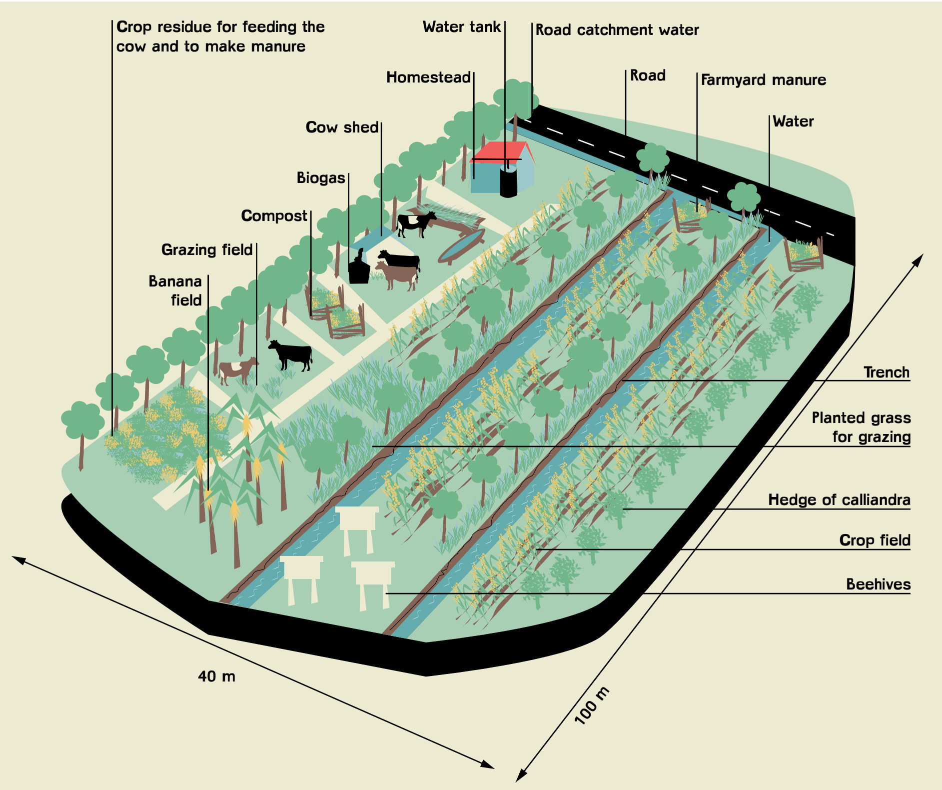


Illustration: Integrated system of livestock, crops and bees on 1 acre

Think about

BENEFITS OF INTEGRATED LIVESTOCK MANAGEMENT:

- Increased livestock productivity.
- Resources are used efficiently (land, water, soil).
- Sustainable intensification.
- No land use change as a result of land expansion.
- Reduced GHG emissions and pollution.
- Reduced land degradation.
- Restoration and rehabilitation of degraded or eroded land.
- Adaptation to climate risks and hazards.
- Reduced cases of pests and diseases.
- Conservation of biodiversity.

9.2 Common practices

The following are some of the most common sustainable integrated livestock management practices:

1. Improved feeding (diet), watering
2. Housing, stall management systems
3. Improved breeding
4. Manure handling
5. Pest and disease control

9.3 Improved feeding (diet) and watering

9.3.1 Feeding

Livestock mainly feed on pasture (perennial fodders, pastures and legumes) found either on grazing land, or bought from specialist outlets (shops or distributors). Efficient pasture management is therefore necessary for improving livestock nutrition. Pasture management involves selective sowing of improved varieties of pasture to enhance livestock grazing. It also increases farm productivity, soil carbon storage, and reduces enteric methane (CH_4) emissions.

There are three main livestock production systems:

1. Land-based grazing system
2. Mixed system
3. Landless system

The integrated livestock management approach can be applied to these three systems in the following ways:

a. Land-based grazing system

The land-based grazing system involves grazing livestock on the grazing grounds or pasturelands through tethering, paddocking and rotational grazing. The effective strategy under grazing management is rotational grazing. Rotational grazing is more effective than tethering or paddocking as it ensures quality and digestibility of forage thereby improving livestock productivity and reducing the emission of enteric and manure methane (CH_4) gases.

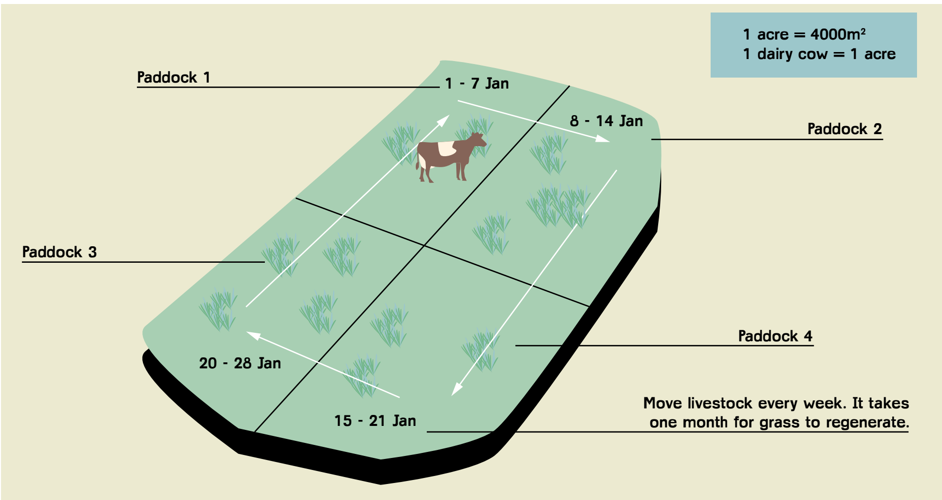


Illustration: Rotational grazing/paddock grazing

Managing soil, grass and livestock requires the use of grazing management techniques. Factors determining optimum grazing of livestock and forage productivity include: existing grazing practices, plant species, soils, and climatic conditions.

Pasture production can also be increased through the rehabilitation and restoration of degraded grazing land, or through intensification process by fertilization, cutting regimes and irrigation practices.

Think about

Pasture production cannot be implemented in arid or semi-arid areas without intensification, which is done through irrigation. The intensification of production can increase productivity, soil carbon capture, pasture quality and animal performance.

b. Mixed systems

The mixed system involves raising both crops and livestock on the same farm. Animals feed on crop residues, fodder from established pastures or fodder banks (in a cash and carry strategy) and feeds (produced on the farm or bought from external sources).

Fodder banks minimise the loss of runoff moisture and soil nutrients, enhancing crop production. Crops such as grass that are grown on fodder banks (see chapter 4) provide food for grazing livestock, and mulch. Grazing livestock also enrich the soil through reduced tillage and manure.

Examples of mixed systems are:

1. Soil–crop–water management
2. Crop–water–livestock management
3. Feed, water and animal management

Integrated soil–crop–water management

Integrated soil–crop–water management systems are agronomic practices with multiple benefits, including increased food security, and climate change adaptation and mitigation.

SOIL AND WATER ADAPTATION STRATEGIES	MAJOR ADAPTATION AND MITIGATION POTENTIAL
Conservation tillage and agriculture.	Manage pests, disease, weeds, reduce compaction, lower N_2O loss.
Terracing.	Control soil erosion.
Use of crop residues.	Moisture conservation.
Use of cover crops.	Reduce runoff speed.
Mulching.	Control weeds.
Green manure.	Soil fertility (nitrogen fixation).
Compositing and manure application.	Increase soil carbon sequestration.
'Pull-and-push technology' (Using pest repellant "push" plants such as *Desmodium* and trap "pull" plants such as napier grass.	Improve animal food and feed.

Table: Soil and water adapatation strategies

Efficient crop–water–livestock management involves:

- Improved crop varieties using water efficiently.
- Improved irrigation techniques.
- Supplementary irrigation in rain-fed systems.
- Water-efficient harvest.
- Modification of cropping calendars (timing or location).
- Energy efficiency (dairy farming, refrigeration, solar).

Feed, water and animal management involves:

- Improving feed quality (protein, minerals, vitamins and starch).
- Using improved grass species and forage legumes.
- Increasing feed-water productivity.
- Enhancing feed selection.
- Strengthening grazing management.
- Increasing animal productivity and health (better veterinary services, preventive health programmes and improved water quality).
- Upgrading livestock (reduce the number) and breeding (e.g. breeds heat-tolerant, fast growing).
- Diversifying e.g. moving from mixed crop-livestock systems to rangeland-based systems.
- Mixing crops and pasture in the cropland.
- Shifting from growing crops to raising livestock.

c. Landless systems

The landless system involves managing waste or manure and enteric methane (methane produced in the rumen chamber of a cow) especially in pig, dairy and feedlots. Landless systems improve the small-holder farming (see table).

PRACTICE/ TECHNOLOGIES	FOOD SECURITY	ADAPTATION	MITIGATION	BARRIER
Biogas and fertilizer (anaerobic digester)	Very high	Very high	Very high	Investments costs
Composting	Higher	High	Higher	–
Improved manure handling and storage (covering manure heaps)	Higher	High	Higher	–
Temperature control systems	Very high	Very High	High	Investments and operational costs
Disease surveillance	Higher	Very High	High	–
Energy use efficiency	–	High	Very High	Subsidy cost
Improved feeding practices (e.g. precision feeding)	Very high	High	Very high	High operating costs
Building resilience along supply chains	Higher	Very high	–	Coordination

Table: How landless systems improve farming

9.3.2 Livestock nutrition (diet)

Animals need appropriate food to supply them with essential nutrients for overall health and productivity. For example, a well fed cow provides more milk than a cow fed on crops with low protein. The main food groups important for livestock are listed below:

1. **Carbohydrates:** To provide energy. Sources include: green grass, roughage, green grass, pasture and hay.

2. **Proteins:** For body-building. Sources include different type of harvested feeds such as crushed maize, cereal grains, various silages (e.g. fermented grass), plant sources meals made from sunflower, soybean, maize, wheat, *Sesbania* and *Calliandra* leaves, and meals based on animal proteins such as blood meal, fish meal and feathers meal.

3. **Vitamins:** Animals require different kinds of vitamins, which in some cases are added as supplements. The importance of vitamins to livestock include: control of diseases, increased livestock productivity and performance, increase growth and development, increase reproduction and fertility.

   - **Vitamin D:** To improve bone formation, growth and starch/glucose (CHO) metabolism. Vitamin D increases the absorption of calcium and phosphates in the small intestine. Lack of vitamin D in animals cause rickets in calves, soft egg shells and reduced growth and leg weaknesses. To get enough vitamin D, animals should be exposed to sunlight for at least 30 minutes every day.
   - **Vitamin A:** Can be found in 2 – 3% of Lucerne mill, carrots and dried crushed amaranth leaves. You can also inject your livestock by multivitamin found in the agro vet. Vitamin A deficiency causes blindness and eye problems, rough skin, swollen legs, incoordination in pigs, reduced egg production and hatchability, skeletal malformations, reduced growth and reproductive failure.
   - **Riboflavin – Vitamin B2:** Riboflavin is synthesised in the rumen. It is important for starch/glucose and protein metabolism, especially in pigs and poultry. Deficiency symptoms include curled toe paralysis in chicks, reduced egg production and hatchability, skin lesions, reduced growth, high neonatal mortality in pigs, hairless dead piglets and moon blindness in horses. Riboflavin is found in Lucerne meal, green plants, fishmeal and milk products.
   - **Vitamin B12:** Is important for maturation, and energy production and synthesis of haemoglobin. Haemoglobin is synthesised in the rumen. The vitamins are essential for pigs and poultry. Deficiency in vitamin B12 leads to: weight loss, suppressed appetite, decreased feeding efficiency, anaemia, reduced growth, poor reproduction, hatching problems in chicks, diarrhoea, rough coat, and scaly ears. Soya meal and fish meal feeds, milk and injection can provide B12 for the animals.
   - **Vitamin E:** Important for strong antioxidant hence longer shelf life for meat, boost immune system, muscle structure and reproduction. Deficiency of Vitamin E causes nutritional muscular dystrophy (while muscular disease in calves and lambs), liver necrosis (death) in pigs, brain degeneration in poultry, retained placentas and low fertility.
   - **Vitamin K:** It is important for blood clotting and activation of prothrombin (plasma protein) to create calcium binding sites. Deficiency of vitamin K causes spontaneous haemorrhages and increased blood clotting time. Sources of Vitamin K include: *gliricidia, sesbania, desmodium* and *calliandra* leaves, sweet clovers, rumen synthesis, green forage (Napier), well cured hays and fishmeal.

   Note: Pigs need more vitamins compared to than other farm animals because, unlike ruminants (e.g. cows), pigs have a simpler digestive system. Pigs are therefore unable to absorb the microbial fermentation, and have limited possibilities to digest fibres. This is why pigs and other similar omnivores require a higher level of vitamin intake. It is especially important to give piglets enough vitamins. Contact a livestock officer for correct information if you are uncertain.

4. **Minerals:** There are two main kinds of minerals: macro minerals (required in large amounts) and micro (required in small amounts) minerals. The following table contains a summary of the most common macro nutrients, together with the sources, functions and health conditions associated with the lack of the minerals.

MINERAL	FUNCTION	SOURCE	DEFICIENCY SYMPTOMS
Calcium	Strengthening bones, teeth.	Agriculture lime, fish meal, milk, crushed shells, marble dust, sea weed, green leafy forage and legumes.	Rickets (soft bones) in young animals and osteoporosis (brittle bones) in old animals.
Phosphorous	Growth, tissue building, milk, bones.	Bone meal, salt licks, cereal grains, hay and straw.	Eating soil, chewing on non-feeding objects, slow or poor appetite, slow gain of body weight, low milk or egg production.
Magnesium	Fastening of nervous system, enzyme, carbohydrates breakdown.	Legumes, peas and lentils.	Hyper-excitability, frequent death, increased blood flow, convulsions, frothing of the mouth.
Sulfur	Synthesis of proteins, active enzyme reactions yolk formation, insulin and bile formation, strengthens wool, fur and feathers and supports cellular respiration.	Kales and cabbage, amaranth leaves, *Sesbania, Calliandra,* soymeal, fish meal.	Slow growth, general unthriftiness (inability to grow, put on weight even if fed well), poor performance, poor wool, fur or feathers.

Table: Minerals

Good quality feeds are digestible, easy convertible and also from sustainable intensification, less fertiliser and integrated sources.

Think about

9.3.3 Water

Water, considered to be the source of life, is a very important part of a healthy animal's diet. In fact, an animal can die faster from lack of water (dehydration) than from the lack of any other feeding need.

Note: Animals need 1 litre of water per 10 kgs body weight.

Think about

WATER IS IMPORTANT FOR ANIMAL LIFE BECAUSE OF THE FOLLOWING REASONS:

- Water is vital body fluid which is essential for regulating the processes such as digestion, transport of nutrients and excretion. Water dissolves ionic and large number of polar organic compounds. Thus, it transports the products of digestion to the place of requirement of the body.
- Water regulates the body temperature by the process of sweating and evaporation.
- Water is a medium for all metabolic reactions in the body. All metabolic reactions in the body take place in solution phase.
- Water provides habitat for various animals in the form of ponds and rivers, sea, and so forth.

The water should be fresh and safe for consumption, so watering points should be shielded from treading and other sources of contaminants. Water can be sourced from boreholes, fresh water systems, or harvested sustainably e.g. through water pans or roof gutters.

Note: Consider factors such as the type of animal (dairy, beef, pigs, horses, sheep, goats, chicken, turkey and rabbits) and kind of products produced when providing water. Animals that produce milk, for example, need more water than those bred for beef and leather. The higher the amount of milk produced the higher the amount of water will be required. A cow producing 36.3 – 45.5 litres of milk per day needs 114 – 155 litres of water per day. In addition, the quality of the water matters.

9.4 Housing, stall management systems

Poorly constructed animal housing stalls exposes animals to pests and diseases, restricts movement, is uncomfortable, and reduces productivity and resilience to the negative effects of climate change. For example, a low level of hygiene and dirty animals housing can lead to animals producing less milk.

It is also important for animals to have access to shade and not be exposed to the UV-light too heavily during daytime since animals tend to use more energy conserving body temperature than producing milk.

9.4.1 Factors to consider when constructing animal houses

- **Type of livestock:** Different animals need different housing and structures or housing conditions.
- **Feeding behaviour:** Different animals have different feeding behaviour. For example, chicken peck, pigs root (carries head to chew) and cows jug (turns tongue and head). The structures should be adapted to minimise feed loss and contamination. The behaviour of animal eating require space and design requirements of the house for the animal.
- **Drinking:** Housing should accommodate water containers and drinking habits. It should also allow for the drainage of spilt water.
- **Breeding:** Housing should be favourable for mating, birthing and free of unnecessary disturbance.
- **Physical or mechanical environment factors.**
- **Climatic factors:** Housing in areas prone to strong winds, for example, should be steady, and built near wind breaks such as trees. Those in flood-prone areas should be raised, away from the path of runoff water.

9.4.2 Forms of housing

- Yards (4 – 5 meters per cow).
- Deep-bedded shed (fitted).
- Loose housing with stalls.
- Bull pens (12 – 15 m feeding paved area large exercise area 20 – 30 m for exercises). Walls of must be very strong.
- Calf pens (build to fit for lactating, concentrates and watering).

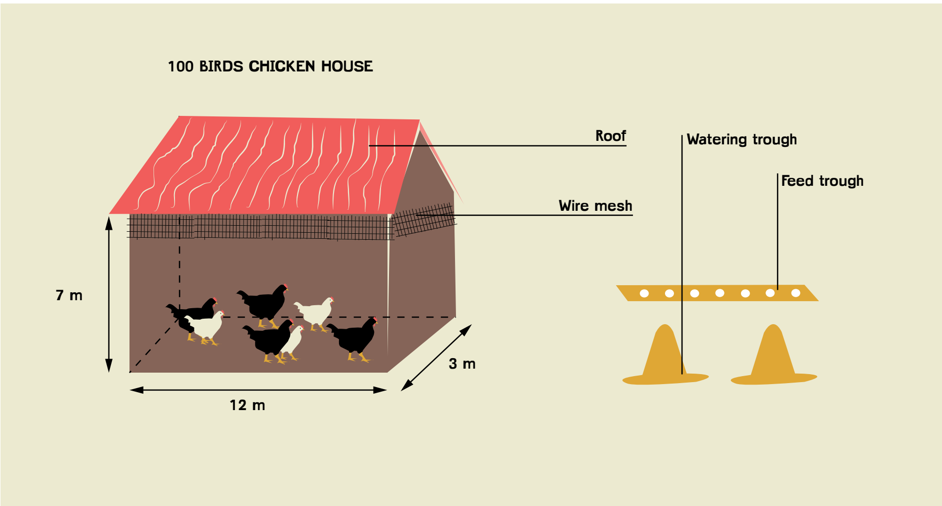


Illustration: Housing for chickens

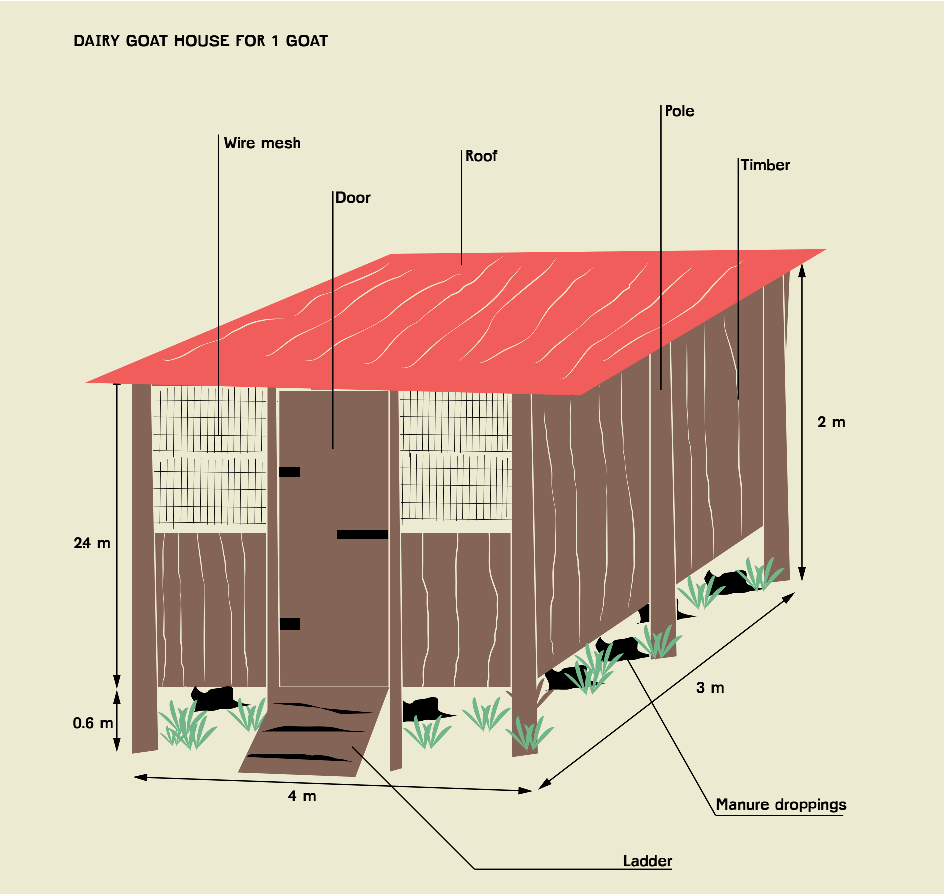


Illustration: Housing for dairy goats

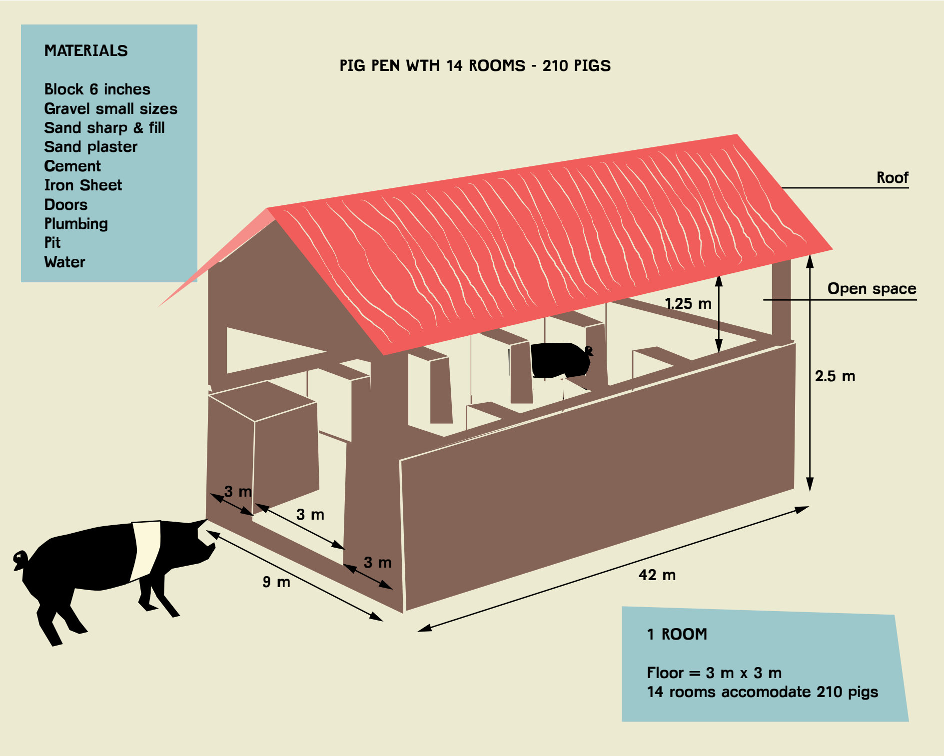


Illustration: Housing for pigs

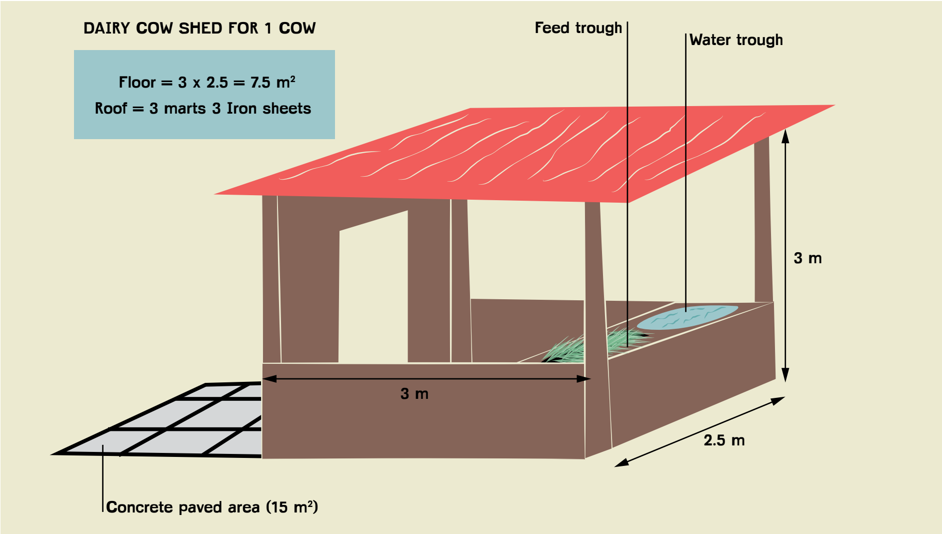


Illustration: Housing for cows

EXERCISE

1. **How do you keep your animals healthy and productive?**
2. **What areas could you improve?**
3. **Pull out your map – where would you build a house for your animals?**

9.5 Improved breeding

Improved breeds are developed and improved livestock, as by selective mating and hybridisation. In order to know what breed to choose, you need to know what issues you are facing in the area. Do you have difficulties with drought, specific pests and/or diseases? In this case, make sure that the breeds are tolerant to certain types of diseases and drought, i.e. require less water to produce the desired levels of milk.

Selection of low methane-emitting breeds, cross-breeding and switching of livestock species can enhance livestock productivity, and climate change mitigation. Cross-breeding of livestock also has food security and mitigation benefits.

Cross-breeding strategies develop composite cattle breeds with heat tolerance, parasite and disease resistance, fitness and reproductive traits as well as resistance to poor nutrition.

Cross-breeding strategies should involve locally adapted breeds and improved breeds to get livestock species more resilient to climate changes.

Animal and herd management, disease control and feeding strategies: These strategies apply in all livestock production systems. These strategies improve livestock productivity, feed conversion efficiency to reduce methane emissions and enhance adaptability of livestock. Better nutrition, improved animal husbandry, regular maintenance of animals' health, vaccination and responsible use of antibiotics can improve reproduction rates; reduce mortality and the slaughter age as well as adaptive climatic capacity.

9.6 Improved waste management (manure handling, biogas)

In the integrated livestock management system, waste – including livestock dung and urine, crop residues and feedlots manure – is managed in the following ways:

- **Covering manure:** Chicken droppings and cow dung, for example, can be added to soil as manure (in the form of slurry or farmyard manure), or to non-porous soil to improve the soil texture and composition. Some fish also feed on animal waste.
- **Biogas gas generation (bio-digestion):** Farmers can also use livestock manure to produce biogas. Chicken droppings, for example, can be used for brooding purposes and for incubation. The farmer dumps the animal waste or slurry into an airtight container (digester). The waste decomposes producing the gas. This is viable if the farmer has many birds, about 450, which can produce about 30 kg of poultry waste per day. About 150 birds can produce the 10 kg of poultry waste needed per day to incubate eggs and brood chicks artificially. Biogas can also be used for cooking, lighting, and powering small electronic gadgets such as mobile phones. See chapter 10 for more information on biogas.
- **Manure application** to stop/use less fertilizers and reduce nitrous oxide.

9.7 Pest and disease control

Climate change can cause conditions for prevalence and proliferation of pests and diseases to mutate (adapt) or increase, lowering livestock production, causing death of animals, and exposing the farmer to health risks.

NOTIFIABLE DISEASES	NON-NOTIFIABLE DISEASES
• Foot and Mouth Disease (FMD) • Anthrax • Contagious Bovine Pleuropneumonia (CBPP) • Rabies • Lumpy Skin disease • Contagious Caprine Pleuropneumonia (CCPP) • New Castle Disease • East Coast Fever (ECF) • Rift Valley Fever • Trypanosomosis • Avian Influenza	• Worms • Reproductive disorders • Mastitis • Scours

Table: Common diseases in East Africa

Diseases can be controlled through feeding and supply of good nutrition, water supply, improved housing, vaccination, deworming or drenching, spraying, pasture management, and improved breeding. Other practices to control diseases include avoid congestion and overcrowding, controlled grazing and accessing information and extension advisory services.

The main challenges facing the control of animal diseases and pests:

- Absence of adequate capacity for disease control and clinical services.
- Little public awareness on disease and pest confirmation.
- Inadequate epidemio-surveillance.
- Poor tick control.
- Weak inspectorate and quality assurance.
- Lack of enforcement on existing rules and regulations on movement of livestock.
- Products both within the country and across the national borders.
- Inadequate human, financial and physical capacity to enhance performance of the Department of Veterinary Services.

Note: Always contact an agricultural or livestock extension officer for advice before and after investing in livestock. Get consistent extension services quarterly or during periods of uncertainties.

DISEASE DIAGNOSIS

Disease diagnosis:	Symptoms.
Appearance:	Skin, coat, mucus membranes, eyes, lymph nodes, behaviour.
Natural functions:	Appetite, respiration, heartbeat, defecation and urination, milk.
Discharges:	Colour of discharge, type of discharge.
Swellings:	Swollen parts, nature and appearances.

CATEGORIES OF DISEASES

Endemic diseases:	Ticks and tick bone diseases.
Zoonotic diseases:	Caused by infectious agents transmitted between man and animals.
Epidemics diseases:	Classical swine fever, African swine fever, contagious bovine pleura-pneumonia, foot-and-mouth, Rinderpest.

CONTROL OF DISEASES

Diseases can be controlled through vaccination.

1. Controlling Bovine Tuberculosis (TB): TB is caused by Bacterium Mycobacterium Tuberculosis which affects: badgers, deer, goats, pigs, camelid (llamas and alpacas), dogs, cats and other animals.
2. Foot-and-mouth Disease: This is a highly contagious viral disease. Symptoms include severe lameness, high fever, serious drop in milk production and cattle stop eating due to pain. Prevention of the disease include: reporting occurrence immediately to the nearest livestock authority office; isolate the animal; and vaccinate regularly so as to ensure the safety of your animal. Recoveries of the animal provide shade and plenty of water, soft feeds, molasses for energy and antibiotics.
3. East Coast Fever (ECF): East Coast Fever is a protozoal disease caused by the bite of infected ticks. The ticks usually attach themselves to ears of animals and then multiply in the lymph nodes. Symptoms include: a soft cough due to fluid in lungs, difficulty in breathing, diarrhoea sometimes blood tinged, muscle wasting and white discolouration of the eyes and gums. Untreated animals can collapse and die within three or four weeks. ECF can be treated using drugs such as parvaquone, buparvaquone and halofuginone.

10. Sustainable energy

Introduction

The purpose of this section is to show how small-holder farmers can produce and utilise sustainable energy, which reduces stress on natural resources. Sustainable energy often offers cheaper and more efficient sources of energy.

Time required: 2 hours

10.1 What is sustainable energy?

Sustainable energy refers to the production and efficient use of renewable energy resources to:

- Ensure land productivity.
- Reduce emission of greenhouse gases.
- Conserve the environment.

Sustainable energy often also has other benefits such as improved health (as a result of less smoke from fuel wood) and lower costs (such as free sun power).

By also conserving the energy used in different areas of farming (e.g. incubation, lighting, transportation) it is possible to reduce the emission of greenhouse gases.

Production of sustainable energy and use of improved cooking stoves improves the environment by reducing the cutting down of trees (deforestation) for firewood and charcoal.

Think about

10.2 Common energy sources

Farmers in East Africa mainly use: firewood, charcoal, wood wastes, and crop residues as sources of energy. But other sources are also available, such as solar, wind and biogas. This usage is summarised in the following table.

ENERGY RESOURCES	CLASS OF SOURCE	ENERGY TYPE	HOUSEHOLDS (%)	
			RURAL	URBAN
Biomass	Traditional	Firewood	90	10
		Charcoal	20	80
		Wood waste	3	1
		Farm residues	-	-
	Modern	Biogas	-	-
		Bio-diesel	-	-
		Ethanol	-	-
Petroleum	Fossil fuels	Kerosene	94	89
		Liquefied Petroleum Gas (LPG)	1.8	23
Other renewable sources	Renewable potentials	Electricity	3.8	15
		Solar	-	-
		Wind	-	-
Chemicals		Batteries and torch cells	2	5

Table: Energy sources in East Africa[2]

EXERCISE

1. **What sources of energy do you use?**
2. **Are there any other sources of energy available that you could use?**

10.3 Renewable energy

Renewable energy is the energy that is derived from sources that can be re-used or replenished such as biomass (firewood, sustainable charcoal, biogas), solar, wind, hydroelectric or geothermal. Biomass and solar are common sources of renewable energy which can be utilised by farmers.

10.3.1 Biomass energy

Biomass energy comes from living and recently dead biological material. The green plants capture energy from solar energy and convert to a chemical (carbohydrate) fuel through photosynthesis process.

Theoretically biomass energy is a renewable source of energy and is carbon neutral. Carbon neutral means that carbon dioxide or methane released when generating and utilisation of energy are generated recently and/or captured back in a sustainable cycle or renewing energy. Planting trees and crops as well as using biodegradable waste for biomass energy can also lead to soil and tree carbon sequestration resulting in net decrease in carbon dioxide emissions levels.

Biomass energy often comes from:

- Trees or forest wood (firewood).
- Biodegradable waste such as manure or cow dung, sewage and crop residues (biogas).
- Biofuels (biodiesel, ethanol).
- Energy crops and plants (such as corn/maize, sorghum, millet, soybean, sugarcane, palm oil, rapeseeds, swithgrass, hemp and willow, and tree seeds such *Croton megalocarpu*s etc).

Note: Biofuel crops should not be necessarily food crop to compromise food security.

ADVANTAGES	DISADVANTAGES
Versatile/many-sided	Low energy density or yield (may yield low or no energy at all)
Renewable	May lead to land conversion, biodiversity loss
No net CO_2 emission (ideally)	Can decrease in agricultural food productivity
Emits less sulfur dioxide (SO_2) and nitrous oxide (N_2O)	Other problems: nutrient pollution, soil depletion, soil erosion, water pollution

Table: Advantages and disadvantages of biomass energy

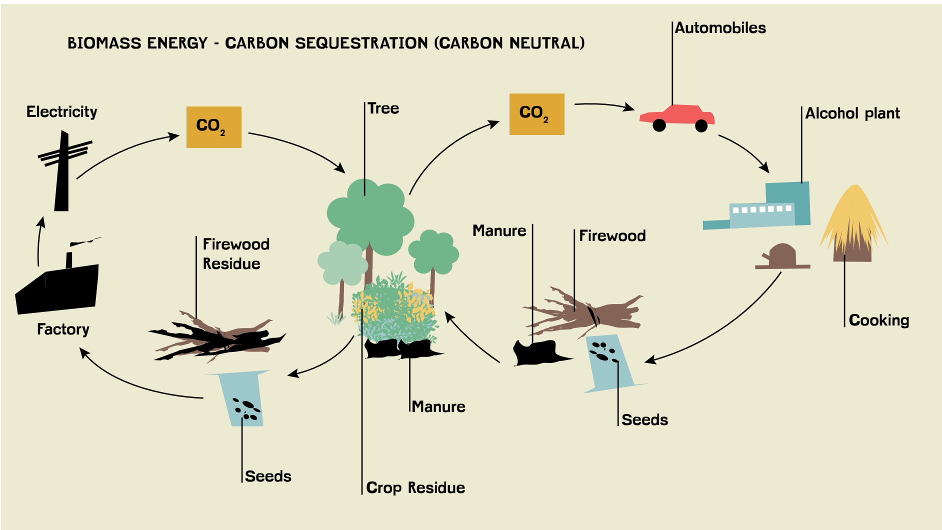


Illustration: Biomass in a carbon neutral utilisation

10.3.2 Biogas

Biogas refers to flammable or combustible gas that is produced when organic matter of plant origin is digested inside airtight containers referred to as digesters. Dung from cattle, sheep, goats, pigs, poultry or even human waste are the cheapest and most readily available organic materials for biogas production in small-holder farms. Making biogas involve generation of methane (CH_4) from manure and this is a carbon neutral energy source.

Think about

Biogas is a cheap alternative source of energy, but building a biogas solution requires some initial investment.

Advantages of biogas use:

- It is a cheap source of alternative fuel for cooking and lighting. The savings by replacing these costly or expensive energy sources can be used to meet other needs of the household.
- It provides an integrated way for sustainable use of nutrients in manure since the manure from the digester is already mineralised (broken down by bacteria), and hence it releases nutrients for crop much faster.
- It improves sanitary conditions, reducing spread of parasites and bacteria since these are killed in the digester.
- The use of biogas also reduces respiratory problems since there is very little smoke produced.
- Improves the environment by reducing cutting down trees (deforestation) for firewood and charcoal.
- Plastic biogas unit is easy to prepare and maintain. The farmer can fill it easily on daily basis.

What to think about before investing in a biogas system:

- Water availability at the farm as a biogas system requires a lot of water.
- Availability of animal manure close by in order to avoid time wastage (go and collect the manure) – important to have the stall and hence manure collection point close to the manure mixer.
- Enough space at the farm for the biogas system.

ITEM DESCRIPTION	QUANTITY REQUIRED	TOTAL COST IN USD
Polythene tube or digester (100–mm gauge), black or white, 90–20 cm diameter	6 – 10 m	70 .00
4" diameter PVC pipes, 1m long (like the ones used for pit latrine ventilation but preferably of stronger gauge)	2pcs	14.00
PVC water pipes (1/2" diameter) for the delivery of gas (from digester to kitchen)	3pcs	9.00
PVC elbows	5pcs	5.00
Rubber straps for tying the 4" PVC pipes and the ½" inch gas pipe into the digester	10pcs	1.50
A burner or jiko (made by jua kali artisan) incl. valve	1pc	17.00
		116.50
OTHERS		
Fresh dung	2 drums	
Wire mesh (optional)	2pcs	
Ordinary nails mixture 2" & 3" (optional)	1kg	
Unskilled labour	–	

Table: Items needed to make a biogas digester

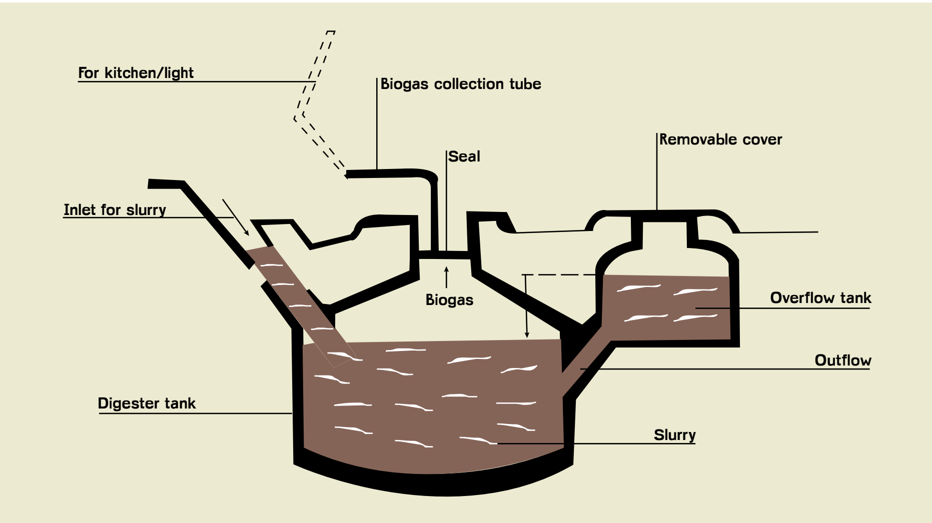


Illustration: Biogas digester

10.3.3 Farm residues

You can use farm residues and agricultural waste to produce energy. The major benefits of using agricultural waste include:

- Energy recovery and conservation.
- Carbon sequestration.
- Recycling to reduce wastages.
- Improving soil organic matter.
- Reduced pollution.
- Reduced deforestation.

a. Biomass biochar

Farm residues such as straw, stalks, leaves, twigs and litter can be carbonised (indirect burning with less oxygen) to make biochar. Biochar can be applied as organic fertiliser to the soil to improve soil functions and to reduce GHG emissions. Biochar sequesters soil carbon.

b. Biomass briquettes

Farm residues can also be used to make biomass briquettes. You can use remains of charcoal, sawdust, paper, husks (rice, coffee), cobs, bagasse, groundnuts shells as well any agricultural biomass waste you can combust through carbonisation process or pyrolysis (decomposition without oxygen) to make blocks of charcoal briquettes.

Illustration: Biomass briquettes

10.3.4 Sustainable charcoal production

Traditional charcoal production severely threats the natural forests and tree cover. Instead sustainable charcoal is needed, because charcoal is still a social-cultural livelihood and cheaper source of energy to especially urban poor. Charcoal provides income to farmers and sustainable charcoal protect natural forest and indigenous trees that are still remaining.

Sustainable charcoal production refers to all practices of sustainable biomass production, processing and packaging, improved utilization with improved cooking stoves and safe disposal without impacting negatively to the environment and people in present and future generations.

Trees that make charcoal must be planted on your farm. No use of forest trees.

Think about

To think about if starting sustainable charcoal production:

- As a farmer you must follow legal and institutional framework that outlines rules, standards and guidelines for the production and transportation of sustainable charcoal.
- You should obtain for license from forest authority to start charcoal enterprise.
- Farmers can start sustainable charcoal production associations.
- The quantity and quality of charcoal must ensure that tree species being promoted are fast growing yielding high quality charcoal (fruit, medicinal, riverine and indigenous trees of importance must not be used for producing charcoal).
- Ensure that charcoal produced through sustainable means is more profitable and attractive and the impact on the environment is not negative.
- Charcoal producer must address inefficiencies during harvesting and conversion during charcoal production to minimise GHG emissions.

The proposed sustainable production and consumption scheme is presented below. The aim is to ensure that wood is obtained from sustainably produced biomass resource, harvested using efficient ways to ensure that minimum waste is generated. At the consumption end, the aim is to minimize material and energy losses.

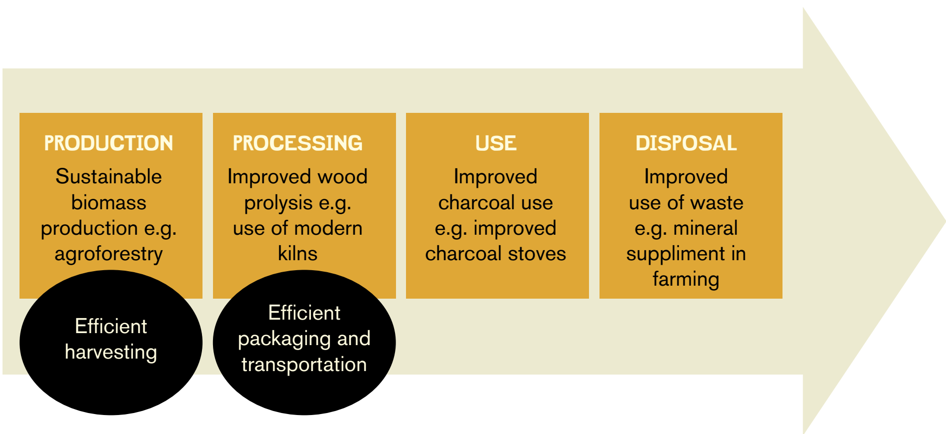


Illustration: Sustainable charcoal production and consumption scheme

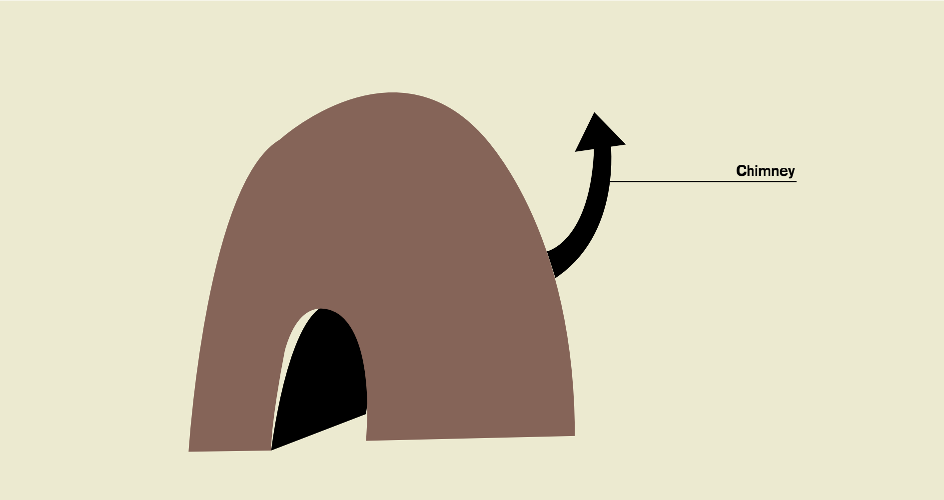


Illustration: Example of local charcoal kiln

10.4 Sustainable energy technologies

Small-holder farmers can use diversified technologies to exploit renewable energy resources. These include improved cooking stoves, solar systems (e.g. solar water purifiers, solar milling machines), windmills and biogas systems.

10.4.1 Cooking stoves

a. Traditional stove

The traditional cooking stove is often made of three stones. It is not energy efficient as it uses a lot of fuel wood such as firewood. It is smoky and cause indoor pollution and affect your health.

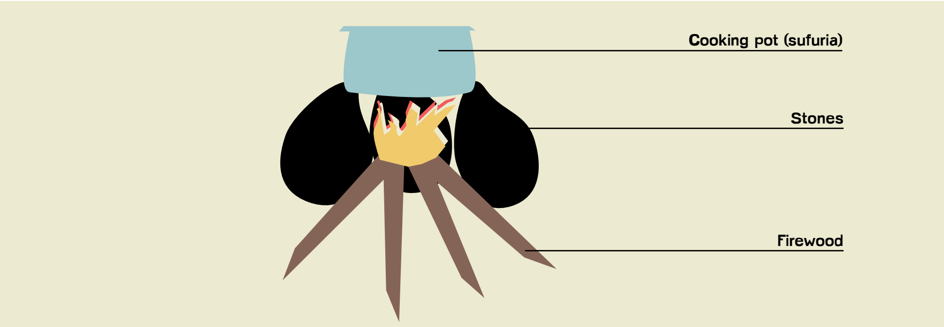


Illustration: Traditional cooking stove

b. Wood-saving stoves

Wood saving stove is a good alternative to the traditional three-stone stove. For example, it uses less fuel wood (firewood, charcoal). This saves resources (e.g. money, time) that would otherwise be lost searching for or buying more fuel. The wood saving stoves also significantly reduces smoke and are therefore better for your health. Use of wood-saving stoves conserves energy resources hence reduces rate deforestation or loss of tree cover in the landscape.

Benefits of the wood saving stove:

- Requires less fuel wood.
- Less smoke – better for your health.
- Saves time and money.
- Reduce emissions of green house gases.
- Easy to build.
- Easy to use.

The stove is made from mud, sometimes bricks and can have a chimney of metal, and it is easy to build.

Illustration: How to build a wood saving stove

c. Fireless cooker, solar cook kit and solar oven

Fireless cookers, solar cook kits and solar ovens use energy from the sun or biogas, reducing the stress on trees caused by deforestation, and land degradation.

The fireless cooker is used to keep food warm and to allow the cooking of food with less fuel wood. To use a fireless cooker, first bring food to the boiling point using for example a wood saving stove. The food is then put into the fire-less cooker which is well insulated and keeps the food from cooling down. The food cooks slightly slower than if it was directly on the stove, but it can save a lot of firewood. For instance, cooking soft foods such as bananas, potatoes and rice, you bring to boil on the stove for 3 mins, then put in the fireless cooker for 25 minutes. For cooking hard food such as pre-soaked beans, bring to boild on the stove for 25 mins, then put in fireless cooker for 2.5 hours.

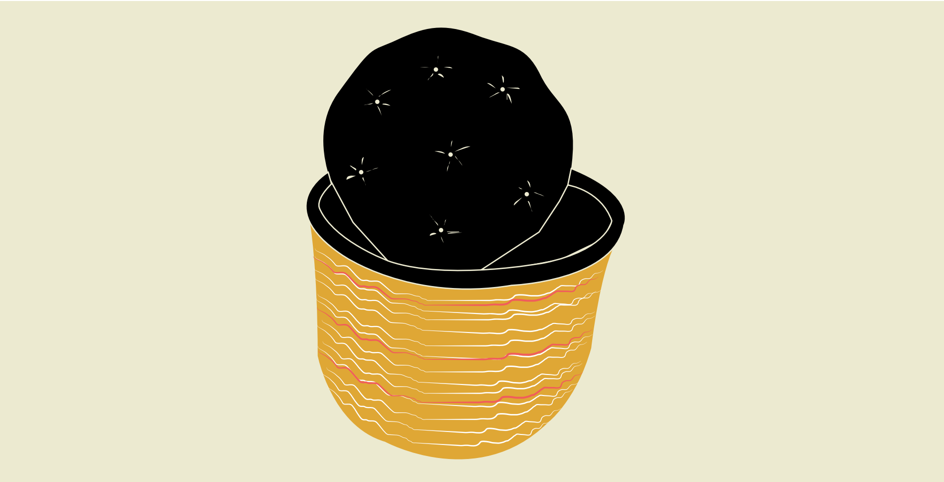


Illustration: Fireless cooker

Solar cook kit is an affordable, effective and convenient solar cooker. The cook kit can be made of cardboard and foil shaped to reflect maximum sunlight onto a black cooking pot that converts sunlight into thermal (heat) energy.

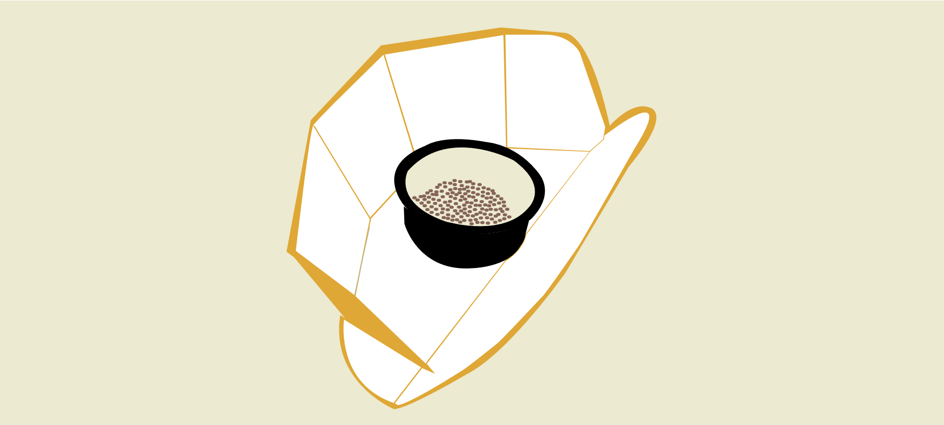


Illustration: Solar cooker kit

10.4.2 Solar water purifiers

Instead of boiling water, it can be purified using solar energy. One example of a solar water purifier is Solvatten. Solvatten (a Swedish word meaning solar and water) is a black plastic container holding 10 litres and designed with two units each holding 5 litres. The units are filled with water opened and exposed to the Sun's UV rays and heat which along with inbuilt filter, treat contaminated water. Solvatten prevents waterborne diseases. The water is heated and heat kills germs that causes diarrhoea, dysentery, typhoid, and cholera. Solvatten treats water in three ways namely: filtration, pasteurisation (heating to temperature that kills harmful germs i.e. 55 – 75°C and then cooled) and UV sterilisation (complete destruction or killing of germs or bacteria).

Major benefits of Solvatten:

- Controls waterborne diseases improving health.
- Saves time and energy.
- Reduces deforestation, soil erosion and carbon dioxide emissions.
- Safe and easy to use.

Note: Solvatten does not destroy the poison and heavy metals which may be present in water.

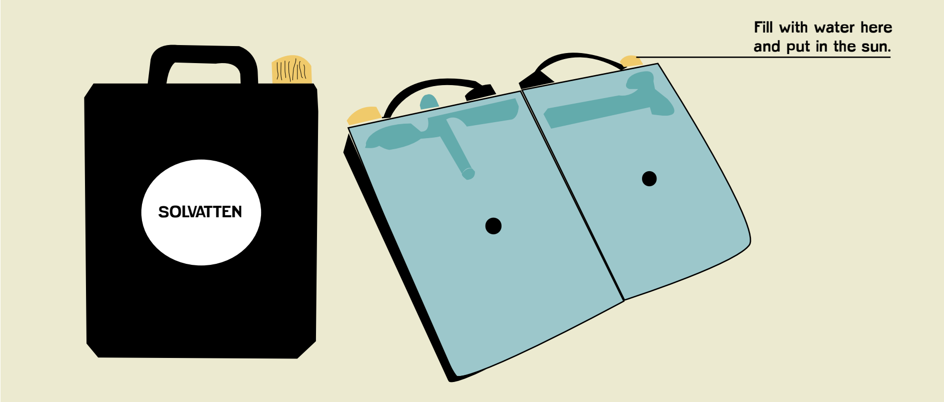


Illustration: Solvatten

10.4.3 Solar milling system

Farmers can use solar-powered mills to grind cereals such as maize, millet and barley. The mill can be placed on the ground, or on the roof. One machine costs approximately 4,600 USD.

EXERCISE

1. **How much time and money do you spend on fuel wood? Could these be reduced? How?**
2. **How do you cook and purify water?**
3. **Is there any method you could use instead or as a complement?**
4. **What benefits could these new methods bring to you, your family and the environment?**

11. Integrated pest management

Introduction

By the end of this session you will know how to control pests and diseases using a variety of methods whilst minimising economic losses, without harming yourself, your farm or the environment.

Required time: 2 hours

11.1 What is integrated pest management?

Integrated Pest Management (IPM) is a system of crop production and protection. It uses a variety of methods to prevent pathogens, insects and weeds from causing economic crop losses whilst ensuring cost-effectiveness and preserving the environment. In other words, it is a long-term technique to reduce/stop pests and diseases from multiplying.

This is done by:

- Introducing beneficial insects (biological control).
- Using crop-resistant varieties.
- Improving cleanliness.
- Using alternative agricultural practices such as pruning, spraying, organic pesticides and using organic fertilizers.

Note: In some instances chemical pesticides and fertilizers can be applied to complement other practices. But overuse can cause low soil fertility, depleted and toxic soil.

Examples of crop pests and diseases include: the striga weed, maize stalk borer, white flies, coffee berry disease, leaf rust and white coffee borers.

Effects of pests (pathogens, insects and weeds) on a small-holder farm:

- Reduced on-farm yields due to damage by pests.
- Low quality of agricultural produce/products.
- Loss of human/livestock health and life through hunger/starvation and food poisoning.
- Malnutrition.
- Loss of income.
- Loss of jobs that are based on agricultural production/produce.
- Rural-urban migration.
- Loss of crop diversity.
- High costs of production due to investment in control measures.
- Environmental pollution due to use of pesticides.
- Loss of international trade quotas.
- Inability to access new markets.

Goals of Integrated Pest Management programmes:

1. To eliminate or reduce initial pests.
2. Reduce effectiveness of initial pests.
3. Increase resistance of host plants (genetic or induced resistance).
4. Delay onset of a pest situation/attack.
5. Slow down pest spread and secondary pest cycles.

Some of the most efficient Integrated Pest Management practices are described below.

11.2 How to control pests and diseases

11.2.1 Pests

A pest is any organism that associates with and prevents the realisation of the genetic potential of a plant, crop or animal; an enemy.

There are four major categories of pests:

1. Arthropods (e.g. invertebrates such as insects)
2. Pathogens (e.g. fungi, bacteria, viruses and nematodes)
3. Plants (e.g. weeds, parasites)
4. Vertebrates (e.g. rats)

11.2.2 Plant diseases

A disease is any deviation from the normal health conditions of plant or crop. Diseases are caused by living organisms (pests) and environmental factors (e.g. frost). The disease-causing agents if caused by living organisms are referred to as biotic agents (e.g. bacteria while environmental agents are abiotic agents).

Think about

Disease symptoms are expressions of a plant's reaction to the cause of a disease. Signs of diesaes are visible disease-causing organisms or parts of a disease-causing organism. Examples of symptoms: spots, lesions, blights, cankers, diebacks, damping off, mildews, rots, rusts, scab, smuts, moulds, wilts, mosaic, chlorosis, galls, streaking, dwarfing/stunting, crinkling, leaf curling/rolling, resetting, enations, vein clearing and vein banding.

There are three broad disease symptoms categorised as:

- **Necrotic:** associated with death of cells, tissues or organs
- **Hyperplastic:** associated with overgrowth of tissues
- **Hypoplastic:** associated with retarded growth

11.2.3 Pest management principles

There are five basic pest management principles: exclusion, eradication, protection, therapy, and host resistance (see table below).

NO.	BASIC PEST MANAGEMENT PRINCIPLES	DETAILS
1	Exclusion	Preventing entrance and establishment of pests (e.g. use of: pest-free/certified seed or planting material quarantine practices).
2	Eradication	Eliminating/removing a pest that is established on plant, e.g. by: • Removal/roguing and destruction of affected plant or plant parts. • Chemical treatment of affected plant or plant parts: 'pesticides'. • Physical treatment of affected plant or plant parts. • Crop rotation.
3	Protection	Application of a protective barrier on a host before the arrival of a pest, e.g. use of: • Windbreaks. • Physical walls. • Chemicals to kill pests or their transmitting agents 'pesticides'. • Biotechnical control: - Biological control agents e.g. microbial antagonists, predators, parasites and parasitoids. These can be formulated and availed as biopesticides. - Biological cycles manipulations e.g. creating low humidity conditions to reduce spore formation by a fungus. - Utilization of natural reactions – pheromones, repellents and attractants. - Plant extracts with biogenic substances.
4	Therapy	Treating a plant in order to inactivate a pest, e.g. by using: • Chemicals (chemotherapy): 'pesticides'. • Heat (thermotherapy).
5	Host resistance	Planting cultivars that tolerate or resist invasion or attack by pests: • Identification of resistant/tolerant materials involves breeding and selection. • Conventional or biotechnological techniques may be used in breeding.

Table: The five basic pest management principles.

Take into account all relevant information:

IPM can only be successful and economical when all relevant information is available and taken into account. The relevant information includes:

- Crop or range of crops.
- Pest or range of pests.
- History of pest in the areas.
- Host susceptibility/tolerance/resistance.
- Prevailing environmental conditions.
- Locality/affected area.
- Available materials.
- Labour.
- Costs.

Pest management advice:

- Accurate and timely diagnosis of a pest situation is an important aspect of successful management.
- Applying management measures to an unknown pest or any other causal agent can lead to failure, more damage, and unnecessary costs.
- It is important to seek advice on diagnosis and management from reliable sources.
- Understanding a pest problem is a process, which may be brief or may take a unfold over a period of time.

Integrated crop and pest management (ICPM)

Integrated crop and pest management (ICPM) is a holistic approach to pest control that combines different strategies/measures based on the five principles of pest control, plus the management of crop and natural resources. ICPM concept is based on two rational points:

1. Individual strategies have limited effectiveness and logistical deficiencies when applied singly.
2. There is a growing concern about environment pollution and health risks associated with the use of chemical pesticides.

11.3 Biological pest control

Biological control is the use of beneficial arthropods or pathogens to keep pest populations down. Biological control also extends to the use of biological cycles of stages of growth to control pests directly or indirectly e.g. time of planting and time of harvesting to increase a plant's resistance capacity to a pest or to escape a pest situation. Pests are controlled by natural agents.

Farmers can manage their fields to provide habitats for species that eat and live on pest insects. This can be accomplished through conserving and augmenting beneficial populations. Using beneficial insects such as ladybirds (predator) which feed on large amount of mites, beetles and aphids controls insect affecting crops. Other examples include digger wasps (parasite) and bacteria (pathogen) which kill larvae.

11.4 Mechanical pest control

Pests are controlled by non-chemical direct physical measures. Examples include: hand-picking to remove insects, tilling to remove weeds and trapping to catch insects or rodents.

11.5 Management of pests using pesticides

Pesticides are agents, substances or mixtures of substances that are deliberately released to the environment to prevent, destroy, repel, mitigate, harm or kill organisms which are considered to be pests. Pesticides may be chemical, biological or physical agents. This is contrary to the common mentality that pesticides are only chemical in nature.

NO	COMMON CATEGORIES	HARMS OR KILLS
1	Insecticides	Insects
2	Acaricides	Ticks
3	Herbicides	Weeds
4	Fungicides	Fungi
5	Rodenticides	Rodents (rats, moles, squirrel and porcupine)
6	Molluscicides	Snails (aquatic or water pests in the fishpond)
7	Bactericides	Bacteria
8	Nematicides	Nematodes
9	Virocides	Virus
10	Algicides	Algae
11	Miticides	Mites

Table: Pesticide categories

Note: Consider using pesticides that are effective on the target pest only – avoid indiscriminate application! For instance, a fungicide may not have any effect on a mite problem and not all fungal problems can be controlled by a randomly-picked fungicide.

11.5.1 Pesticides application

Mixing

- Accurately mixing pesticides and calibrating equipment is critical to successful pest management.
- Mixing and diluting of pesticides is usually the first step in pest control operations.
- All recommended and registered pesticides are availed to consumers with instructions on the rates to be applied to the quantity of commodity to be treated.

Calculation

- The area of a given tract is determined by applying the formula that fits the shape of the tract.
- In mixing a finished spray it is important to put the correct amount of pesticide in the water.
- Too little will result in poor job while too much may result in injury to the surface being sprayed or the operator.
- Instructions for mixing are often given on the label hence only simple calculations.

11.6 Cultural methods

Pests can be prevented or reduced by using methods to alter the plant environment.

Examples include:

1. Irrigation and fertilization schedules
2. Early planting
3. Sanitation practices
4. Intercropping (crop rotation, relay)
5. Use of improved crop varieties

11.6.1 Intercropping

Intercropping is an effective weed control technique. It involves growing legumes as cover crops. The legumes act by: restricting the access of weeds to light, suppressing the weeds (e.g. striga), and disposing of trap roots (e.g. of striga). The legumes dispose of trap roots, stimulating for examples striga seeds to germinate. However, unlike cereal crops, striga cannot attach its roots to the roots of the legumes. The germinated striga seeds die. Other examples of trap crops that can be grown as intercrops are: tobacco, sesame and cotton.

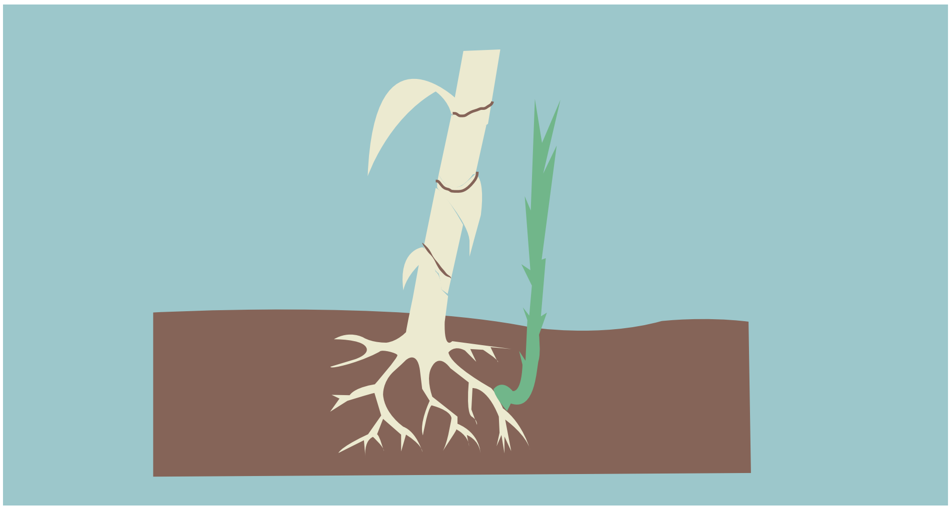


Illustration: Trap roots

How to intercrop legumes with cereals:

1. Grow separate rows of legumes and cereals with close spacing, e.g. one row with sorghum followed by two rows of soybean.
2. Apply organic and mineral fertilizer on the soil.

   Note: It will take approximately six weeks for the legumes to cover the ground.

3. Apply compost to the soil.

11.6.2 Striga weed

The striga weed is a parasitic weed that attaches itself to the roots of cereal and grass crops and absorbs the water and nutrients meant for the crops. The weed spreads quickly. For example, striga sticks to the cloven hoof of livestock that have been left to grazing freely, and enters the farm. Striga also spreads through the manure spread on a farm if the livestock has grazed where striga grows.

There are five species of striga weed: *Striga hermonthica, Striga asiatica, Striga aspera, Striga forbesii,* and *Striga gesnerioides.*

Stiga is difficult to combat. However, it can be eliminated using a combination of different IPM techniques.

How to combat striga:

1. Get to know the characteristics of the weed, how it spreads and how you can treat it with biological control. Know the enemy.
2. Increase soil fertility. This is because there is a link between poor and degraded soils and striga.
3. Cooperation with neighbours is a good striga control effort. This will help to ensure that the threat of striga spread is managed at the community level.
4. Combine at least three different striga control methods:
   - Apply compost to conserve humidity and increase the uptake of nutrients. Also, if possible, apply a micro-dose of black fertilizer; approximately 2 grams/hill. If you are hilling or ridging, you can apply the same dose of white fertilizer.
   - Hand-pull the striga left in the field in order to decrease the number of seeds present at the soil surface.
   - Start intercropping with 1 – 2 rows of the legume and 1 – 2 rows of the cereal or grass. (See more below on intercropping).

Illustration: How to eliminate the striga weed

For more information about intercropping for the purpose of eliminating striga, see chapter 5 or visit:
http://www.accessagriculture.org/node/255/en and
http://www.accessagriculture.org/node/243/en

11.6.3 Alley cropping (see chapter 5)

11.6.4 Contour strip cropping (see chapter 5)

11.6.5 Crop rotation and relay cropping (see chapter 5)

11.6.6 Improved crop varieties

Improved crop varieties (e.g. hybrid maize) can resist crop pests and diseases. Pest-resistant crop varieties, such as cassava and yams are resistant to several pests (see also chapter 5).

11.7 How to develop a Pest Management Plan

- **Identify agricultural activities and enterprises on your farm:** You are probably interested in the production of, for example, kales, maize, tomato, beans, coffee, banana, sorghum, groundnuts, green grams, and cassava, dairy, goat, sheep and rabbits. Prioritise which activity is common and which common pests affects your enterprise to the economic levels you want to control.
- **Identify common pests and prioritise them by ranking per enterprise:** For each enterprise or crop/livestock practice identify the common pests, issues and challenges on your farm in the area and rank.
- **Identify pest management practices on your farm:** Identify the best management practices such as use of pesticides, cultural, mechanical, sanitary, natural, and biological or host plant resistance you are integrating to reduces economic losses of pest on your farm.

- **Develop new pest management strategies/methods per crop/ enterprise on your farm:** Read or ask an extension officer about pest management practices you can use in the area on different crop/livestock enterprises and choose to your farm situation considering financial, economic, environmental health and risks factors associated with the choice.
- **Handling of pesticides:** Choose a method or variety of methods under IPM approach to control pests. Safety, application and alternative measures should be considered to reduce the use of pesticides or use them wisely.
- **Review legal framework on pesticides in your country:** After considering methods ask an extension officer to link the choice of methods/pesticide application if it's in line with the government or county regulations. Is the pesticide, natural agent allowed registered or unregistered, banned or restricted?
- **Choose best practices:** Choose the best method only based on the performance and regulatory information and develop a rapid pest management plan with help of questions leading to answer what, where, when, how and who?
- **Plan-Do-Check-Audit:** This is the same as monitoring. Record all the planning process putting measurable indicators and time period. Record all that pertains use of pesticides (crop, kind of pest, pesticide used, time of application, dosage, safety – did you use a knapsack sprayer, disposal of packs, and effect). Keep records precisely.

Think about

ADVANTAGES OF IPM:

- Decreased use of chemical application will reduce risks to the health of farmers.
- Decreased use of chemical application will reduce the risk of deterioration cropland.
- Decreased use of chemical application may result in a financial savings.
- Long-term environmental improvements.
- IPM may be the only solution to some long-term pest problems where chemical application has not worked.

EXERCISE

1. What type of pests and diseases do you have on your farm?
2. How do you handle pests and diseases today?
3. Are the method effective? If not, how can you improve it?
4. Develop a Pest Management Plan for your farm.

Acronyms

IPM – Integrated Pest Management.
ILM – Integrated Livestock Management.
SALM – Sustainable Agriculture Land Management.

Key words

ADAPTATION – a measure to adjust to the social, environmental and economic impacts of climate change such as increased droughts, floods, and erratic and unreliable rainfall.
A-FRAME – an A-shaped wooden or metallic tool used to make contours bunds and terraces.
AGRICULTURAL SYSTEM – a set of components (e.g. crops, livestock, trees) that interact with and depend – to some extent – on each other. These components work within a prescribed boundary to achieve a specified agricultural goal.
AGRO-ECOLOGICAL ZONE – area with particular climatic conditions that suit the growing of suitable crops and trees, and rearing livestock.
AGROFORESTRY – land use that involves deliberate retention, introduction or mixture of trees or other wood perennials in a cropland or animal production field to benefit from the resultant ecological and economical interactions.
AGRONOMY – land use that involves the deliberate planting and managing of crops in a way that increases productivity.
AGRO-VET – an agricultural expert who specialises in livestock health.
BASIN – planting hole that is similar to but larger than a pit that collects and stores some runoff water so that crops can be grown successfully especially in the drier seasons.
CLIMATE CHANGE – a broad array of alterations in climatic and weather conditions that is characterised by shifts in average conditions and in the frequency and severity of extreme conditions, over a long period of time.
CLIMATE HAZARD – climatic or weather event or situation in the environment that has potential to harm the health and safety of people, or damage plants and equipment (has already occurred at least once before) e.g. flooding.
CLIMATE RESILIENCE – the ability to adapt to or reduce climate risks or challenging climatic conditions, via, e.g. combining appropriate SALM practices, getting a micro-crop insurance for weather risks, investing in crop storage and/or in livestock, etc.
CLIMATE RISK – condition that results from exposure to vulnerability to changing climate that has the potential to harm the environment (likely to occur or happen).
CLIMATE VARIABILITY – unexpected weather or seasonal change(s) within the normal climate of a place or region, e.g. erratic rainfall or severe drought.
COMPOSTING – the natural process of turning organic materials such as crop residues and farmyard manure into plant food or humus.

COPING MEASURES – efforts by communities to manage severe impacts of climate change, natural hazards and environmental risks. If not done properly, certain coping measures can be more destructive to the environment, the climate and finally the agricultural land, e.g. increased application of agrochemicals and/or inorganic fertilizers.
COVER CROPS – crops that have the capacity reduce erosion, retain nutrients, combat weeds, break disease cycles and improve soil quality.
DIET – the food and water consumed by livestock.
DISEASE – any deviation from the normal health conditions of plant or crop.
DITCH – long channel dug on the side of a field to hold or take away water.
FEEDS – food for farm animals or plants.
FODDER – food farm animals, including horses.
FURROWS – long narrow cut in the ground.
GREEN MANURE – plants that are grown solely to improve and protect soil.
GREENHOUSE EFFECT – the process by which greenhouse gases absorb heat and raise atmospheric temperature.
GREENHOUSE GASES – gases with long wavelengths that occur naturally in the atmosphere.
INTEGRATED – a system where many different parts are closely connected and work successfully together.
IRRIGATION – use of collected water for agricultural purposes.
LIVELIHOOD RESOURCES – natural, physical, financial, human and social assets used to support livelihoods of a given community.
LIVESTOCK – farm animals such as cattle, sheep, goats, pigs, rabbits and poultry that are reared for different products.
MANAGEMENT – ability to achieve a given goal at a particular time through proper control of resources (e.g. cash, time, information).
MITIGATION – reduction of greenhouse gas emissions.
NATURAL RESOURCES – biotic (animals and plants, organic matter, fossil fuels) and abiotic (land, water, air, minerals and metals) resources for human and ecological functions.
NUTRIENT MANAGEMENT – the process of maintaining and/or enhancing soil fertility.
NUTRIENTS – substances that crops and livestock need to grow and thrive.
PEST – any organism that associates with and prevents the realisation of the genetic potential of a plant, crop or animal.
PITTING – digging of holes to grow crops.
RE-GENERATE – re-establish healthy vegetation and biomass on degraded land.
RENEWABLE – a resource that can be re-used or replenished.
RIDGE – a narrow area of high land along a slope or top of a line of hills.
STRIGA – a parasitic weed.

STUBBLE – short stalks left on farm after crop has been harvested.
SUSTAINABLE AGRICULTURE – economic, social, ecological or environmental/technological sound/sustainable method of crop and livestock production.
TERRACING – the changing of the profile of a slope to reduce runoff in steep or hilly areas.
TILLAGE – preparation of soil for planting.
TRENCHES – short ditches or pits on a slope that are used to trap moving water.
VULNERABILITY – The degree to which a system is susceptible to, or unable to cope with adverse effects of climate change.

Notes

1. Hatibu et al. 2000
2. Otieno et al. 2006

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Vi Agroforestry – Head Office
105 33 Stockholm
Tel: +46 (0)8 120 371 00
E-mail: info@viskogen.se
Web: www.viskogen.se

Vi Agroforestry Regional Office East Africa
Postal address: P.O. Box 45767, 00100 Nairobi, Kenya
Visiting address: Lower Kabete/Ngecha Road, Nairobi
Tel: +254 20 418 4480/1383
E-mail: info@viagroforestry.org
Web: www.viagroforestry.org

Vi Agroforestry – Kitale
Postal address: P.O. Box 2006, Kitale 30200, Kenya
Visiting address: Along Kitale-Eldoret Road, next to Kitale Museum
Tel: +254 54 314 98
E-mail: kenya@viagroforestry.org

Vi Agroforestry – Kisumu
Postal address: P.O. Box 3160, Kisumu 40100, Kenya
Visiting address: Aga Khan Rd, Milimani Estate
Tel: +254 57 202 204
E-mail: kenya@viagroforestry.org

Vi Agroforestry – Uganda
Postal address: P.O. Box 1732, Masaka, Uganda
Visiting address: Plot 21, Birch Avenue
Tel: +256 481 420 946
E-mail: uganda@viagroforestry.org

Vi Agroforestry – Rwanda
Postal address: P.O. Box 2911 Kigali, Rwanda
Visiting address: Nyarutarama Road KG9 St, House11
E-mail: rwanda@viagroforestry.org

Vi Agroforestry – Tanzania
Postal address: P.O. Box 1315, Musoma, Tanzania
Visiting address: Lakeside Area, Musoma
Tel: +255 28 262 22 93
E-mail: tanzania@viagroforestry.org

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