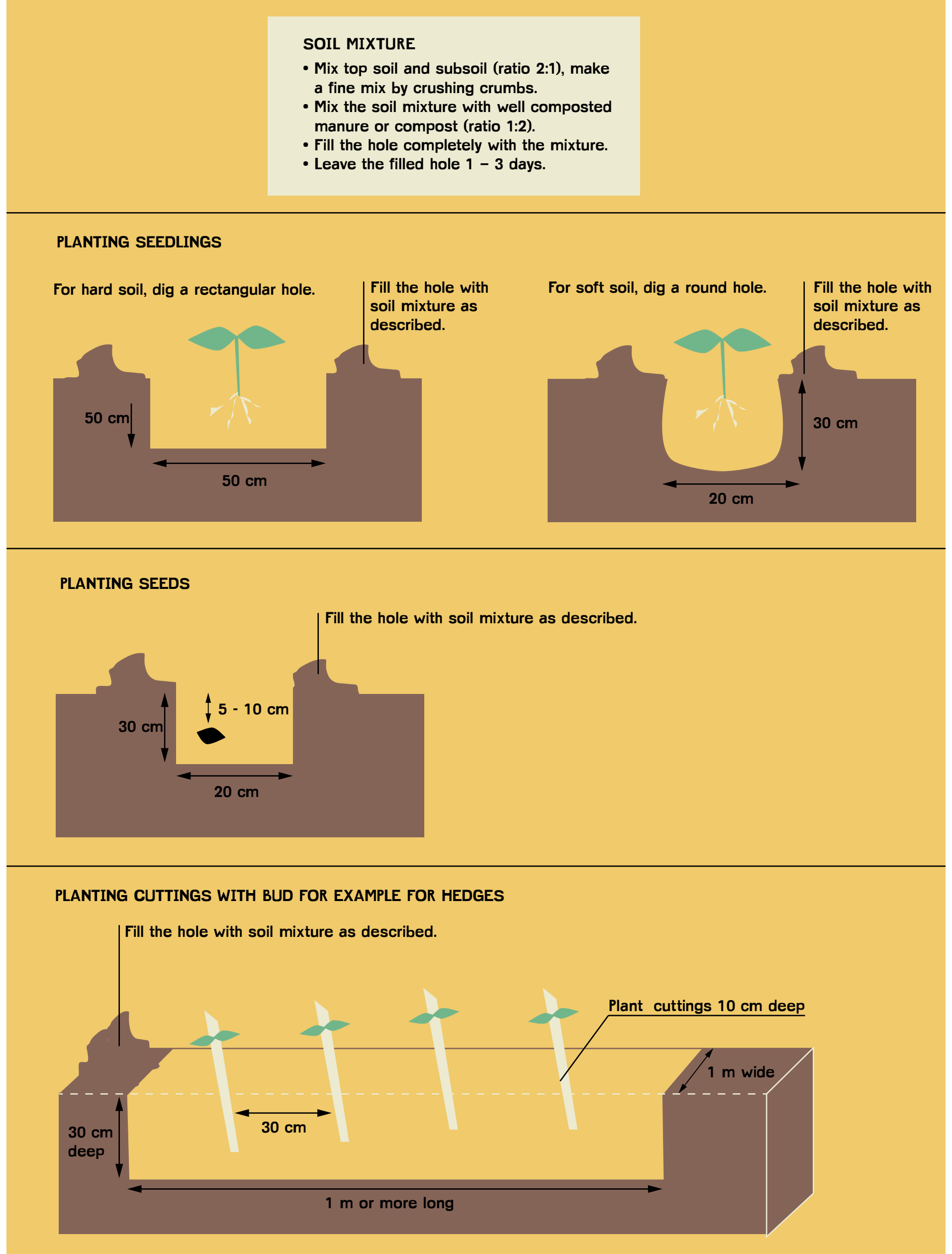


Illustration: How to plant a tree: seedlings, seeds and cuttings with buds.

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.

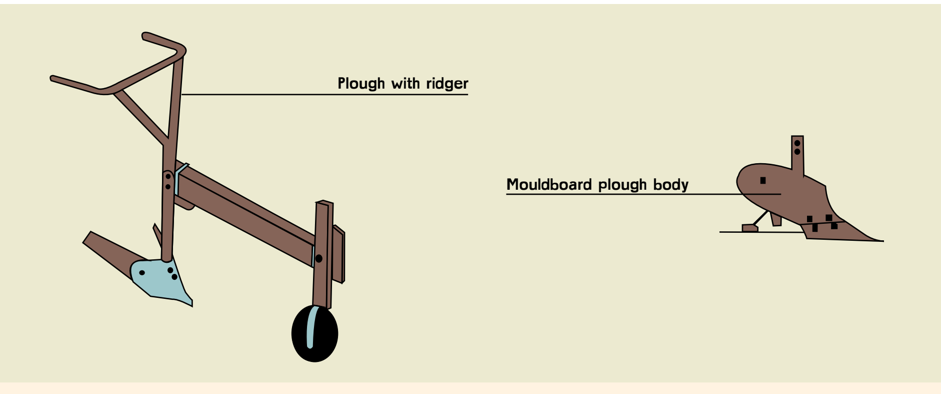


Illustration: Plough with ridger (mouldboard plough body also shown)

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.

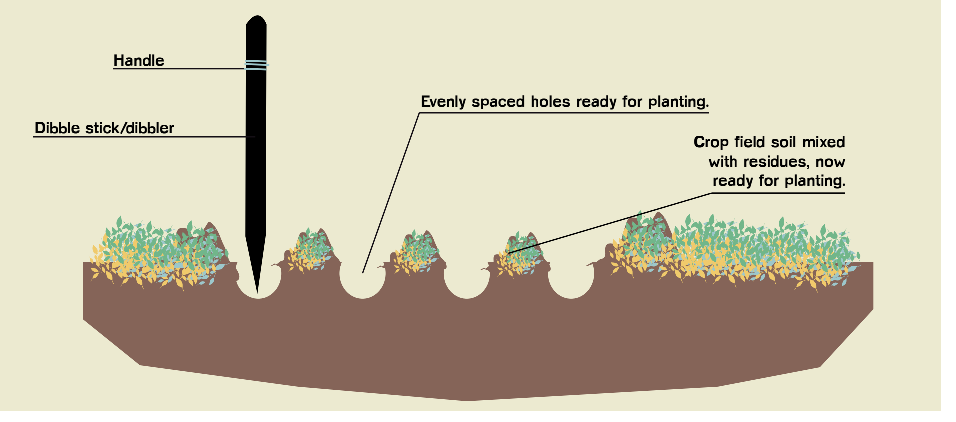
Ridges are made with alternate furrows that run across the field parallel to the contours. Rows of crops are planted on ridge top, in the furrow or along both sides of the ridge. A ridger (tool for making ridges), jembe, hoe or mouldboard plough can be used for cultivation.

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.

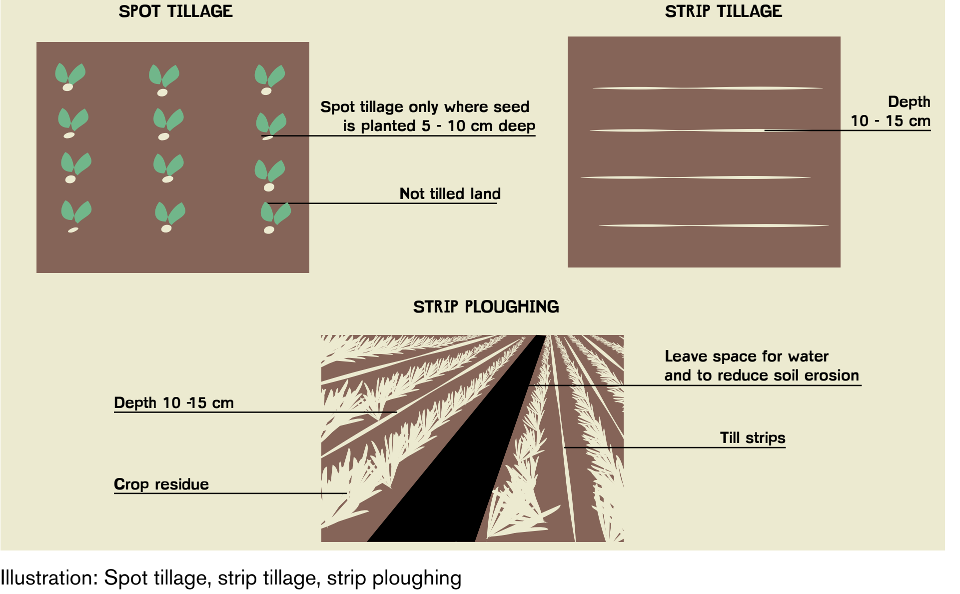


Illustration: Spot tillage, strip tillage, strip ploughing

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.

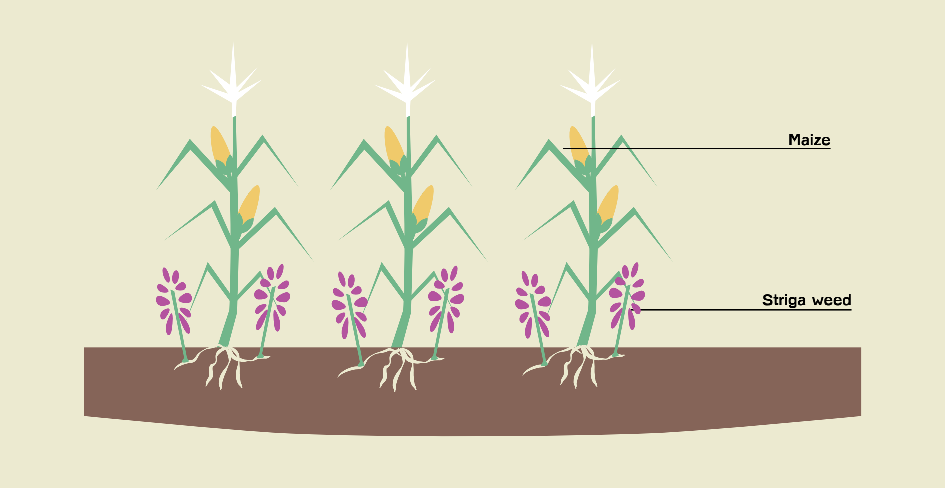


Illustration: Example of degraded land - 1

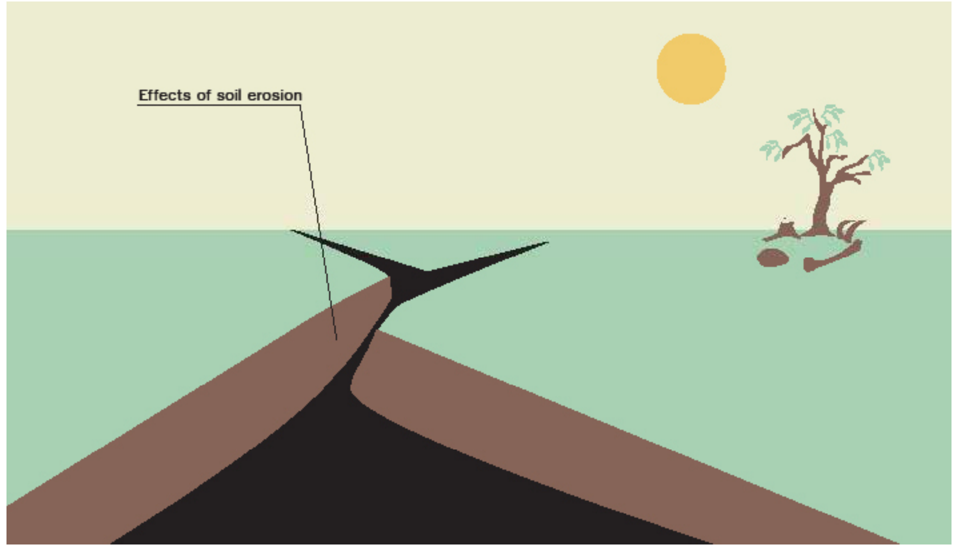


Illustration: Example of degraded land - 2

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.

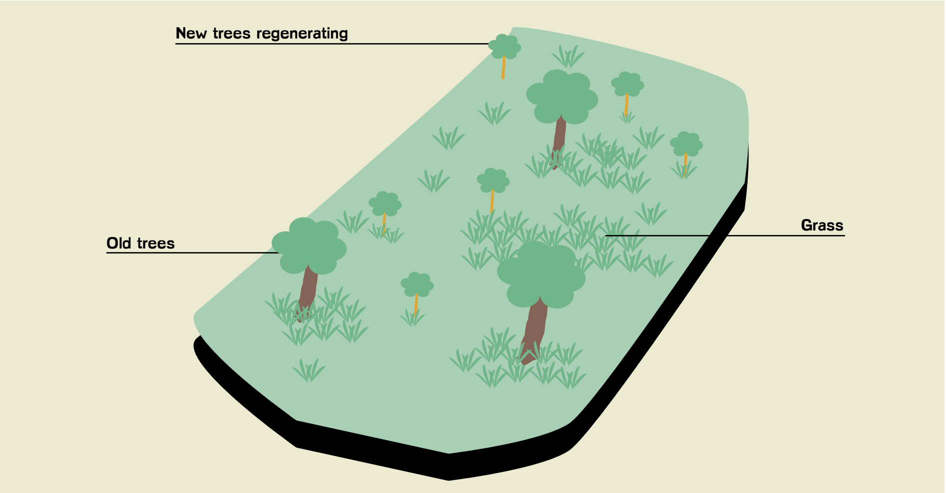


Illustration: Natural regeneration

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.

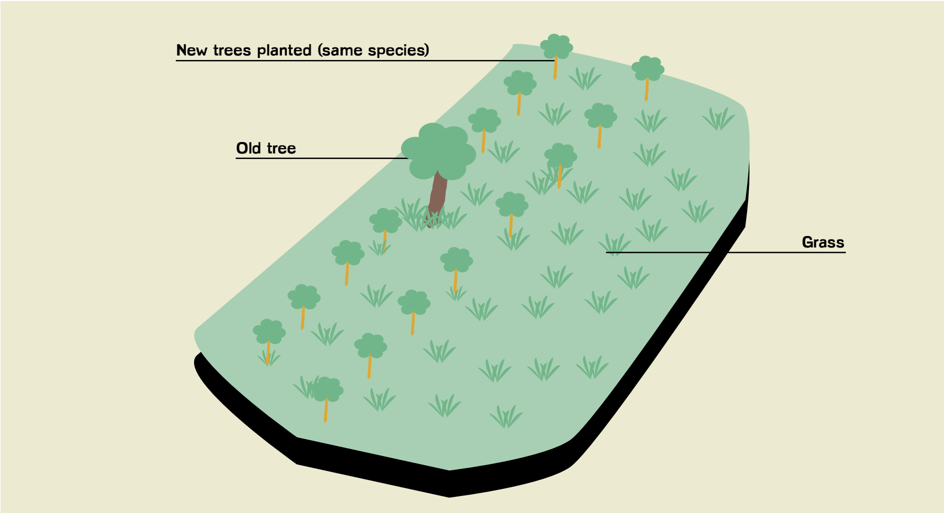


Illustration: Assisted natural regeneration

8.4 Enrichment planting

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

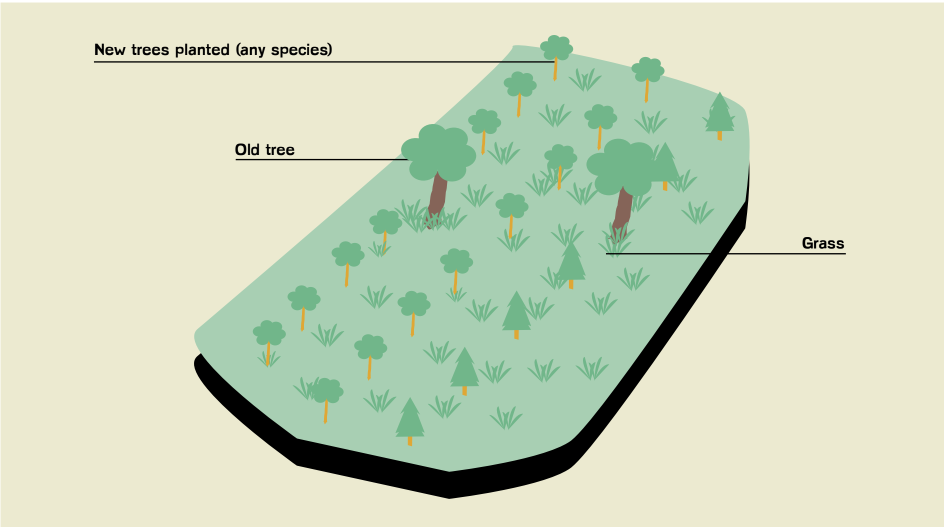


Illustration: Enrichment planting

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.

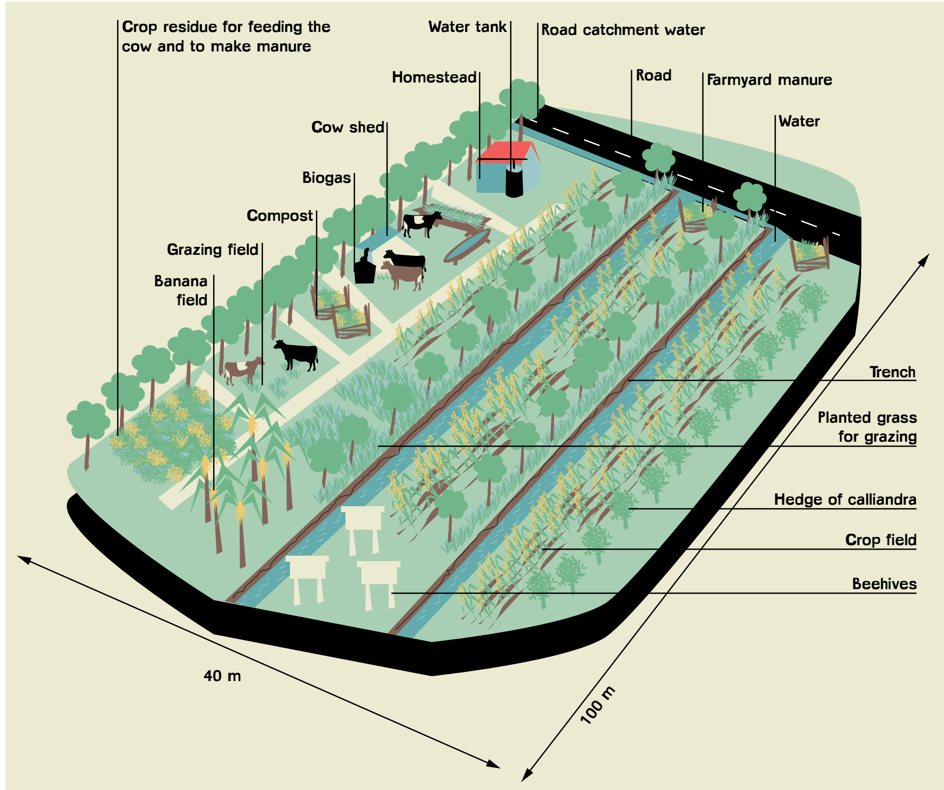


Illustration: Integrated system of livestock, crops and bees on 1 acre

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.

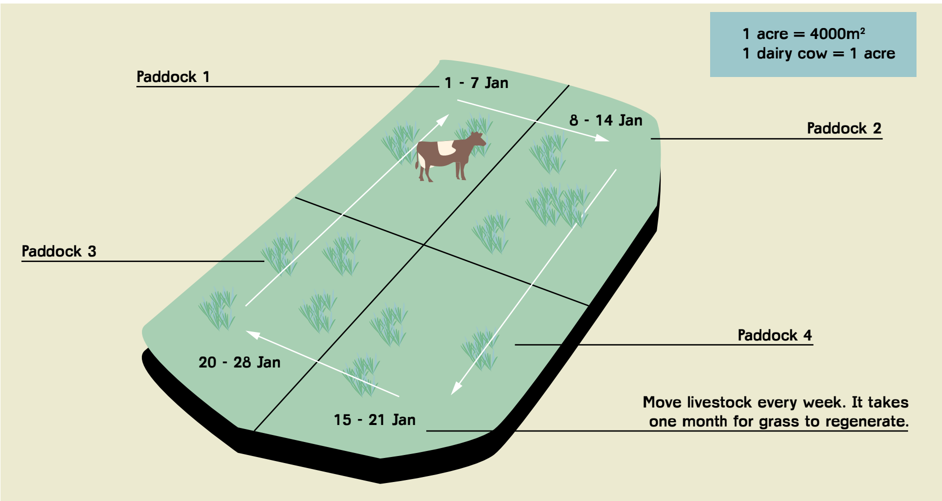


Illustration: Rotational grazing / paddock grazing

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 silag-es (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).

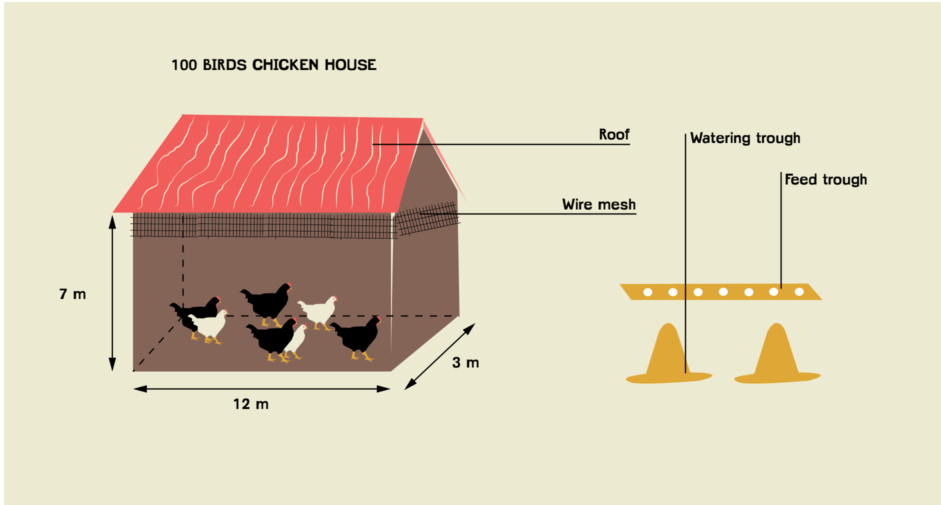


Illustration: Housing for chickens

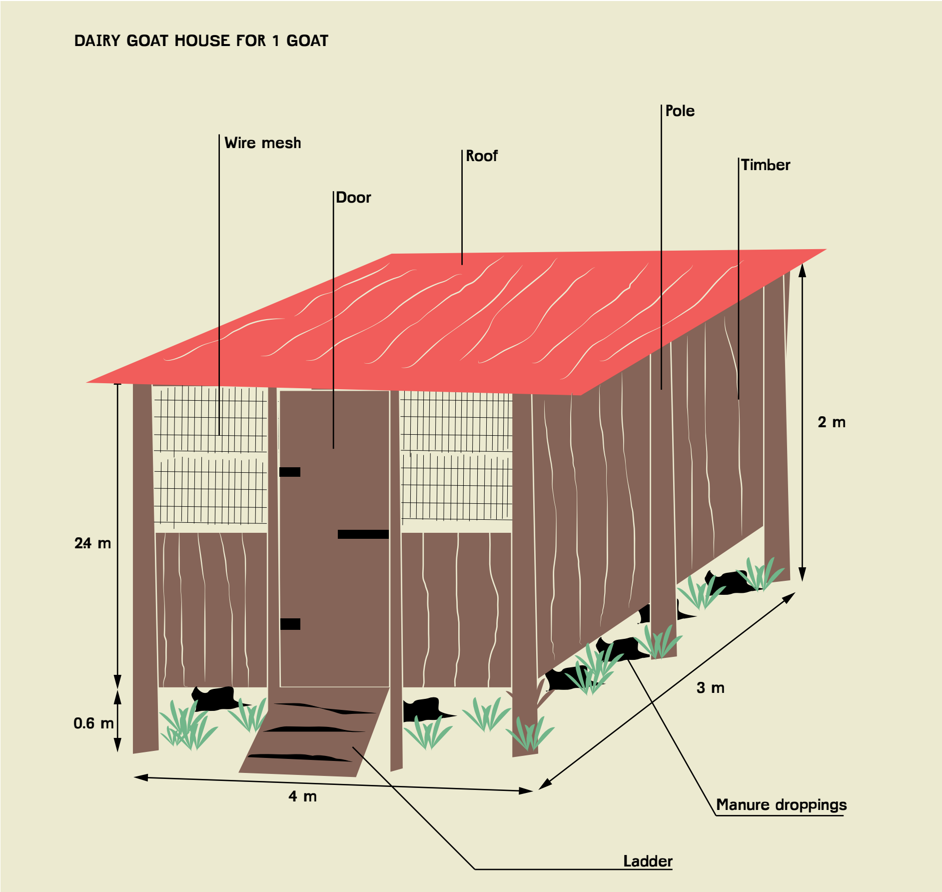


Illustration: Housing for dairy goats

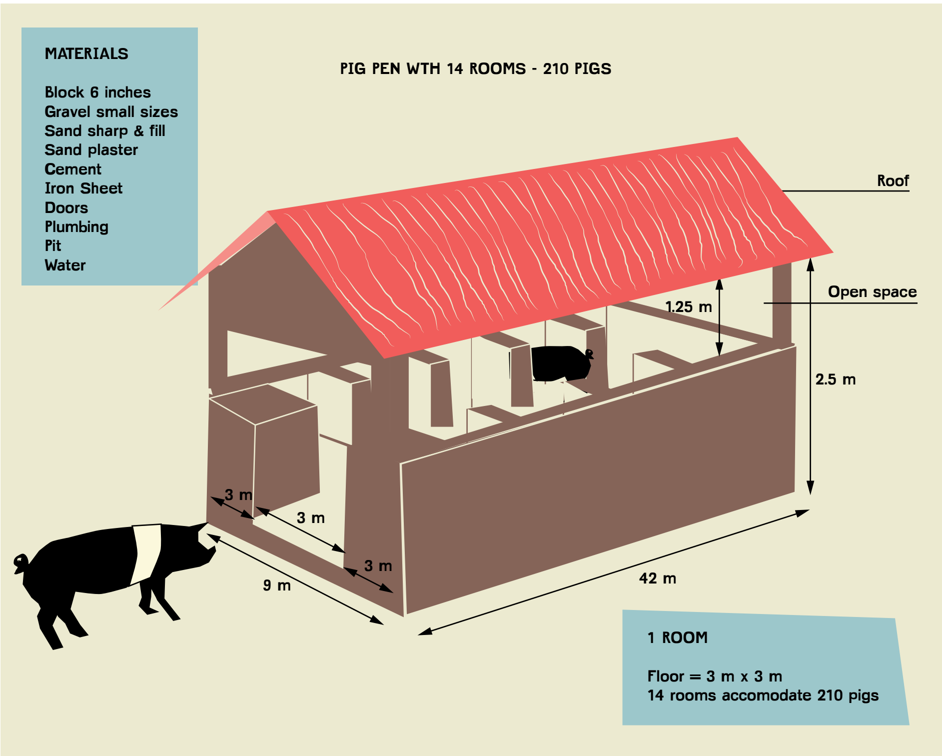


Illustration: Housing for pigs

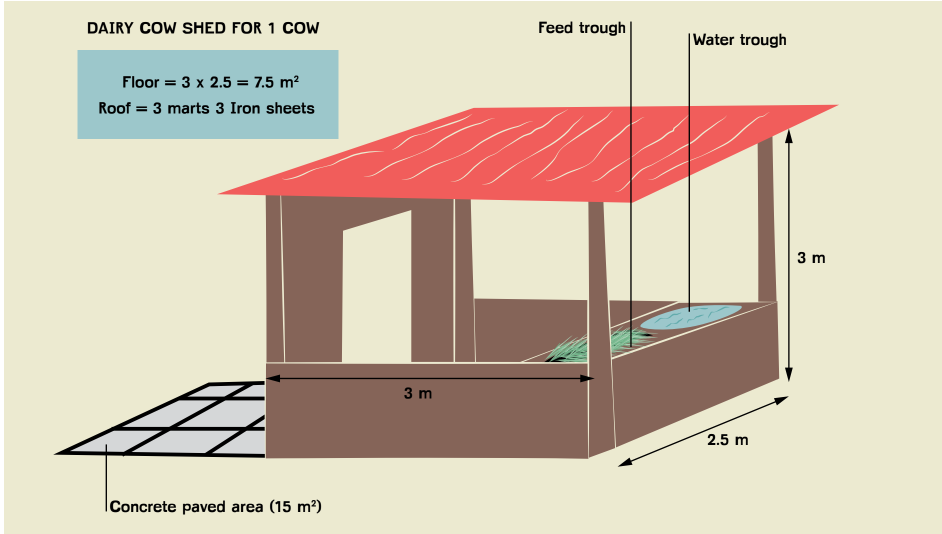


Illustration: Housing for cows

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

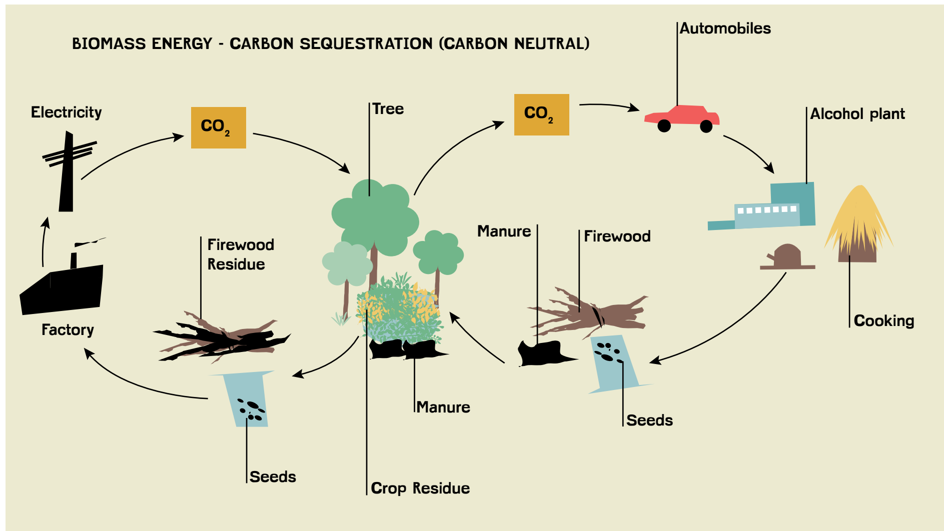


Illustration: Biomass in a carbon neutral utilisation

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 arti-san) 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

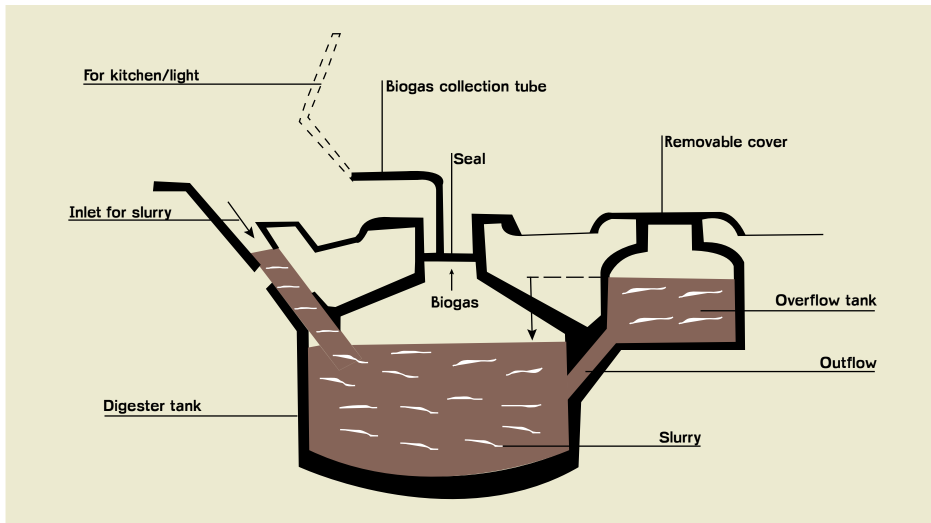


Illustration: Biogas digester

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.

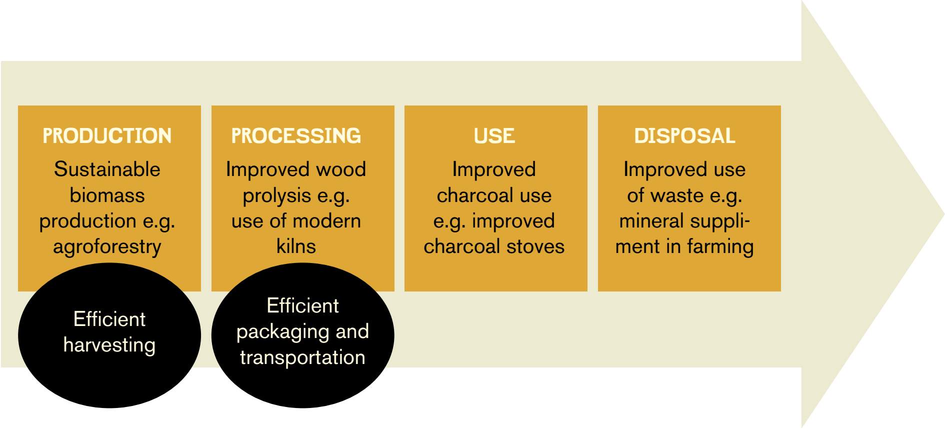


Illustration: Sustainable charcoal production and consumption scheme

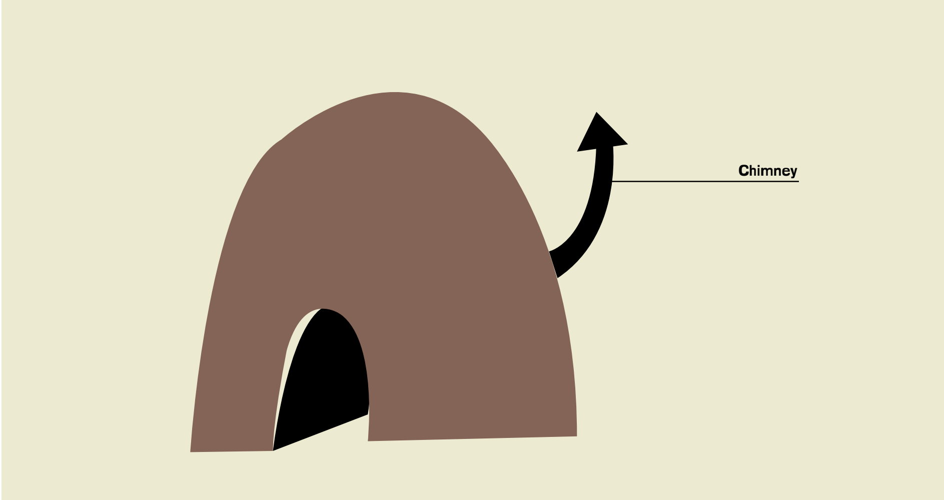


Illustration: Example of local charcoal kiln

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.

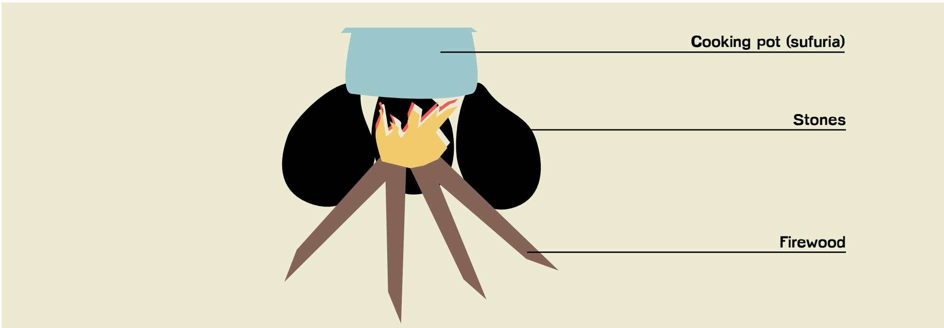


Illustration: Traditional cooking stove

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.

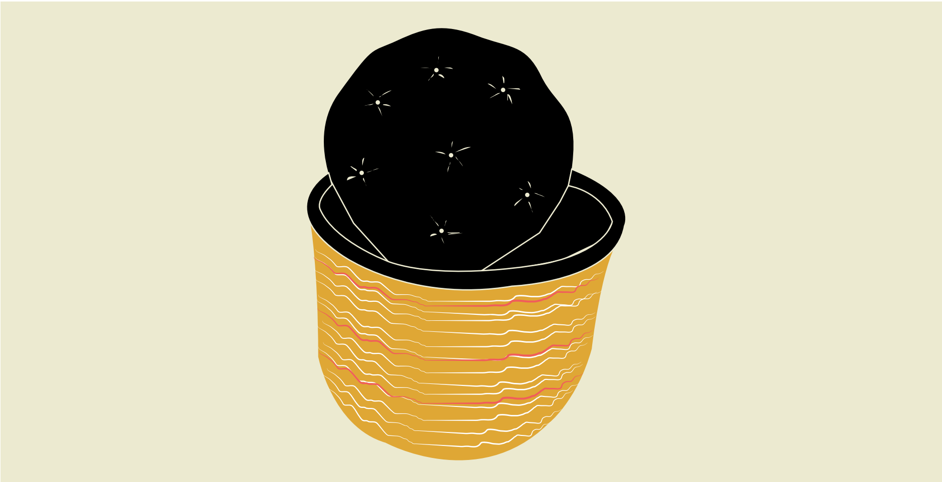


Illustration: Fireless cooker

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.

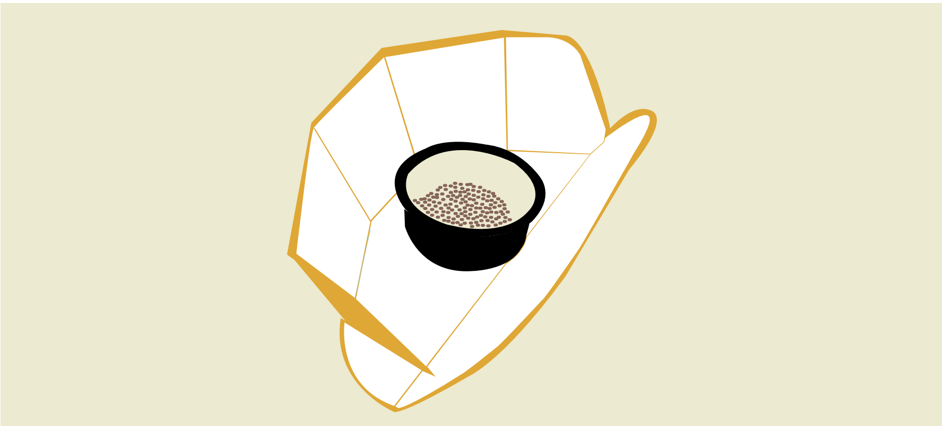


Illustration: Solar cooker kit

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.

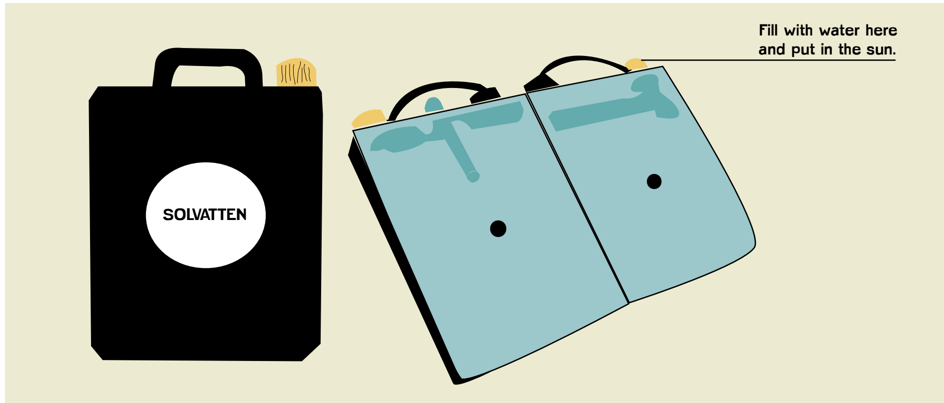


Illustration: Solvatten

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).

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.

Think about

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.

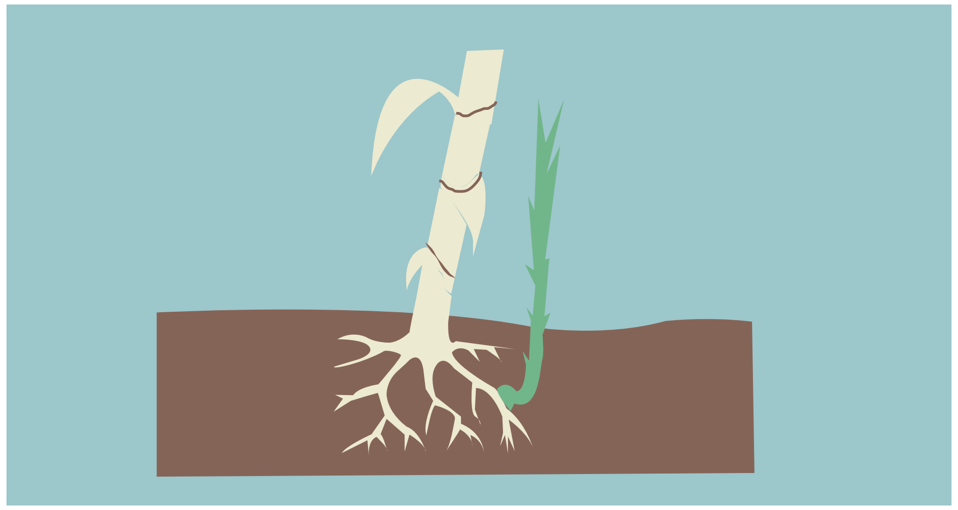


Illustration: Trap roots

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 alsoo 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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