Transforming Rural Economies and Youth Livelihoods

AGROECOLOGY TOOLKIT

Practical ACTION

A guide on selected Agroecology Technologies by
Agroecology Stakeholders Network (AESTANET)

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

BACKGROUND

Land degradation remains a major challenge in Kenya's agricultural landscapes. It is estimated that about 0.25% of the country's arable land is lost through soil erosion and other land degradation mechanisms each year. Land, water, and atmospheric degradation have placed serious consequences on all living organisms, food security, rural livelihoods and the socio-economic wellbeing of most households in the country. The situation is attributed to unsustainable land management practices caused by a weak extension support system, particularly in light of emerging external challenges such as climate change. Practical Action, through AESTANET, has responded to the challenge by developing this training toolkit to guide extension support and information dissemination on suitable soil and water conservation measures, composting technologies, agrobiodiversity, kitchen gardening, agroforestry, farmers seed systems, crop livestock integration, bio-fertilizers, ecological pest management, conservation agriculture through improved fallows, principles of soil health management and value addition.

This toolkit presents the techniques applicable in different agricultural production systems and environmental conservation and management in a simplified format to be easily understood and applied by both extension agents and farming communities.

OVERALL OBJECTIVE OF THE TOOL KIT

Reverse land degradation, improve agricultural productivity and enhance socio-economic wellbeing of farming households.

TRAINING PROCEDURE

1. Provision of training venue, training programme, writing materials and sitting arrangements
2. Welcome the participants to the training venue
3. Prayers – give a chance to one of the volunteers from participants to prayer
4. Registration of participants
5. Carry out climate setting and ground rules for the training
6. Carry out self or colleague introduction
7. Pick up and generate list of expectations from participants e.g. ask participants to present their expectations and share their experiences on the subject
8. Introduction of the topics e.g. start the session by writing the title of training course on a flipchart "e.g. catchment rehabilitation procedures"
9. State the objectives of the training
10. Link participants' expectations with the training objectives by listing them down – write key words e.g. "catchment", "protection" and "rehabilitation," on a flipchart and invite participants to brainstorm on what they understand by these concepts
11. Where possible, have group discussions on concepts that require their experiences. Organize participants to work in groups and allow them to come up with possible solutions to the training objectives.
12. If possible, visit a learning site for practical demonstration of the concepts i.e. carry out demonstrations if possible to allow participants to learn more by doing.
13. The facilitator should use prepared notes or handouts and where possible make a presentation on the same.

TRAINING MAINTENANCE TIPS

1. In between trainings sessions introduce energizers and comic sessions
2. Stick to timeframe allocations in the training program
3. Provide opportunities for questions and feedbacks
4. Make the training lively, participatory and as interactive as possible
5. Allow trainees to do recaps as a means of reminding themselves what was learnt on previous topics etc.
6. Give a chance to participants to fill evaluation forms as a means of evaluating the training exercise.
7. If possible, arrange for field excursion to show case examples of the technologies, success stories, learning themes, etc.

TEACHING AIDS

- LCD
- Illustration chats
- Pictorial diagrams
- Posters
- Pointers
- Brochures
- Portable materials for actual demonstrations

i) Teaching materials

- Pens
- Flip chats
- Notebooks
- Cards
- Masking tapes
- Felt pens
- Tripod stand
- File folders

ii) Mobilization and logistics

- Inviting participants
- Confirmation of training venue
- Transportation and delivery of trainees, training materials to the venue
- Arrangement for meals and drinks during training periods


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1 SOIL AND WATER CONSERVATION

1.1 Introduction

Poor soil and water management is a major constraint to sustainable agricultural production in western Kenya. It leads to loss of land productivity through soil erosion and nutrient depletion. Each year, an estimated 0.25% of the region's arable land is lost through soil erosion. The situation has serious consequences on food security and the socio-economic wellbeing of most farming households in the region. Practical Action, through the western Kenya Agro-ecology Network, has responded to the challenge by developing a training toolkit to guide extension support in building the capacity of farmers on suitable soil and water conservation measures to reverse the situation.

The toolkit presents the techniques applicable in sustainable soil and water management in a highly simplified manner in order to make it easy for extension agents and farmers to apply them.

1.2 Overall Objective

To reverse land degradation, improve agricultural productivity and enhance socio-economic wellbeing of farming households through sustainable soil and water management.

Conservation refers to preventing wasteful use of a resource.

1.3 Modules Covered in Soil and Water Conservation

1. Terracing
2. Micro-catchment management
3. Spring protection
4. Water harvesting
5. Riverbank protection
6. Catchment protection and rehabilitation

1.4 Terracing

The purpose of this toolkit is to equip extension personnel and farmers with knowledge and skills on principles of terracing.

1.4.1 Training outcomes

At the end of the training, participants should be able to:

i) Outline the importance of terracing in agricultural production

ii) Identify types of terraces suitable for different agricultural landscapes

iii) Understand the design of different types of terraces

iv) Successfully construct terraces on their farms

v) Maintain terraces as required

1.4.2 Training outline

- Definition of terracing
- Importance of terracing
- Application of terraces
- Types of terraces
- Designing and constructing terraces
- Maintenance of terraces
- Challenges with adoption of terraces
- Alternative terracing technologies

Trainer's Notes

1.5 What is Terracing – Terracing refers to constructing an earth-embankment that resembles a step across the slope on a farmland. Its function is to reduce soil erosion through control of runoff by serving as intercepts that divide the sloping land surface into strips that slow the pace of runoff flow.

1.5.1 Why are terraces important?

a) They help to maintain soil fertility by reducing the erosive power of runoff

b) Help to conserve moisture within farmlands by facilitating retention and infiltration of runoff into the soil

c) Facilitate safe cropping on very steep slopes by diminishing the effect of runoff and soil erosion

d) Maybe used to support crops that require irrigation, such as rice

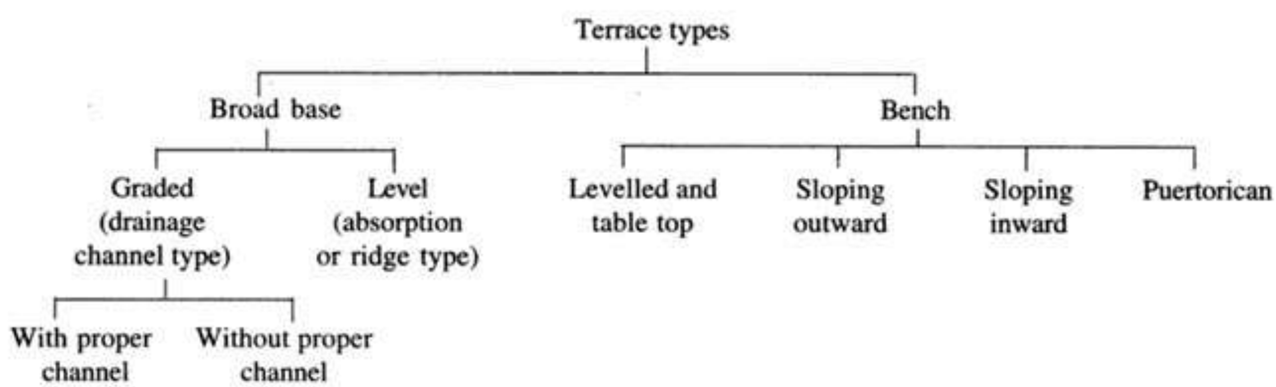
1.5.2 Where are terraces applied?

1. On agricultural land with at least 5 percent slope
2. In areas with high erosion risk
3. In areas where crops require flood irrigation

1.6 Types of Terraces

Terraces are classified into two major types – broad-based terraces and bench terraces.

- Broad-based terraces are applied where the main purpose is either to drain or retain water on a sloping land that is suitable for cultivation.
- Bench terraces are applied where the main purpose is to manipulate the slope to reduce the speed of runoff in order to control erosion.



Fig

1.6.1 Bench terracing

A series of flat shelf-like embankments cut across a slope resulting in several small strips across the landscape. They are separated at regular intervals by vertical drops protected by vegetation. They may be packed with stone retaining walls.

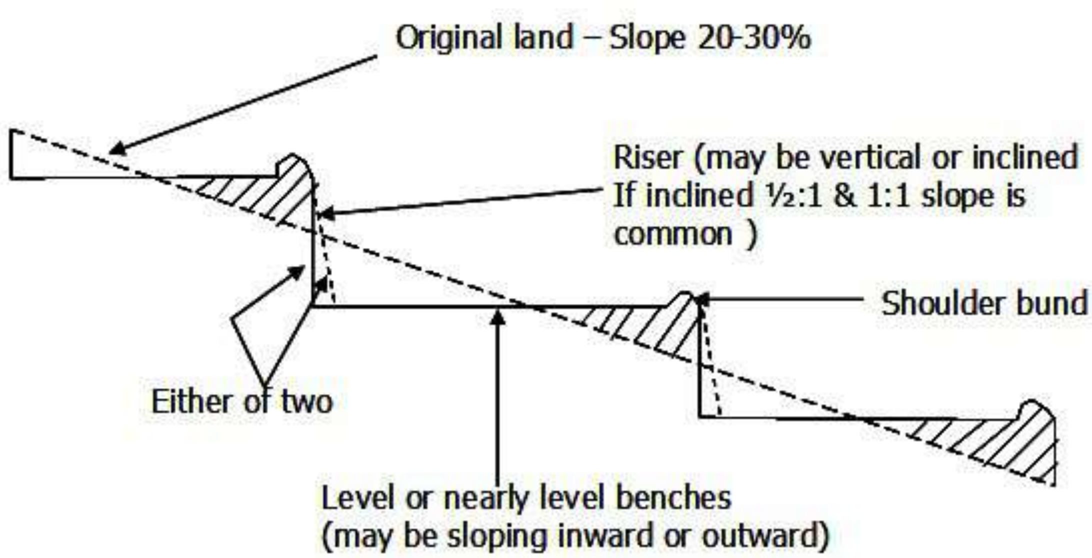


Figure 2: A bench terrace and its components

1.6.2 Types of bench terraces

There are three types of bench terraces

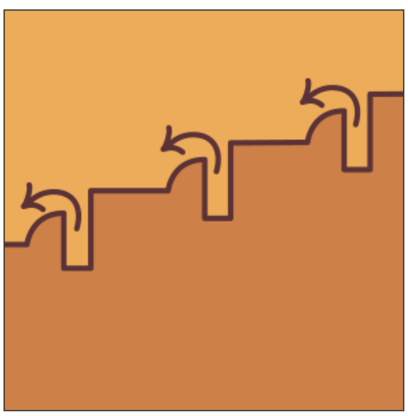
a) ***Bench terraces sloping inward*** - hill-type bench terraces - are to be adopted in heavy rainfall or hilly areas where the rainfall is to be drained as surface runoff. The inward slope serves as a drain for the runoff.

b) ***Bench terraces with level top*** - irrigated bench terraces – bench terraces with level top are suitable for areas of medium rainfall, evenly distributed and having deep and highly permeable soils. Since no slope is given to the benches it is expected that the most of the rainfall coming over the area is to be absorbed by the soil and very little water is to go as surface drainage. This type of terrace is also suitable where irrigation facilities are available and are hence referred to as irrigated bench terraces.

c) ***Bench terraces sloping outward*** - are to be used in low rainfall areas with permeable soils. They have a shoulder bund. In these terraces the rainfall thus conserved will have more time for soaking into the soil. Are suitable for fruit orchards hence often referred to as orchard bench terraces.

In Kenya, the bench terraces are grouped into two categories: **Fanya chini** and **Fanya juu** terraces

i) **Fanya chini terraces –** As the name suggests, soil is dug and deposited on the lower end of the trench. They are normally dug at the top of the slope to direct runoff. The runoff collects in its trench and can be directed to use within the farm. Perennial crops, such as bananas, can be grown in the trench created through the Fanya chini terrace as a way of creating a permanent barrier.



ii) **Fanya juu terraces –** As the name suggests, the soil is dug on the lower end and deposited on the upper side in order to control erosion and run off that may have escaped the Faya chini terrace. For this reason, they are normally constructed in the middle of the farm i.e. on the lower slope of the Fanya chini terrace. Perennial crops, such as bananas, can be grown in the trench created through the Fanya juu terrace as a way of creating a permanent barrier.

1.7 Designing Terraces

The design of terraces follows very similar design principles. They are embankment along a field's contour. A trench is dug to obtain soil to heap either on the upper or lower side of the trench. The heaped soil serves to slow down the speed of runoff in order to control the amount of soil that it carries. The water contained in the runoff goes into the trench and is directed appropriately.

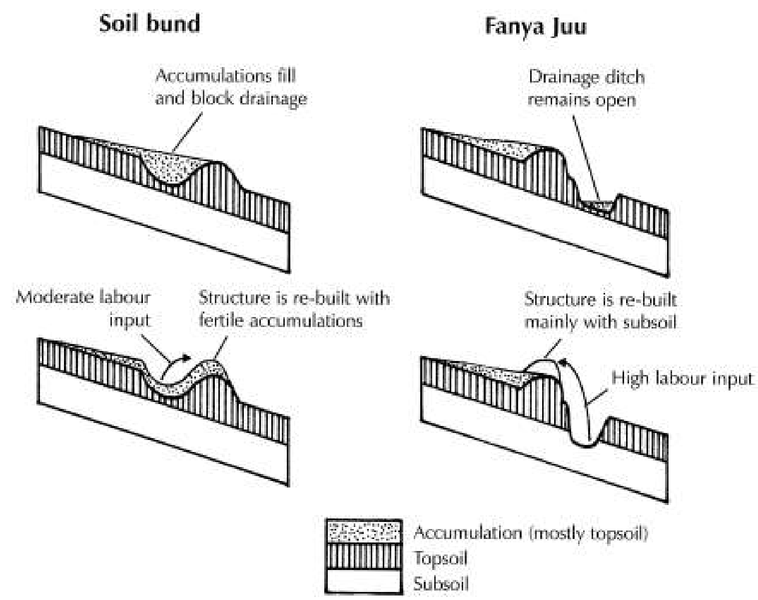


Figure 4: An illustration of the procedure for constructing terraces

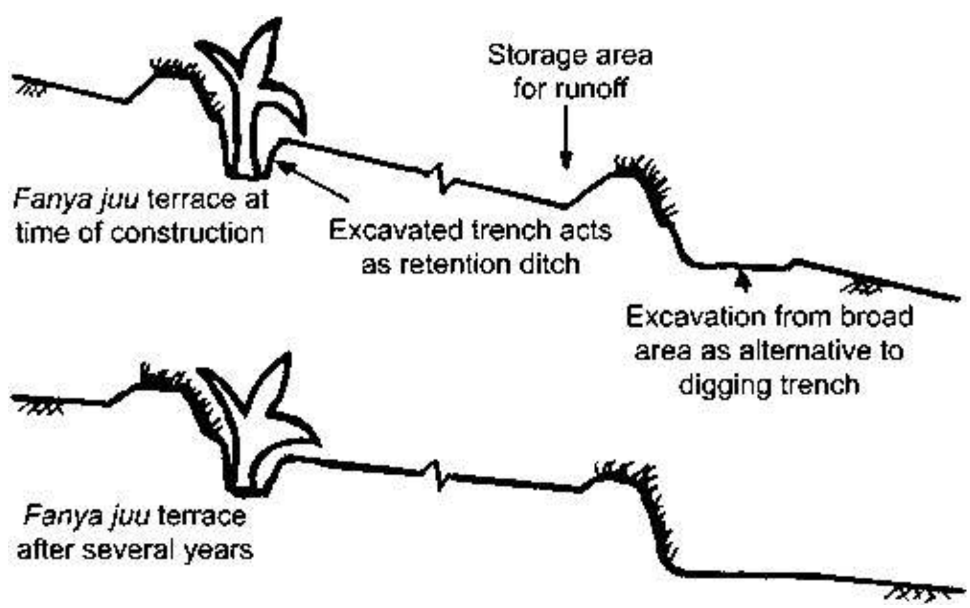


Figure 5: Bananas planted on the lower trench of the Fanya juu terrace

1.7.1 Maintenance of terraces

a) Terraces should be inspected annually or after every rainy season to identify areas that might need repair and realignment

b) Grass trips on terraces should be protected from grazing and trampling by livestock in order to protect the embankment

c) Terraces should be protected against use as routes across the slope by vehicles, livestock and footpaths to maintain their efficiency

1.7.2 Challenges in adopting terracing

- The great challenge to widespread adoption of terracing is the cost of constructing them. It costs a minimum of KShs 10,000 to 25,000 per acre to construct a terrace depending on the type of terrace.
- It is also expensive to maintain terraces. It may cost a minimum of KShs 7,000 to maintain a terrace per year.

1.7.3 Alternative terracing technologies

The high cost of terracing has led to the development of alternative terracing technologies. These include:

- Grass strips
- Shrub strips
- Tree hedge
- A combination of any two or all the three

1.8 Micro-catchment Management

The purpose of this toolkit is to equip extension personnel and farmers with knowledge and skills on micro-catchment management.

1.8.1 Training outcomes

After reading this toolkit, extension personnel and farmers should be able to:

a) Explain the importance of micro-catchment management

b) Relate micro-catchment approaches to land use management

c) Illustrate how to develop spatial / land use plans and guidelines

d) Make use of micro-catchment implementation guidelines

1.8.2 Training outline

Specific topics to be covered in this toolkit include:

1. Definition of a micro-catchment
2. Importance of micro-catchment conservation
3. Characteristics of a good micro-catchment
4. Causes of micro-catchment degradation
5. Micro-catchment approach to land use management
6. Community micro-catchment management action plan
7. Micro-catchment implementation guidelines

Trainer's Notes

1.8.3 What is a micro-catchment?

A micro catchment is a specially contoured area with slopes and berms designed to increase runoff from rain and concentrate it in a planting basin where it infiltrates and is effectively "stored" in the soil profile e.g., a water pan.

They are designed to trap and collect runoff from a relatively small designated area, usually (10 – 500 m2) within the farm boundary. The runoff water is guided into an application area where it accumulates in holes, pits, basins and bunds. The water is available for plants, but is protected from evaporation

1.8.4 Micro-catchment conservation and management

Integrated catchment management (ICM) is a subset of environmental planning which approaches sustainable resource management from a catchment perspective, in contrast to a piecemeal approach that artificially separates land management from water management.

It is important to note that:

- Micro catchment alone might not be sufficient to improve crop yields, its recommended to combine it with improved soil fertility management such as micro dosing and composting.
- Neglect of micro catchments can lead to soil erosion hence it is its recommended to regularly maintain them.
- Water logging can be a problem in areas with poor drainage hence it is advisable to consider the soil drainage features before constructing a micro-catchment in an area.
- Where grasses and shrubs form barriers, this may permit rodents to become established in the field, so it's advisable to combine micro-catchment management with biological pest control methods.
- Cross-border conflicts may arise in situations where consultations were not done prior to constructing a micro-catchment. It is necessary to consult neighbours and farmers located downstream beforehand.

1.8.5 Physical protection of a catchment

It is important to protect water catchments by planting suitable trees and grasses around it. This may entail the identification, mapping, design, and planting of water friendly and economically beneficial trees and monitoring of their growth and development over time.

1.8.6 Characteristics of a good micro-catchment

- Is simple and inexpensive to construct
- Is sufficient to supplement irrigation in arid and semiarid regions
- Should reduce the risk of crop failure
- Enhances leaching and reduces soil salinity hazard
- Reduces production risks
- Reduces soil erosion
- Enhances water availability
- Increases water use efficiency
- Improves crop productivity and income
- Enhances rainwater management
- Contributes to food security
- Reduces production costs

1.8.7 Causes of micro-catchment degradation

i) Uneven distribution runoff on steep slopes

ii) Sandy soils have a high water infiltration rate, thus run off does not occur hence there are high chances of degrading the micro-catchment

iii) High maintenance costs that hinder periodic maintenance

1.8.8 Micro-catchment approach to land use management

Micro-catchment water harvesting (MCWH) requires development of small structures across mild land slopes, which capture overland flow and store it in the soil profile for subsequent plant uses. Water availability to plants depends on the micro-catchment runoff yield and water storage capacity of both the plant basin and the soil profile in the plant root zone.

1.8.9 Process for developing a micro-catchment management action plan

Element 1: Identify the top hazards
The objective is to develop a better understanding of our micro-catchments so that we can make an informed decision about their future management. This is carried out by identifying and ranking the hazards of micro-catchments and potential impact to water quality.

Element 2: Having effective legislation
Strong legislation in the Micro-catchment to ensure that land is managed with a focus on water quality protection to minimize risk.

Element 3: Working with stakeholders
To ensure that water quality monitoring effectively detects changes in source water quality, promote partnerships across stakeholder groups for more effective management of water catchments

Element 4: Monitor high risk areas to ensure that water quality monitoring effectively detects changes in source water quality.

Element 5: Foster research
It is essential to be involved in national and local catchment research to have quality information that enables informed decisions. This can be achieved through collaborative funding opportunities for targeted local micro-catchment research.

Element 6: Performing proactive surveillance
To perform regular, documented surveillance of micro-catchments, gathering knowledge about a micro-catchment status is an essential foundation.

Element 7: Engaging the local community
It is important to inform, connect with and empower the community to make a positive change in micro-catchments.

Element 8: Plan for emergencies
To mitigate against unforeseen risks that may cause injury, damage or loss of water supply, it is important to plan ahead in regard to emergency preparedness.

1.9 Spring Protection

The purpose of this section of the toolkit is to equip extension personnel and farmers with knowledge and skills on spring protection.

1.9.1 Training outcomes

After reading this toolkit, extension personnel and farmers should be able to:

a) Explain the importance of spring protection

b) Relate spring protection to sustainable land management

c) Illustrate how to develop spring protection plans and guidelines

d) Make use of spring protection guidelines

1.9.2 Training outline

Specific topics to be covered in this toolkit include:

1. Definition of a spring
2. Importance of springs
3. Characteristics of a well-protected spring
4. Spring protection principles
5. Spring selection for protection
6. Causes of spring degradation
7. Threats to sustainable spring management
8. The spring protection - Construction of retaining wall, catchment dam, spring box and valve chamber
9. Community spring protection action plan
10. Spring protection implementation guidelines

Trainer's Notes

1.9.3 Definition of a spring

Springs occur where underground water flows out of the ground onto the land surface by gravity. This occurs when the water table is higher than the ground level mostly because of a shape drop of the ground level at a particular point.

1.9.4 Importance of springs

- Sources of streams and rivers
- Sources of portable water for domestic use
- Habitats for biodiversity

1.9.5 Characteristics of a well-protected spring

- Flow freely from the ground
- They are normally surrounded by natural vegetation
- They are naturally protected by a holding rock
- Water is safe for use by human and animals
- May flow all year around or during a period of the year.

1.9.6 Threats to sustainable spring management

- Reduction in water table due to loss of vegetation cover
- Soil erosion
- Crop cultivation around springs
- Landslides

1.9.7 Causes of spring degradation

- Deforestation
- Crop cultivation around the spring
- Planting trees with water draining properties
- Human settlement / urbanization
- Mechanical works, such as road construction

1.9.8 Spring selection for protection

The following considerations are important to make when selecting a spring for protection:

- The conservation significance of the water catchment
- Vulnerability of a spring to landslides, erosion and other forms of degradation
- Water yield versus the demand
- Proximity to agents of degradation

1.9.9 Spring protection principles

- Protection of water catchments from animals and humans
- Preventing contaminated water from mixing with spring water
- Keeping latrines away from upstream zones of springs
- Maintaining natural vegetation around springs
- Constructing recommended structures for obtaining water from the spring e.g. a spring box and a pipe for delivering the water to users
- The area around the spring should be fenced to prevent access by animals
- Direct overflow water to an area outside the protection zone from where the animals and livestock can access the water
- The spring box should be cleaned out regularly

1.9.10 Spring protection - Construction of retaining wall, catchment dam, spring box and valve chamber

a) A dry stone retaining wall should be built against the excavated slope. This wall is built using brick sized stones and it acts as a retaining wall and also allows the water to pass through into the collection areas with minimal sediment.

b) A catchment dam or 'cut-off' wall with wing walls, is designed to catch as much water as possible and direct it into the collection chamber - constructed in an excavated trench of minimum depth 20cm to help ensure that water does not seep under the wall.

c) The collection chamber and valve chamber are then constructed on the downstream side of the catchment wall and the bottom of the collection chamber should be concreted.

d) The overflow pipe from the collection chamber should be lower than the catchment dam walls to prevent back-pressure.

e) The area behind the catchment dam is filled with stones and gravel to the same level as the catchment chamber lid, with smaller stones nearer the eye and larger ones nearer the wall.

f) Heavy duty sheeting is then placed over the catchment area and the edges sealed with clay. The sheet is covered with the excavated soil and a layer of topsoil. Shallow root thorny-type vegetation can then be planted to deter vandalism and to stabilize the soil.

1.9.11 Community spring protection action plan

- Identify a spring that requires protection
- Carry out stakeholder engagements on necessary protection intervention
- Identify specific spring protection needs
- Develop a spring protection action plan outlining key strategies and relevant activities
- Prepare a work plan and budget
- Clearly spell out responsibilities
- State avenues for dispute resolution, plan monitoring and review

Place a sketch and/ or diagram

1.9.12 Spring protection implementation guidelines

- Prepare guidelines outlining the procedure for implementing strategies and activities listed in the community spring protection action plan.

1.10 Water Harvesting

The purpose of the toolkit is to equip extension personnel and farmers with knowledge and skills on sustainable water harvesting.

1.10.1 Training outcomes

After reading this toolkit, extension personnel and farmers should be able to:

1. Understand different water harvesting methods
2. Relate the application of water harvesting methods to agro-ecology principles
3. Apply selected water harvesting methods
4. Use water harvesting techniques to strengthen water use efficiency in agricultural production

1.10.2 Training outline

Specific topics to be covered in this section of the toolkit include:

1. Definition of water harvesting
2. Why should we harvest water?
3. Benefits of water harvesting
4. Water harvesting methods
5. Factors that may affect the quality of harvested water
6. Maintenance and cleaning of water storage facilities
7. How to clean a water tank
8. Maintaining rainwater quality

Trainer's Notes

1.10.3 Definition of water harvesting – The collection and concentration of rainwater and runoff

- For use in irrigation of annual crops, pastures and trees
- For domestic and livestock consumption and
- For groundwater recharge

1.10.4 Why should we harvest water?

a) The water is free; the only cost is for collection and use.

b) To ensure that the end use of harvested water is located close to the source, eliminating the need for complex and costly distribution systems.

c) Rainwater provides a water source when groundwater is unacceptable or unavailable, or it can augment limited groundwater supplies.

d) The zero hardness of rainwater helps prevent scale on appliances, extending their use; rainwater eliminates the need for a water softener and the salts added during the softening process.

e) Rainwater is sodium-free, important for persons on low-sodium diets.

f) Rainwater is superior for landscape irrigation.

g) Rainwater harvesting reduces flow to storm water drains and also reduces non-point source pollution.

h) Rainwater harvesting helps utilities reduce the summer demand peak and delay expansion of existing water treatment plants.

i) Rainwater harvesting reduces consumer utility bills.

j) Rainwater harvesting increases water resource and thus increases the rate of water accessibility.

1.10.5 Benefits of water harvesting

- Direct use by farmers, herders and investors.
- **Environmental health –** controlling soil erosion and desertification, supporting ecosystems, reducing flood risk
- **Social benefits –** creating employment, reducing migration to cities, better health for rural households

1.10.6 Water harvesting methods

a) Flood water harvesting – diversion of flood water for agriculture

b) Macro-catchment water harvesting – trapping runoff into excavated ponds and pans

c) Micro-catchment water harvesting – trapping water into planting pits / basins, contour terraces

d) Rooftop or courtyard water harvesting – trapping the water into storage tanks, reservoirs or cisterns

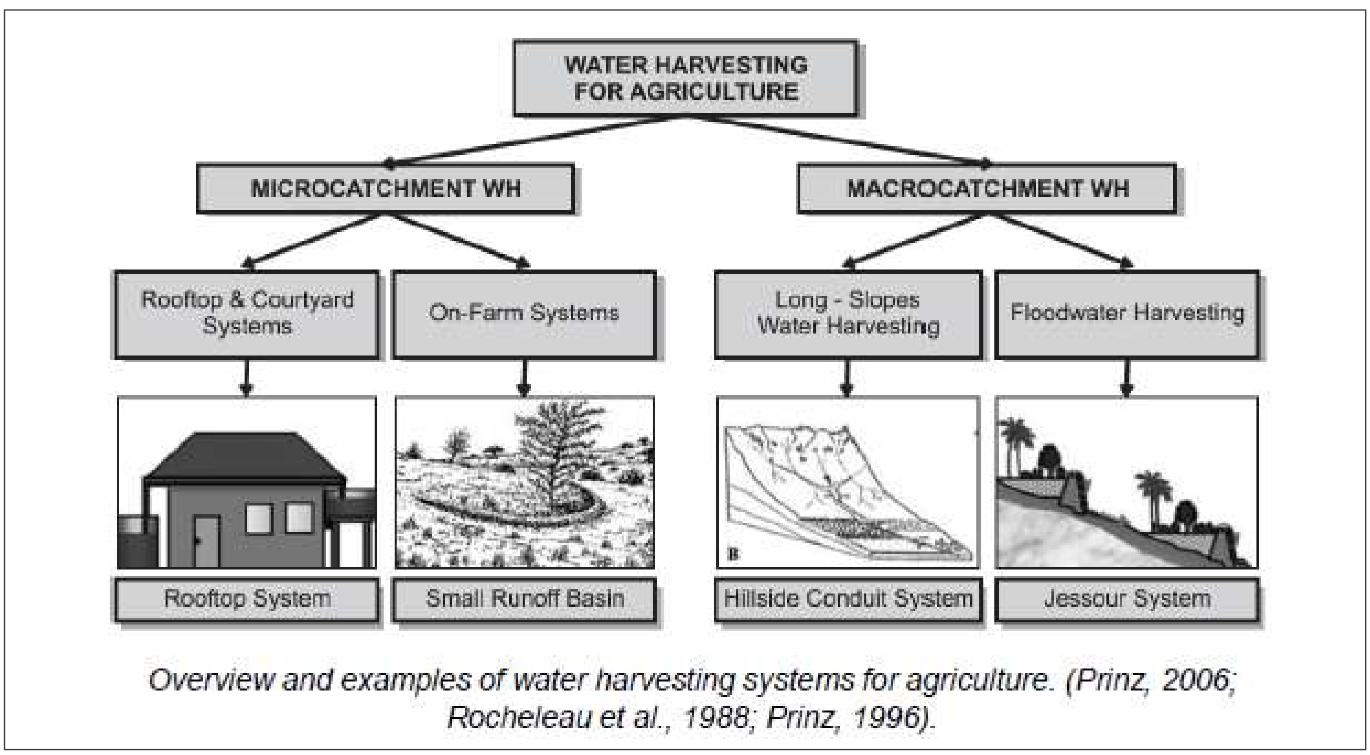


Figure 6: Water harvesting methods (Source: Prinz, 2006)

1.10.7 Factors that may affect quality of harvested water

a) **pH (acidity/alkalinity)** – As a raindrop falls and comes in contact with the atmosphere, it dissolves naturally occurring carbon dioxide to form a weak acid. The resultant pH is about 5.7, whereas a pH of 7.0 is neutral.

b) **Particulate matter** – As rainwater falls through the atmosphere, it incorporates particulate matter (smoke, dust, and soot suspended in the air). The fine particles are emitted by industrial and residential combustion, vehicle exhaust and burning of agricultural residue.

c) **Chemical compounds** – rainwater could have nitrates from fertilizer residue in the atmosphere including pesticide residues from crop dusting in agricultural areas.

d) **Catchment surface** – when rainwater comes in contact with a catchment surface, it can wash bacteria, molds, algae, fecal matter, other organic matter, and/or dust into storage tanks.

e) **Storage tanks** – filtering of rainwater prior to reaching the storage tanks reduces sedimentation and introduction of organic matter will occur within the tanks. Gutter screens, first-flush diverters, roof washers, and other types of pre-tank filters can be used.

f) **Water treatment** – the cleanliness of the roof in a rainwater harvesting system most directly affects the quality of the captured water. The cleaner the roof, the less strain is placed on the treatment equipment. It is advisable that hanging branches be cut away to avoid tree litter and to deny access to the roof by rodents and lizards.

1.10.8 Maintenance and cleaning of water storage facilities

Maintenance and cleaning of water storage facilities entails:

- Cleaning gutters
- Purging the first flush system
- Regularly cleaning roof washers and tanks
- Maintaining pumps and filtering system
- For potable water systems, it is necessary to replace cartridge filters, maintain disinfection equipment on schedule, test water quality and monitor tank levels
- Repairing leaks
- Adopting efficient water use practices

1.10.9 How to clean a water tank?

a) Should be done once a year – Requirements include liquid chlorine or chlorine tablets, bucket, brush and eye and hand protection (glasses, rubber gloves)

b) Drain any water in the tank

c) Transfer the water to clean contaminant-free storage or temporary vessel

d) Add 1 bottle of bleach or a number of chlorine tablets to the remaining water in the tank

e) Climb inside the tank and use a brush to thoroughly scrub the bottom and sides of the tank

f) Remove the water and bleach solution with a bucket

g) Refill the tank with water and leave the water to settle overnight before use

h) Note – wear proper hand and eye protection when preparing and handling chlorine solutions to avoid burning skin and damaging eyes.

1.10.10 Maintaining rainwater quality and health

- Keep the catchment surface safe from biological contaminants, such as fecal matter
- Prevent insect vectors, such as mosquitos from breeding inside the tank
- Avoid contamination of the water by agricultural residue
- Promote safe handling of stored water

1.11 Catchment Protection and Rehabilitation

Purpose of the Toolkit

The purpose of this toolkit is to equip extension personnel and farmers with knowledge and skills on catchment protection and rehabilitation procedures

1.11.1 Training outcomes

By the end of this module participants should be able to:

1. Outline importance of catchment rehabilitation
2. Identify degraded catchment sites
3. Identify catchment rehabilitation needs
4. Develop a catchment rehabilitation plan
5. Apply sustainable catchment management methods

1.11.2 Training outline

Specific topics to be covered in this module include;

1. What is a catchment?
2. Importance of a catchment
3. Catchments characteristics and water flow
4. Effect of soil texture on catchment characteristics
5. Anthropogenic effect on catchment characteristics
6. Causes of catchment degradation
7. Features of a degraded catchment
8. Catchment rehabilitation procedure
9. Tree species identification in catchment rehabilitation
10. Development of a catchment rehabilitation plan

Trainer's Notes

1.11.3 What is a catchment?

A catchment is an area where water is collected by the natural landscape. Gravity causes all rain and run-off in the catchment to run downhill where it naturally collects in streams, rivers, lakes or oceans. Since the outer edge of a catchment is the highest point, if rain falls outside the edge of one catchment, the water will flow in a different catchment into other streams and rivers. However, they may end up in the same river or lake downstream.

1.11.4 Importance of a catchment

a) Catchments provide people, stock and flora and fauna with drinking water.

b) They provide people with water for domestic and industrial use, including irrigation.

c) They cater for recreation and tourism.

d) They may also include important cultural sites.

e) Wildlife depend on catchments for food, shelter and breeding sites.

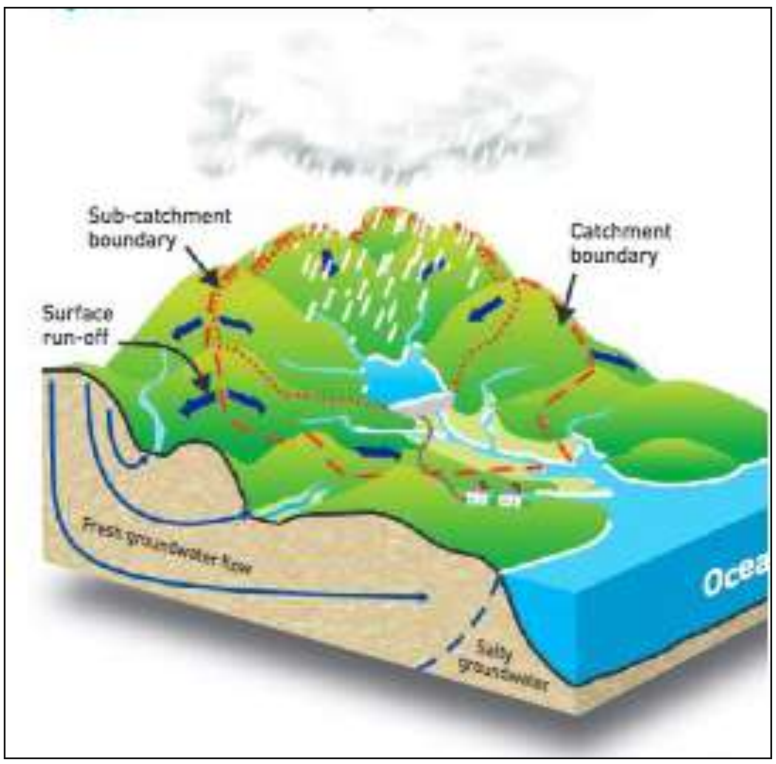


Figure 7: An illustration of a water catchment

1.11.5 Catchments characteristics and water flow

Catchment terrain interact with different patterns of rainfall to determine the character and size of runoff volumes and peak flows. Where a catchment has high slopes and low vegetation, the slope plays a major role in determining the runoff pattern. The pattern tends to exhibit high runoff proportions; rapid increase in flows to high peaks and equally rapid falls. If the slope was gentler and the vegetation cover were to increase, then peak flows would be smaller but more prolonged and total runoff volumes would be less. In catchments with low slopes, the vegetation cover and microclimate often exert a stronger influence on runoff than the land slope.

1.11.6 Effect of soil texture on catchment characteristics

Soil texture influences catchment characteristics. Soil texture is related to slope as well as to parent material, and the climatic regime under which the soil formed will often have been a determining factor of the soil textural type. Heavy textured soils tend to give a higher proportion of runoff and vice versa.

1.11.7 Anthropogenic effect on catchment characteristics

Human activities, such as grazing, tree-felling and settlement, and agricultural activities, such as method of ploughing, tend to alter catchment characteristics and runoff pattern.

1.11.8 Causes of catchment degradation

- Deforestation and destruction of natural vegetation
- Grazing in the catchment leading to its alteration
- Irrigation in the catchment area
- Human settlement
- Crop cultivation within a catchment

1.11.9 Features of a degraded catchment

- Loss of natural vegetation leading to bare ground in the upper edge of the catchment
- Eroded river banks
- Destructive runoffs
- Gullies and cracks in the landscape

1.11.10 Catchment rehabilitation procedure

- Assess catchment degradation status
- Identify catchment rehabilitation needs
- Identify stakeholder interests and roles in catchment rehabilitation
- Identify suitable catchment rehabilitation tree species
- Develop a catchment rehabilitation plan together with a budget
- Implement the rehabilitation plan
- Maintain rehabilitated areas
- Monitor and document the catchment restoration process

1.11.11 Tree species identification in catchment rehabilitation

- Suitable species should be those that thrive in riparian zones
- Preference should be given to native tree species depending on the agro-ecological zone
- The list should comprise a mix of light-demanding and shade-tolerant species

1.11.12 Development of a catchment rehabilitation plan

- The plan can be guided by an expert in catchment rehabilitation
- The process should be participatory
- The draft plan should undergo validation by all key stakeholders
- The plan should have a work plan, budget and roles and responsibilities of key stakeholders

1.12 River Bank Protection

The purpose of this toolkit is to equip extension personnel and farmers with knowledge and skills on riverbank protection.

1.12.1 Training outcomes

After reading this toolkit, extension personnel and farmers should be able to:

a) Understand techniques of protecting riverbanks

b) Relate the application of river bank protection methods to agro-ecology principles

c) Apply selected river bank protection methods

d) Use river bank protection techniques to strengthen water use efficiency in agricultural production

1.12.2 Training outline

Specific topics to be covered in this toolkit include:

1. Definition of a riverbank
2. Why should we protect riverbanks?
3. Causes of riverbank destabilization
4. Impacts of riverbank degradation
5. Methods of riverbank protection
6. Installing coir netting
7. Planting trees along the river bank to prevent erosion
8. Building a riprap wall

Trainer's Notes

1.12.3 What is a riverbank?

A river bank is the land that borders the edge of a river or stream. If you were to have a picnic immediately by the river edge, you would sit on the river bank.

1.12.4 Why protect riverbanks?

Rivers flow with a lot of force and in the process, the land around their banks easily erodes with time. As the erosion occurs, their channels widen or even change and could intrude into adjacent farms and property. Protection of river banks ensures that the erosion is controlled to save lives and property.

1.12.5 Causes of riverbank destabilization

- Direct causes: trampling by livestock, removal of riparian vegetation and crop cultivation along the riparian zone
- Indirect: Change in river flow regime leading to channel incision, widening of the river and destabilization of the bank

1.12.6 Impacts of riverbank degradation

- Societal impacts – property loss from undermining structures, loss of agricultural land
- Environmental impacts – Sediment and nutrient loading affecting water quality and causing eutrophication

1.12.7 Methods of riverbank protection

- Using coir netting
- Planting trees to prevent erosion
- Build a rock wall (called a riprap) that blocks out water
- Building gabions

1.12.8 Installing coir netting - Coir netting is made from coconut fiber and is biodegradable. It is recommended to use coir netting of 700-900 grams per square meter. Heavy duty netting can be used when there is a large amount of water flow. Ensure that the netting lies flat at the bottom of the riverbank and covers the soil entirely. Coir netting can be purchased from outlets that deal in landscaping materials. Depending on the climatic conditions of an area, coir netting lasts between 24 and 48 months. A measuring tape can be used to find the size of the area that is to be covered with the net in order to estimate the size to buy.

1.12.9 Planting trees along the river bank to prevent erosion - Cover the river bank with soil so you have a healthy base to plant vegetation. Rake and fertilize the soil so it's prepared for planting. The soil should not have clumps because the coir netting on which it is heaped needs to lie flat. Grass seed can be applied to the topsoil to grow and cover the spaces of the coir netting. Recommended plant species for riverbank stabilization include bamboo (modi), phragmites (odundu), papyrus (togo), Ficus (n'gou), Acacia meansii (wattle tree), Acacia polyacantha (ogongo), Sesbania sesban (sau sau), Kigelia africana (yago) and Owich / orindi / Omburi. All the trees used should be natives to the area. The trees and shrubs should be planted about 1m from the river edge.

1.12.10 Building a riprap wall – Determine the velocity of the river to assist in estimating the size of stones to use. The higher the velocity, the larger the stones. It is recommended to use granite or limestone because they are more resilient to water force. Angular shaped stones are preferred to round ones because they leave relatively small spaces. The wall should be tall enough to accommodate river water at its highest level.

1.12.11 Building gabions - Gabions are wire mesh boxes compactly filled with earth, stones, or other materials. They are used as erosion control structures, which stabilize steep slopes and river banks as retaining walls.

1.12.12 Riparian Land: Riparian areas are transitional between terrestrial and aquatic ecosystems and are distinguished by gradients in biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface hydrology connect waterbodies with their adjacent uplands. They include those portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems (i.e., a zone of influence). Riparian areas are adjacent to perennial, intermittent, and ephemeral streams, lakes, and estuarine–marine shorelines.

Riparian areas as "three-dimensional ecotones of interaction that include terrestrial and aquatic ecosystems, that extend down into the groundwater, up above the canopy, outward across the floodplain, up the near slopes that drain to the water, laterally into the terrestrial ecosystem, and along the water course at a variable width."

Importance of riparian areas

Relating to water quality, the ecological benefits of riparian areas are numerous.

a) By acting as buffers between upland areas and open water,

b) They help filter pollutants such as nutrients and sediment- Biofiltration prevents sediments and nutrients from entering the stream. Vegetation and leaf litter increase infiltration and slow overland flows preventing erosion.

c) Healthy riparian vegetation helps to reduce stream bank erosion and maintain stable stream channel geomorphology. Trees and grasses in riparian areas stabilize streambanks and reduce floodwater velocity, resulting in reduced downstream flood peaks. The zone provides flora and fauna habitat and corridors between remnants.

d) Riparian areas supply food, cover, and water for a large diversity of animals

e) It serves as migration routes and stopping points between habitats for a variety of wildlife.

2 AGROFORESTRY

2.1 Introduction

Shifting cultivation has been, and still is a traditional method of food crop production system in some parts of western Kenya, Homa Bay and Kisumu Counties included. The sustainability of shifting cultivation is now threatened as result of increasing population in the region and changing land-use patterns. The natural fallow periods have since reduced significantly to a point where exhausted farmlands cannot regain their lost fertility to support high crop production. In traditional fallow systems, naturally regenerated trees restore soil fertility during the long fallow periods after farming has been stopped and the land is allowed to "rest". Practicing agroforestry means that soils stay productive, while the farm provides food for the family, wood for biomass energy and construction, better ways to raise livestock and money when products from the system are sold.

2.2 Objective of this Training Module

The main objective of this section is to enhance the knowledge of the end users of this toolkit on suitable agroforestry practices to be implemented by communities for socio-economic gains.

2.3 Training Outline

1. Agroforestry defined
2. Reasons for practicing agroforestry
3. Emerging problems that can be addressed through agroforestry practices
4. Benefits of agroforestry components (tree/crop/livestock) in a system
5. Role of trees in agroforestry systems
6. Agroforestry practices for soil improvement
7. Pattern of tree planting in intercropping systems
8. Tree crop interactions in agroforestry systems and suitable tree species
9. Beneficial effects of tree-crop interactions in agroforestry systems
10. Land-use problems that can be addressed through agroforestry systems
11. Trees for soil erosion control
12. Summary of valuable tree species commonly used in agroforestry systems and where they can be planted
13. Possible limitations of agroforestry

Trainers Notes

2.4 What is Agroforestry?

An interaction between trees, crops and/or livestock that have both ecological and economic benefits.

2.4.1 Why agroforestry?

Shifting cultivation, a traditional way of producing food crops by using land and thereafter leaving it fallow for a period. This has become unsustainable due to;

- Increase in human population
- Growing of export-oriented commercial crops
- Need for land for grazing by livestock
- Decline in soil fertility hence low crop yield

2.4.2 Emerging issues

- Deforestation
- Harvesting of fuelwood from unsustainable sources and environmentally sensitive areas such as watersheds.
- Increased soil erosion and siltation of rivers

2.5 Benefits of Agroforestry

a) Benefits of agroforestry to crops

- Improved soil fertility
- Soil conservation
- Improved micro-climate

b) Benefits to livestock

- Trees may provide fodder
- Trees provide cooling shade

c) Benefits to trees

- Trees are better protected
- Trees may receive better weed management when inter-planted with crops
- Trees may benefit from fertilizers applied to crops

d) System benefits

- Low external input production system
- Diversification of products - food, cash crops, fodder, building materials, medicine, etc.
- Reduced pest and diseases due to mixed cropping and increased species diversity

Note: All the above four Agroforestry benefits are contributing both directly and indirectly to man.

2.5.1 Role of trees in agroforestry systems

The tree component in an agroforestry system can provide benefits through services and products.

a) Service functions

- Improve soil quality and erosion control
- Provide shade for crops, livestock and human beings
- Support for crops such as yams, passion fruits, beans, tomatoes, etc.
- Fencing, boundary marking and windbreaks

b) Production functions

- Fuelwood
- Timber and building materials
- Staple food, fruits and nuts
- Fodder
- Medicine

2.5.2 Agroforestry practices for soil improvement

Traditional fallow system (shifting cultivation or slash & burn agriculture)

a) Planted tree fallows (improved fallow systems using selected leguminous trees and shrubs). It is important to consider:

- Choice of species
- Method of establishment
- Tree spacing
- Management interventions
- Time of tree planting
- Method of removal

2.5.3 Pattern of tree planting in intercropping systems

- **Alley cropping/hedgerow intercropping -** trees and shrubs are closely planted in continuous hedgerows separated by alleys of crops of varying width.
- **Grid intercropping -** trees are planted as individuals in a uniform grid pattern throughout the farm.
- **Informal intercropping -** a few trees are either planted or deliberately left in the farm during site preparation. Crops are planted in the spaces between the trees.

Factors to be considered during establishment when intercropping trees with crops in an agroforestry set up:

a) Spacing between plants in a row (0.25 – 1.0m)
b) Spacing between the hedgerow/alley width (4.0 – 6m)
c) Hedgerow management
    - Pruning (reduce shading effect and provide biomass that can be fodder or green manure)
    - Root pruning (to reduce competition for nutrient and moisture with annual crops)

2.5.4 Tree crop interactions in agroforestry systems

- **Improved fallows in shifting cultivation –** for soil fertility improvement (suitable species include Gliricidia sepium, Tephrosia vogelii, Cajanus cajan (obong), Sesbania sesban (sao sao), Crotalaria grahamiana (mitoo). The candidate species are mainly N2-fixing species and can produce high quality litter to be used as green manure in crop production.
- **Hedgerow –** soil erosion control, soil fertility improvement and livestock fodder (Calliandra calothyrsus, Leucana leucocephala, L. diversifolia).
- **Tree gardens/home gardens -** Fruit trees mixed with annual crops/vegetables. The trees are within the proximity of the homestead and can be well protected. The trees in this agroforestry system takes the upper storey while integrated annual crops or vegetables takes the lower canopy.
- **Multi-purpose trees and shrubs -** Mangifera indica (Maeba), Persia Americana (avocado), Syzygium cumini (Jamna), Grevillea robusta and many other species planted as boundary markers, windbreak, fodder, firewood, timber and shade trees.

2.5.5 Beneficial effects of tree-crop interactions in agroforestry system

- Increase inputs (organic matter, nitrogen fixation, nutrient uptake from deep soil layers)
- Reduce losses (organic matter, nutrients) by lowering surface temperatures, protecting surface structure and decreasing erosion)
- Improve soil physical properties, including water holding capacity and permeability.
- Improve beneficial effects of soil biological processes
- Litter and mulch-leaves, twigs and branches die and fall on the ground as litter or trees managed to produce biomass applied as mulch to benefit annual crops
- Fine root turnover-short lived root hairs die and decay thereby resulting in increased soil organic matter
- Nutrient pumping- tree roots penetrate deeper soil layers than the roots of crops
- Soil protection along steep slopes which prevents loss of fertile top soil

2.5.6 Addressing landuse problems through agroforestry

- **Pollution:** agricultural chemicals widely used can be harmful to the environment and people
- **Soil erosion:** agroforestry systems help reduce soil erosion especially in sloppy areas
- Loss of agro-biodiversity
- **Logging/deforestation:** when areas are logged and not replanted, not only is the timber gone but also many valuable tree products for local people
- **Shifting cultivation:** the rotation period has reduced significantly so the soil cannot regain its lost fertility hence the introduction of improved fallow system

2.5.1 Trees for soil erosion control

Vegetation protects the soil in the following ways:

- Ground cover-suppressing weeds
- Soil binding by the root network
- Reduce raindrop impact
- Slow down surface runoff
- Reduce temperature, hence protect soil organic matter

A combination of trees and grasses can be planted along contours in sloppy areas to act as erosion control structures. Fodder species such as Calliandra calothyrsus, Leucaena diversifolia and L. trichandra among other candidate tree species.

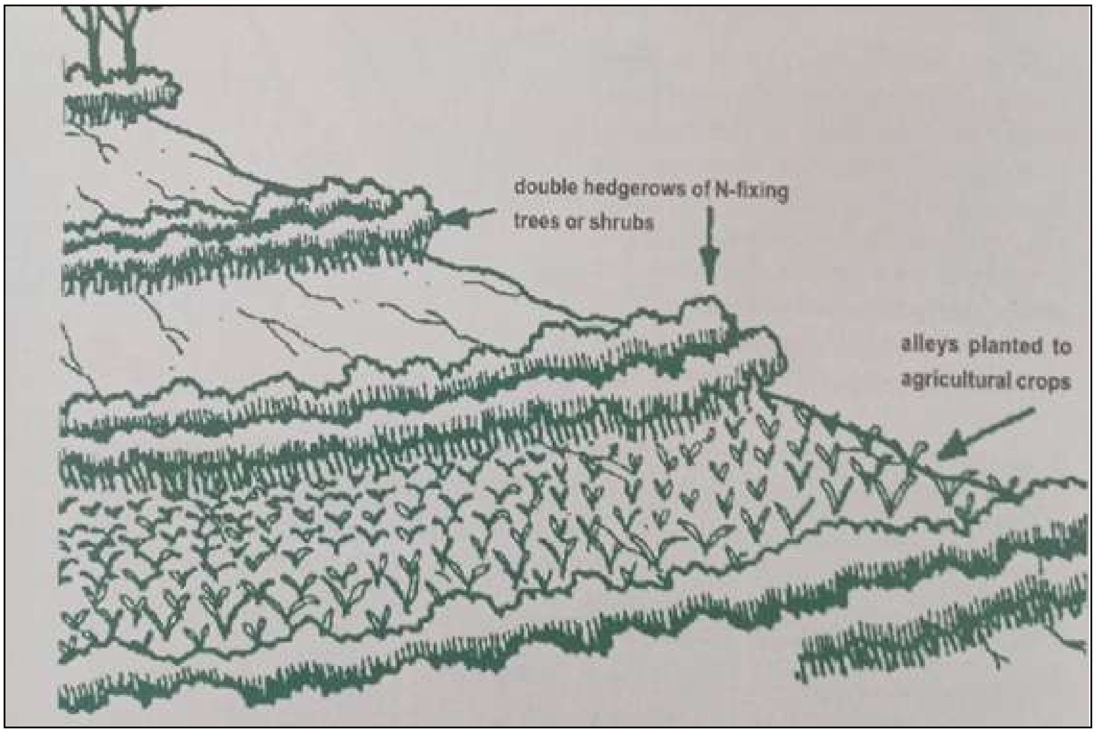


Figure 8: Contour hedge on sloppy areas to prevent soil erosion

2.5.2 Summary of valuable tree species commonly used in agroforestry system and where they can be planted

Table 1: Timber and fuel wood production in agroforestry systems

Species	Benefits to local communities	Where to plant the trees
Grevillea robusta, Markhamia lutea, Senna siamea, Albizia coriara, Maesopsis eminii, Gmelina arborea, Bischofia javonica, Casuarina equisetifolia	• Timber • Poles & Posts • Fuel wood • Timber • Poles & Posts • Fuel wood • Rehabilitation of degraded areas	• Boundary • Mixed with crops • Woodlots • Along terraces • Boundary • Wind breaks around homesteads • Woodlot in quarry areas
Eucalyptus grandis E. saligna	• Timber • Poles & posts • Fuel wood	• Woodlots
Cupresus lusitanica (Cypress)	• Timber • Posts	• Wood lots • Boundary • Living fence around homestead

Table 2: Livestock fodder production in agroforestry systems

Species	Benefits to local communities	Where to plant the trees
Calliandra calothyrsus Leucaena lecucephala Gliricidia sepium Sesbania sesban Desmodium	• Livestock fodder • Bees forage • Improving soil fertility • Fuel wood • Soil erosion control • Control of fall army worm	• Mixed with crops • Woodlots • Along terraces • Improved fallows

Tables 3: Fruit trees species integrated in agroforestry systems

Species	Benefits to local communities	Where to plant the trees
Avocado (Persea americana) Improved mangoes (Ngowe, Apple, Kent e.tc) Paw paw (Papaya carica) Improved varieties of guavas (Psidium guajava) Syzygium cumunii	• Improved nutrition for household members • Source of income from sale of fruits • Bees forage	• Fruit orchard • Home gardens • Mixed with crops • Along terraces within the farm

Table 4: Medicinal trees that can be domesticated in agroforestry systems

Species	Benefits to local communities	Where to plant the trees
Prunus africana Weburgia ugadensis Zanthoxylum gilettii Abizia coriara Psidium guajava	• Improved health for household members • Source of income from sale of products	• Home gardens • Mixed with crops • Homesteads

2.6 LIMITATIONS OF AGROFORESTRY

- Competition of trees with crops for space, sunlight, moisture and nutrients which may reduce crop yields
- Some trees may serve as hosts to insect pests of crops
- Rapid regeneration and growth of some trees make them potential weeds
- The practice may require extra labour inputs
- Tree take longer time to mature to acquire an economic value
- Tree can hinder mechanization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3 AGROBIODIVERSITY

3.1 Background Information

Biodiversity is the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems. It forms the foundation of the vast array of ecosystem services that critically contribute to human well-being and it is important in human-managed as well as natural ecosystems. Ultimate decisions humans make that influence biodiversity affect the well-being of themselves and others. Practical Action, through the western Kenya Agro-ecology Network, has responded to the challenge by developing a training toolkit to guide in extension support and information dissemination on intra and inter specific diversity for risk reduction, crop rotation and intercropping to support the most food and nutrition insecure households and communities to meet their food needs in quality and quantity in a sustainable manner.

This biodiversity toolkit presents methods of crop rotation and intercropping applicable in sustainable food production in a simplified format to be easily understood and applied by both extension agents and farmers.

3.2 Overall Objective

To enhance agro biodiversity for improved sustainable food security, nutrition and livelihoods for farming households.

3.3 Training Outcomes

- To enable smallholder farmers, embrace use of intra and inter specific diversity for risk reduction, crop rotation and intercropping for improved productivity
- To have smallholder farmers practice biodiversity with regard to crop rotation and intercropping

3.4 Crop Rotation

Crop rotation is the practice of growing a series of different types of crops in the same area in sequenced seasons

3.4.1 Course outcome

i) By the end of training at least 90% of the participants shall have understood the importance of crop rotation and its application.

ii) By the end of training the trainees shall have understood the importance and benefits of intercropping and its application.

3.4.2 Training outline

- Why crop rotation (Benefits)
- Disadvantages of crop rotation

Trainers Notes

3.4.3 Benefits of crop rotation / why crop rotation

a) **Soil organic matter** – Soil organic matter (SOM) is the organic component of the soil, which consists of plant and animal detritus that are at different stages of decomposition. It includes also cells and tissues of soil microbes. The use of different crop types or species in rotation increases soil organic matter, good soil structure, moisture retention and improves soil chemical and biological environment for crops. It also provides increased drought tolerance and decreased erosion

b) **Soil organic carbon** – Soil organic carbon (SOC) refers to the carbon component of soil organic matter. Crop rotation greatly increases soil organic carbon content. Carbon, along with hydrogen and oxygen, are macronutrients for plants. This happens when crop rotation is practiced for a long period of time.

c) **Nitrogen fixation** – Crop rotation add nutrients to the soil especially when legumes, plants of the family Fabaceae (also referred to as Leguminosae) are incorporated in the rotation. During nodulation, the rhizobia bacteria use nutrients and water provided by the plant to convert atmospheric nitrogen into ammonia, which is then converted into an organic compound that the plant can use as its nitrogen source.

d) **Pathogen and insect pest control** - Crop rotation is also used to control pests and diseases that can become established in the soil over time. The changing of crops in a sequence decreases the population of pests by interrupting pest life cycles and habitats. Plants within the same family have similar pests and pathogens.

e) **Weed management** - Integrating certain crops, especially cover crops, into crop rotations is of particular value to weed management. These crops crowd out weeds through competition

f) **Preventing soil erosion** - Crop rotation can significantly reduce soil erosion by water, especially in areas susceptible to erosion

g) **Biodiversity** – Increasing the biodiversity of crops has beneficial effects on the surrounding ecosystem and can host a greater diversity of fauna, insects, and beneficial microorganisms in the soil.

h) **Farm productivity** – Crop rotation contributes to increased yields through improved soil nutrition. By requiring planting and harvesting of different crops at different times, more land can be farmed with the same amount of machinery and labour.

i) **Risk management** – Different crops in the rotation reduce the risks of adverse weather for the individual farmer

j) **Challenges** – Green manure from legumes can lead to an invasion by snails or slugs, while decay of green manure can occasionally suppress the growth of other crops

3.4.4 Disadvantages of crop rotation

a) **It Involves Risk:** In crop rotation, investing in a season involves the input of much money to buy different seedlings of the different types of crops to be planted. Moreover, certain crops need specific kinds of equipment, so farmers may have to invest in different types of machinery. This means the initial costs can be higher. The success, however, for each crop type is not guaranteed, and one can end up incurring a loss of harvest. In addition, pests and diseases from other crops can spread and infect more crops. There is also the risk of a certain crop yield not being successful, and that was the only crop type grown, meaning there will be no yields for that planting season, and the farmer will have to wait for the next season.

b) **Improper Implementation Can Cause Much More Harm Than Good:** Improper implementation of this technique causes much more harm than good. If one lacks the technical knowhow of crop rotation, there is no need to experiment because there can be nutrient buildup that will take a longer time to correct. One has to have the skills to know what crops can be planted after the other and in which season for the process to be successful. Improper implementation, hence, makes the farmer incur very great losses. Still, information about the different planting techniques are easily available, and the farmer should be vigilant as well as ready to practice them as required.

c) **Obligatory Crop Diversification:** For crop rotation to work, one has to plant different crops every time. Nonetheless, it does not allow a farmer to specialize in a single type of crop. The farmer is not able to produce a single crop on a large scale over a long period of time because of the damage it will do to the soil. The practice of crop rotation is necessary to improve yields. Crop diversification also requires investment in different planting techniques for each unique crop that costs time and money because each crop needs a different type of attention.

d) **Requires More Knowledge and Skills:** Crop rotation means a variety of crops; therefore, it requires a deeper set of skills and knowledge regarding each type of crop harvested. It also requires different types of machinery, and operating them also requires knowledge. This means farmers will have to invest more time and resources in learning and mastering this agricultural practice.

e) **The Difference in Growing conditions:** Certain locations and their climates are more favorable for monoculture, meaning a certain kind of crop. Other than that particular kind of crop, other crops cannot grow well in that specific type of temperature and soil conditions.

3.5 Intercropping

Intercropping is a multiple cropping practice involving growing two or more crops in proximity. In other words, it is the cultivation of two or more crops simultaneously on the same farm.

3.5.1 Training Outline

- Resource partitioning
- Potential benefits
- Pest management
- Ways by which pests can be controlled through intercropping

3.5.2 Training outcome

a) At the end of the training the learning should be able to know what intercropping means

b) The learners should be able to know which crops can be easily intercropped and they have beneficial interaction.

Trainers Notes

3.5.3 Resource partitioning in intercropping

Intercropping requires careful planning and when planning, the following aspects should be taken into account:

- Soil type
- Climate of an area
- Crop types and their varieties.

It is important for crops not to compete for physical space, nutrients, water or sunlight. The best strategies of intercropping are planting a deep-rooted crop with shallow-rooted crops, or planting a tall crop with a shorter crop or a crop that requires exposure to full sunlight with one that requires partial shading. When crops are carefully selected, other agronomic benefits are also achieved.

3.5.4 Potential benefits of intercropping

a) Mutualism - intercropping of compatible plants that benefit from each other. Planting two crops in close proximity can especially be beneficial when the two plants interact in a way that increases one or both of the plant's fitness (and therefore yield). For example, plants that are prone to tip over in wind or heavy rain (lodging-prone plants), may be given structural support by their companion crop. Climbing plants such as black pepper can also benefit from structural support. Some plants are used to suppress weeds or provide nutrients. Delicate or light-sensitive plants may be given shade or protection, or otherwise wasted space can be utilized. An example is the tropical multi-tier system where coconut occupies the upper tier, banana the middle tier, and pineapple, ginger, or leguminous fodder, medicinal or aromatic plants occupy the lowest tier.

Intercropping of compatible plants can also encourage biodiversity, by providing a habitat for a variety of insects and soil organisms that would not be present in a single-crop environment. These organisms may provide crops with valuable nutrients, through nitrogen fixation.

b) Pest management

Pest control

There are several ways in which increasing crop diversity helps to improve pest management. It may limit outbreaks of crop pests by increasing predator biodiversity. Also crop heterogeneity potentially increases the ability of a companion crop to serve as a barrier against biological dispersal of pests to other crops.

3.5.5 Ways by which pests can be controlled through intercropping:

- **Trap cropping -** this involves planting a crop nearby that is more attractive for pests compared to the production crop. The pests will target this crop and not the production crop.
- **Repellant intercrops –** planting an intercrop that has a repellent effect to certain pests. The repellant crop masks the smell of the production crop in order to keep pests away from it.
- **Push-pull cropping -** this is a mixture of trap cropping and repellant intercropping. An attractant crop attracts the pest and a repellant crop is also used to repel the pest away.

Place diagram of pull and push here

3.5.6 Types of intercropping

- **Mixed intercropping -** as the name implies, is the most basic form in which the component crops are totally mixed in the available space.
- **Row cropping -** involves arranging the component crops in alternate rows. Variations include alley cropping where crops are grown in between rows of trees, and strip cropping where multiple rows, or a strip, of one crop are alternated with multiple rows of another crop.
- **Temporal intercropping -** uses the practice of sowing a fast-growing crop with a slow-growing crop so that the fast-growing crop is harvested before the slow-growing crop starts to mature.
- **Relay cropping -** where the second crop is sown during the growth, often near the onset of reproductive development or fruiting of the first crop, so that the first crop is harvested to make room for the full development of the second.

3.5.7 Limitations

- Trap cropping often fails to decrease pest densities in large scale commercial landscapes.
- Increasing crop diversity through intercropping does not necessarily increase the presence of the predators of crop pests.

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4 CONSERVATION AGRICULTURE

4.1 Background Information

Conservation agriculture is a farming system that promotes minimum soil disturbance (i.e. either minimum or no tillage), maintenance of a permanent soil cover, and diversification of plant species. It enhances biodiversity and natural biological processes above and below the ground surface, which contribute to increased water and nutrient use efficiency, and to improved and sustained crop production.

4.2 Objective of Training of Conservation Agriculture

To enhance conservation agriculture for sustained environmental conservation, improved food security, nutrition and livelihoods for farming communities.

4.3 Course Outcomes

- To enable smallholder farmers to embrace conservation agriculture for improved productivity
- To have smallholder farmers practice conservation agriculture for sustainable food security, nutrition and livelihoods

4.4 Training Outline

1. What is Conservation Agriculture?
2. Principles of conservation agriculture
3. Wildlife-friendly farming
4. Land sparing
5. Benefits of conservation agriculture
6. Mulching

Trainers Notes

4.5 What is Conservation Agriculture?

Conservation Agriculture (CA) can be defined as "the concept for resource-saving in agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment" (FAO 2007).

4.5.1 Principles of conservation agriculture

- **Minimum tillage** - Practicing minimum soil disturbance which is essential to maintaining minerals within the soil, stopping erosion, and preventing water loss from occurring within the soil.
- **Zero tillage** – practicing agriculture without having to till the land. It is the opposite of complete tillage, which requires a lot of labor, time, and fuel. Producers therefore can save 30% to 40% of time and labor by practicing zero-tillage.
- **Maintenance of soil organic cover** - this is the principle of managing the top soil to create a permanent organic soil cover that allows for the growth of organisms within the soil structure.
- **Practicing diverse crop rotations** or crop interactions
- Other types of CA include the practice of wildlife-friendly farming and land sparing

4.5.2 Wildlife-friendly farming

Wildlife-friendly farming is a practice of setting aside land that will not be developed by the producer (farmer). This land will be set aside so that biodiversity has a chance to establish itself in areas with agricultural fields. At the same time, the producer is attempting to lower the amount of fertilizer and pesticides used on the fields so that organisms and microbial activity have a chance to establish themselves in the soil and habitat (Green et al. 2005). But as in all systems, not all can be perfect. To create a habitat suitable for biodiversity, something has to be reduced, and in this case, yield may decline. This is where the second idea of land sparing can be looked on as an alternative approach.

4.5.3 Land sparing

Land sparing is another way of balancing the interests of producers and conservationists. Land sparing advocates for the land that is being used for agricultural purposes to continue to produce crops at increased yield. With an increase in yield on all land that is in use, other land can be set aside for conservation and biodiversity conservation. Agricultural land stays in production, but its yield potential has to increase in order to cope with demand. Land that is not under agriculture would be used for conserving biodiversity (Green et al. 2005). In fact, data from the FAO shows that between 1961 and 2012, the amount of arable land needed to produce the same amount of food declined by 68 percent worldwide.

4.5.4 Benefits of conservation agriculture

i) Economic benefits that improve production efficiency.

- Time saving and thus reduction in labour requirement.
- Reduction of costs, e.g. fuel, machinery operating costs and maintenance, as well as a reduced labour cost.

- Higher efficiency in the sense of more output for a lower input.

ii) Agronomic benefits that improve soil productivity.

- Organic matter increase.
- Soil water conservation.
- Improvement of soil structure, and thus rooting zone.

iii) Environmental benefits

- Reduction in soil erosion, and thus of road, dam and hydroelectric power plant maintenance costs.
- Improvement of water quality.
- Improvement of air quality.
- Biodiversity increase.
- Carbon sequestration.

4.6 Mulching

A protective covering, such as of bark chips, straw, or plastic sheeting, placed on the ground at the base of the plant to suppress weed growth and retain soil moisture.

a) Benefits of mulching

- Conservation of soil moisture
- Improving fertility and health of the soil
- Control of weed growth
- Enhancing the visual appeal of the area
- Food for microorganisms in the soil

b) Choice of materials for mulching

Factors to consider when choosing mulching material include availability, cost, appearance, the effect it has on the soil (including chemical reactions and pH), durability, combustibility, rate of decomposition, free from weed seeds and/or plant pathogens

c) Organic mulches

Organic mulches decay over time and are temporary. The way a particular organic mulch decomposes and reacts to wetting by rain and dew affects its usefulness. Commonly available organic mulches include:

d) Leaves

Leaves from deciduous trees. They tend to be dry and blow around in the wind, so are often chopped or shredded before application. As they decompose they adhere to each other, but also allow water and moisture to seep down to the soil surface.

e) Grass

Grass clippings from mowed lawns are sometimes collected and used elsewhere as mulch. Grass clippings are dense and tend to mat down, so are mixed with tree leaves or rough compost to provide aeration and to facilitate their decomposition without smelly putrefaction. Rotting fresh grass clippings can damage plants; their rotting often produces a damaging buildup of trapped heat. Grass clippings are often dried thoroughly before application, which mitigates against rapid decomposition and excessive heat generation. Fresh green grass clippings are relatively high in nitrate content, and when used as a mulch, much of the nitrate is returned to the soil, conversely the routine removal of grass clippings from the lawn results in nitrogen deficiency for the lawn.

f) Peat moss

Peat moss, or sphagnum peat, is long lasting and packaged, making it convenient and popular as a mulch. When wetted and dried, it can form a dense crust that does not allow water to soak in. When dry it can also burn, producing a smoldering fire. It is sometimes mixed with pine needles to produce a mulch that is friable. It can also lower the pH of the soil surface, making it useful as a mulch under acid loving plants.

g) Woodchip mulch

Woodchip mulch is a byproduct of timber (usually packaging pallets), which are disposed of as wood waste by creating woodchip mulch. The chips are used to conserve soil moisture, moderate soil temperature and suppress weed growth. Woodchip mulch is often used under trees, shrubs or large planting areas and can last much longer than arborist mulch. In addition, many consider woodchip mulch to be visually appealing, as it comes in various colors. Woodchips can also be reprocessed into playground woodchip to be used as an impact-attenuating playground surfacing.

h) Bark chips

Bark chips of various grades are produced from the outer corky bark layer of tree logs. Sizes vary from thin shredded strands to large coarse blocks. The finer types are very attractive, but have a large exposed surface area that leads to quicker decay. Layers of two or three inches deep are usually used, bark is relativity inert and its decay does not demand soil nitrates. Bark chips are also available in various colors.

i) **Straw mulch / field hay / salt hay**

They have an unkempt look and are used in vegetable gardens and as a winter covering. They are biodegradable and neutral in pH. They have good moisture retention and weed controlling properties, but also are more likely to be contaminated with weed seeds. Salt hay is less likely to have weed seeds than field hay. Straw mulch is also available in various colors.

j) **Straw**

The needles that drop from pine trees is termed pine straw. It is available in bales. Pine straw has an attractive look and is used in landscape and garden settings. On application, pine needles tend to weave together, a characteristic that helps the mulch hold storm water on steep slopes. This interlocking tendency combined with a resistance to floating gives it further advantages in maintaining cover and preventing soil erosion. The interlocking tendency also helps keep the mulch structure from collapsing and forming a barrier to infiltration. Pine straw is reputed to create ideal conditions for acid-loving plants. Pine straw may help to acidify soils, but studies indicate this effect is often too small to have adverse effects.

k) **Cardboard / newspaper**

Cardboard or newspaper can be used as mulches. These are best used as a base layer upon which a heavier mulch such as compost is placed to prevent the lighter cardboard/newspaper layer from blowing away. By incorporating a layer of cardboard/newspaper into a mulch, the quantity of heavier mulch can be reduced, whilst improving the weed suppressant and moisture retaining properties of the mulch. However, additional labour is expended when planting through a mulch containing a cardboard/newspaper layer, as holes must be cut for each plant. Sowing seed through mulches containing a cardboard/newspaper layer is impractical. Application of newspaper mulch in windy weather can be facilitated by briefly pre-soaking the newspaper in water to increase its weight.

4.7 Minimum Tillage

Minimum tillage is also called conservation tillage; the ultimate goal of minimum tillage is minimum soil manipulation necessary for a successful crop production. It is a tillage method that does not turn the soil over. It is contrary to intensive tillage, which changes the soil structure using a plough. In this case, primary tillage is completely avoided and only secondary tillage is practiced to a small extend

4.7.1 Minimum tillage / zero tillage system

In this system, crops are grown from year to year with zero or minimum soil disturbance. In Minimum tillage, soil disturbance is kept to minimum level. In Zero tillage or No-till system, no soil disturbance is done season in season out.

4.7.2 Why Minimum Tillage (Benefits)

i) **Water retention -** retains and increase the amount of water in the soil.

ii) **Organic matter increase -** plant remains are left on the soil surface to rot and add to the organic matter content in the soil.

iii) **Cycling of nutrients -** when the remains of the previous crops are left to rot and mix with soil, the nutrients they had accumulated are returned to the soil.

iv) **Reduce soil erosion -** the minimum or no soil disturbance strengthens soil structure which resist movement of soil by rain water.

v) **Micro-organism enhancement –** the minimum soil disturbance ensures that the small organism in the soil thrive and multiply.

vi) **Saves money** – the reduced activities means money is saved on fuel, man power and hire/use of machinery.

vii) **Faster crop maturity -** the crops are planted immediately the rains are on which means they germinate and mature faster compared to systems where ploughing is done after the rains. More so because of the extra moisture the soil had.

viii) **Soil evaporation reduction -** the organic matter and plant remains cover the soil ensuring no loss of soil moisture. If the rains are insufficient, the crop will continue growing due to the extra moisture.

ix) **Easier weed control –** after sowing, the weeds which germinate are easily controlled using a non-selective herbicide. After several years of the system, the soil cover increases reducing temperature in the soil. The weeds don't grow except in the planting line where soil will be exposed to the sun.

x) **Improved soil fertility –** the activities of minimum soil disturbances, improves organic matter and enhances soil matter leading to improved soil fertility. This results in better crops yield.

xi) **Better profits -** all the costs saved in the farm operations lower the cost of production leading to increased profits.

4.8 Improved Fallow and Land Rehabilitation

The improved fallow system is an attempt to improve traditional shifting cultivation. This is done by supplementing the fallow vegetation to hasten the rejuvenation of soil during the fallow period. Instead of waiting for nature to vegetate, leguminous nitrogen-fixing plants are planted on the field. The Improved fallow practice has its origins in slash-and-burn agriculture. Farmers use improved fallow to accelerate the process of rehabilitation and thereby shorten the length of their fallow periods.

4.8.1 Why improved fallows?

- Improve soil fertility
- Accumulate nutrients
- • Add organic matter
- Keep down undesirable weeds while land is not under cultivation
- Break up hard soil
- Regulate temperatures (less extremes of hot/cold)
- Provide shade
- Protect from winds
- Reduce erosion
- Encourage or sustain populations of beneficial soil microorganisms
- Break up physical barriers to root growth (rock and hard pan)

When the fallow shrubs and trees are removed at the end of the fallow period, they can also yield products such as firewood or poles for sale or farm use.

4.8.2 Improved fallow species

Characteristics of species used:

- Nitrogen-fixing and/or produce large amounts of organic matter
- Hardy; tolerant of drought and neglect
- Easy to establish
- Removable or short-lived; will not sprout continually if cut down
- Not weedy; will not spread to neighbouring farms
- Deep rooted
- Able to produce useful or marketable by-products such as firewood, poles, edible seeds, etc.

Table 5: Leguminous plants and their importance

Name of species	Importance
Lablab, , Dolichos (Njahe)	Control striga, cover crop, control weeds, fodder, protein source, vegetable, fix nitrogen, mulch
Soy bean	Nitrogen fixer, biomass, mulch (food (snack), multi-purpose raw material for soy milk, soy meat and sweets)
Gliricidia sepium (rata maton)	Fodder, nitrogen fixer, Mulch, fuel (firewood)
Mucuna	Insect repellant, nitrogen fixer, animal feed and food for human beings, mulch, cover crop, intercrop
Pigeon pea	Food, drought tolerant, suitable as an intercrop, nitrogen fixer
Crotalaria sp. (sunn hemp)	Nitrogen fixer, livestock feed, food vegetables
Tephrosia vogelli	As traditional vegetables

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5 BIO-FERTILIZERS

5.1 Introduction

Bio-fertilizers are promising, cost-effective, eco-friendly, renewable sources of plant nutrients for supplementing chemical fertilizers as well as being helpful for the remediation of polluted soils. Microbial-based fertilizers are a vital part of sustainable agricultural practices. The remediation of polluted sites to avoid soil deterioration is extremely important, as soil is a non-renewable resource. To alleviate the harmful effects of polluted soil, bio fertilizers have been used to remediate the fertility of chromium-polluted soil. Crop productivity, in general, is greatly affected by the use of toxic metal-polluted water for irrigation. Bio fertilizer-based remediation of polluted sites is a vital and significant approach toward sustainable development of the environment.

5.2 Objective

To eliminate significantly the use of external inputs that are detrimental to the environment, animals and general surrounding of the ecosystems through bio fertilizer application.

5.3 Course Outcome

- By the end of the training at least 80 per cent of the participants shall have known and understood the importance of bio fertilizers.
- By the end of the training, participants shall have known bio fertilizer technologies suggested in this tool kits.
- By the end of training, both trainer and participants shall be willing to minimize the application of external chemical inputs.

5.4 Training Outline

- Meaning of bio-fertilizer?
- Principles of bio-fertilizers as applied in agroecology
- Why is bio fertilizer used?
- Preparation of different bio-fertilizers
- Materials required to make bio-fertilizers.
- How to make bio-fertilizers?
- Types of bio-fertilizer
- Advantages of bio-fertilizers
- Disadvantages of bio-fertilizers
- Comparison between bio-fertilizers and inorganic fertilizers.
- Application of bio-fertilizer - time, methods and attire

Training Notes

5.5 Definition of Bio-fertilizer

A bio fertilizer is a natural fertilizer which is a living microbial inoculate of bacteria, algae and fungi etc.

5.5.1 Principles of bio-fertilizers as applied in agroecology

- Enhancing recycling of biomass with a view to optimizing organic matter decomposition and plant nutrient cycling.
- Strengthening the "immune system of agricultural systems through enhancement of functional biodiversity using natural enemies and antagonists.
- Providing the most favorable soil conditions for plant growth particularly by managing organic matter and enhancing synchronization of soil's physical, chemical and biological activities.
- Minimization of losses of energy, water nutrients and genetic resources by enhancing conservation and regeneration of soil and water resources and agrobiodiversity.
- Enhancing diversity among natural species and generic resources in the agro ecosystems over time and space at the field and scape level.
- • Enhancing beneficial biological interactions and synergies among the components of agrobiodiversity promoting key ecological functions, process and services.

5.5.2 Why bio-fertilizer?

- Provides elements needed by plants to grow well such as nitrogen, phosphates and potassium.
- They can make crops grow faster and big so that yields are increased.
- The compound used must be water soluble to enable plants to absorb them through their roots.
- It keeps the soil environment rich in all kinds of micro-macro nutrients through nitrogen fixation.

5.5.3 Disadvantages of bio-fertilizers

Its takes some time for them to be ready for use/ application.

- Bokash / fermented organic amendments.
- Biochar fertilizer

- Super Margo
- Apichi solution e.g. foliar spray to control fungal and whiteflies.
- Bio activated charcoal.
- Plant and manure tea.
- Nitrogen making based on livestock blood.
- Chromatography based on soil testing techniques.
- Vicosa – foliar spray to control fungal diseases
- Tithonia leave and in liquid

5.5.5 Materials required to make bio-fertilizer.

Some of the materials required for making bio-fertilizer include 40-50 litres of fresh cow dung, 2kg of molasses, 2 kg of milk, 150 grams of yeast, 1 kg of phosphate, 1 kg of wood ash, 1 kg of rock ash. Finally mix the solution. Green Tithonia leaves as green leaves.

5.5.6 Functions of above materials on bio-fertilizer making.

Cow dung brings microbes, molasses provides energy, milk provide protein and produce amino acids, phosphate, ash and sawdust help in increasing the mineral content of the brew, fresh cow dung complements micro-biology of the soil.

5.5.7 Preparation of bokash / fermented organic amendment to improve soil health, texture, structure and plant health.

The materials to be used: Large quantities of dry matter, soil and manure, this include chicken manure, wheat/rice bran, rock dust and water. Turn the mixture after two weeks to release oxygen supply, microbes and water as well as heat release. This process enhances soil humidity, oxidation of the soil, housing for the microbes, removal of the toxins in the soil, regulation of gases in the soil, inoculating soil biology release of energy for microorganisms with yeast acting as a catalyst.

5.5.8 How to make Nitrogen based bio-fertilizer from livestock blood

Take 10 litres of blood, 1kg of pawpaw, 1Litre of sour milk, 1kg of skin of pineapples and 2 Litres of molasses and then mix the solution. Livestock blood from abattoir is used as certification and molasses acting as preservative.

5.5.9 Ormus / Seed coating

Preparation: Take 37 grams of salt for every 1 litre of sea water, 20 grams of sodium hydroxide or caustic soda, molasses, Zinc sulphate, Iron sulphate, boron. Copper sulphite normally used as storage to avoid fungi. Dry the material and then plant.

The mixture of bio activated charcoal can be added to bokash and apply to the crops.

Lactic acid bacteria: Take 2 Litres of lactic bacteria, 100 litres of molasses, rice/wheat bran. Can be consumed by human beings or used as fish feed.

5.5.10 Preparation of raw phosphate from animals' bones

Take jaw bones of an animal, metal drums and fire wood. Bones are rich in phosphate and calcium.

5.5.11 Preparation of organic pesticides

Take bar soap, chills, copper sulphate, lime, water, rock dust, bones ash, milk and slurry then mixed the solution. The organic pesticide control nematode and aphid attack on indigenous vegetables

5.5.12 Making simple compost based on farm residues and wild biodiversity

Take 4 layers of dry farm waste, leaves, grasses and maize stalks, raw cow dung, bags of fresh Tithonian leaves, ash, slurry and water. This should be turned around weekly for 3 months to facilitate continues oxidation. Reason being to improve the soil texture and structure, humidity, water retention, oxidation and temperature.

5.5.13 Preparation of Apichi Solution

Take 10 Kg of garlic, 2 kg of black paper, 10 kgs of chillis, 20 litres of bio fertilizer, 45 litres of alcoholic pure, crush, mix together and leave for 3 days. Application – take 180 litres of water mixed with the solution and then spray on crops after 3 days. You can also dilute with 2/3 % solution to 20 litres of water.

5.5.14 Comparison between bio-fertilizers and inorganic fertilizers

Bio-fertilizer	Inorganic fertilizer
• Provide micro-macro organisms to inoculate in the soil **(Living soil)**	• Kills micro-macro organisms in the soil **(Dead soil)**
• Maintain soil structure	• Deplete the soil structure

5.5.15 Application of bio-fertilizer

a) **Time –** time of application should be at the onset of long rains if the bio fertilizers are applied to the soil directly, and this should be commensurate with the beginning of land preparations. Its administration normally saves time on land preparation, planting, top dressing, spraying for pests and diseases control and harvesting.

b) **Methodology -** digging holes, scoping, spraying and broad casting e.g. vegetables

c) **Attire –** Well dressing for safety e g. Overall, mask, gumboots or relevant foot wear.

Note: The preparation of the above bio-fertilizers depends on the type of bio-fertilizer you are working on.

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6 CROPS AND LIVESTOCK INTEGRATION

6.1 Introduction

The integration of crop and animal production is well developed in the farming systems all over the world, particularly those in small-scale agriculture. There is marked complementarity in resource use in these systems, with inputs from one sector being supplied to others. Specific examples of the main crop–animal interactions are given for different countries, and reference is made to the results of a number of case studies. These have demonstrated the important contribution that animals make to increased production, income generation, and the improved sustainability of annual and perennial cropping systems. The crop-livestock integration contributes to the productivity of the farming system and also in promoting environmental resilience.

6.2 Objective of Crop-livestock Integration

To promote crop-livestock integration practices that enhance agro-ecological performance in terms of efficiency, resilience and productivity.

6.3 Course Outcome

- By the end of the training farmers will have acquired relevant knowledge on crop-livestock integration practices.
- By the end of training the farmers will have understood the application of crop-livestock integration in local farming systems.
- By the end of training, farmers will have acquired skills on key steps in crop-livestock integration

6.4 Training Outline

1. What is integration?
2. What is the meaning of crops and livestock integration?
3. Why integrate crops and livestock?
4. What are the benefits of integrating crops and livestock?
5. Advantages of crops and livestock integration.
6. Disadvantages of crops and livestock integration.
7. Key steps in crop-livestock integration.
8. Factors to consider when integrating crops and livestock.
9. Comparison between integrated farm and a non-integrated one.

Training Notes

6.5 Meaning of integration

It is an act of bringing together smaller components into single system that functions as one unit. Crops and livestock integration involves rearing of animals and growing crops on the same farm.

6.5.1 Why integrate crops and livestock?

- Improve soil fertility, soil structure, soil texture and other physical qualities.
- Improve farm income.
- Enhance food security.
- Create job opportunity.
- Balance the function of micro-macro organisms in the soil.

6.5.2 Benefits of Integrating Crops and Livestock

- Enhancing the recycling of biomass
- Strengthening the immune system of micro-macro organisms.
- Minimizing loss of energy and nutrients.
- Providing soil favorable conditions.
- Enhancing conservation and regeneration of soil and water resources and agrobiodiversity.
- Enhancing beneficial biological interactions.

6.5.3 Advantages of integration of crops and livestock to the farmer

- Create room for value addition e.g. meat, hides / skin and feather from poultry.
- It improves household livelihood.
- It creates employment.
- Farmers can keep their farms under continuous production.
- It enhances the productivity of the farm land.
- It increases the per capita profitability.
- Both farming practices complement each other.

- It enhances the productivity of the farmer.
- Reduces dependency on external inputs and costs.

6.5.4 Disadvantages of integration between crops and livestock

- It is labour intensive
- It requires specialized skills in certain aspects e.g., management of pests and diseases.
- Decreased level of production as compared to monoculture.
- Growth rate and optimal harvest dates differ.
- Animals can be hazardous to crops if they are not properly enclosed or tethered.
- Makes controlling, monitoring and maintenance procedure more difficult.
- Competition among the farming agents for resources.

6.5.5 Factors to be considered in crops and livestock integration

- Land size
- Cost of production such as capital, and labour.
- Managerial skills.
- Marketing and market accessibility.

6.5.6 Comparison between integrated farm and a non-integrated farm

Integrated farm	None integrated farm
• Improving soil condition for more yield. • Promote enterprise diversification for risk management. • Ensures continuous production because of the capability to maintain soil fertility.	• Production is just for a short while and excessive use of inorganic fertilizers result in deterioration of soil and environment.

7 VALUE ADDITION IN AGROECOLOGY SYSTEMS

7.1 Introduction

Generally, value addition is the process of changing or transforming a product from its original state to a more valuable state. Many raw commodities have fundamental value in their original state. The value of a changed product is added value, such as processing wheat into flour. It is important to identify the value-added activities that will support the necessary investment in research, processing and marketing. The application of biotechnology, the engineering of food from raw products to consumable products and the restructuring of a distribution system are all opportunities for adding value.

Economically a commodity is added value by changing its current place, time, and from one set of characteristics to another that is more preferred in the marketplace. A better meaning would be like processing wheat into flour and eventually into more desired products by customers, such as bread, cakes, etc. Those involved in value addition should think of themselves as part of a food chain that processes and markets products to consumers.

In Kenya, the majority of agricultural commodities are marketed in their raw forms, hence losing the opportunities for higher return on investment. The main constraints facing Kenya's agro processing industry include among others;

- High operational costs mainly due to the high prices of imported fuel and spare parts,
- Unavailability of appropriate processing machines and spare parts, and
- Limited knowledge in operation of the machines.

Despite these constraints, agro processing has a tremendous potential for increasing income through value addition and increasing shelf life and access to food security through the establishment of small scale agro processing enterprises and rural based industries. Value added is the difference between the price of product or service and the cost of producing it. The price is determined by what customers are willing to pay based on their perceived value. It's the amount by which the value of an article is increased at each stage of its production, exclusive of initial costs.

7.2 Overall Objective

- To increase household income through value addition.
- To improve the source of income from the farm produce by value addition.
- To increase production, marketing and utilization of agro ecology products by changing their value and physical appeal.

7.3 Course Outcome

- By the end of the training farmers will have known how to control and avoid wastage through value addition.
- By the end of the training the farmers will have known simple aspects of value addition.

7.4 Training Outline

i) Introduction to value addition

ii) Importance of value addition

iii) Policies affecting value addition

iv) Items needed for value addition process

v) Why value addition?

vi) Factors to consider while carrying out value addition

vii) Challenges facing Agriculture value addition in Kenya

viii) What constitutes added value?

Training Notes

7.5 Definition

The term "value-added" describes the enhancement a producer gives his produce, product or service before offering it to customers. It can be considered as an extra special feature added by a producer or a company to increase the value of a produce, product or service.

Value-addition applies to instances when a farmer takes a product/produce that may be considered homogeneous in a given area and provides potential customers with a feature or add-on that gives it a greater perception of value. For instance, a company may add a brand name to a generic product or produce something in a way that no one has thought of before.

7.5.1 What is value addition?

A change in the physical state or form of a products e.g. milling wheat into flour or making strawberries into jams.

7.5.2 What constitutes added value?

A product must have one or more of these qualities to generate additional value.

- **Quality —** does the product or service meet or exceed customer expectations?
- **Functionality —** does the product or service provide the function needed of it?
- **Form —** is the product in a useful form?
- **Place —** is the product in the right place?
- **Time —** is the product in the right place at the right time?

7.5.3 Importance of value addition

i) To the farmer

- Increased profit margins.
- Opportunity to open new markets.
- New job creations along the agricultural value chain.
- Reduces agricultural losses due to product quality deterioration.
- Reduction of post-harvest loss especially in horticulture
- Increases product storability and shelf-life.
- Aid in agricultural waste management e.g. making briquettes from fruit peels.

In order to ensure that farmers reap maximum benefits from value addition, Kenya Agribusiness and Agroindustry Alliance (KAAA) does the following;

- Trains farmers on better post-harvest handling of produce since that is the start of the journey towards a good product on the market.
- Trains farmers on multiple processing alternatives of a produce.
- Creates village teams of farmers (clusters) that can combine their expertise and resources to collectively engage in a value addition exercise.
- Harnesses indigenous technologies for food processing that are already embedded in the local skillsets.
- Educates the farmers on the potential uses of the 'waste' material from processed raw material, for instance, dried banana peels can be used to make animal feeds.

ii) To the government

- Emergence of integrated agro-based and cottage industries
- A strategy for luring both local and foreign direct investment
- Increased capacity utilization by firms thus providing ready market for farm produce
- Employment creation
- Higher disposable income
- Increased demand for goods and services
- Increased revenue for Government from taxes from both corporates and individuals.
- Increase in export earnings as the products become more competitive on the international market
- Shock absorption from international price volatility of primary products.

7.5.4 Challenges facing value addition in agriculture

- Inadequate capacity building across Kenyan borders.
- Fear among consumers against new products, cultural concerns.
- Inadequate finances, some innovations may require huge funding.
- Innovation gaps, few innovations available to enrich value addition.
- Marketing challenges, a lot of product awareness is required.
- Unavailability of required equipment.
- Lack of motivation among the innovative group/persons

7.5.5 Policies affecting value addition technology

- Import restrictions on raw materials, processing plants, packaging materials, etc
- Strict rule on vocational colleges not to offer similar specific technical skills
- Heavy value added tax on finished product discourages smallholder processors and business actors.
- Public health policy in quality control and hygiene

7.5.6 Items needed for value addition process

- **Raw materials -** availability, accessibility and affordability
- **Technology -** available technology to apply in value additions
- **Capacity building –** having vocational centres that train on relevant technology and skills
- **Markets -** prevailing suitable market that absorb all the products
- **Empowered population -** purchasing power of the population to buy the processed products
- **Infrastructure -** well-developed and supportive infrastructures in the country.
- **Security -** guarantee of safety and security for workforce and products

7.5.7 Factors promoting value addition

1. **Changing tastes and preferences of consumers -** Consumers are value conscious and tend to focus more on convenience, quality, variety, service, health and social consciousness.
2. **Massive post-harvest losses -** A major contributor to food scarcity in the country has been massive post-harvest losses that occur due to low-value addition and inadequate cold storage facilities.
3. **Government enabling environment –** support for young people to invest in small and medium enterprises that target agribusiness.

8 KITCHEN GARDEN AS AGROECOLOGY PRACTICE OF HOUSEHOLDS

8.1. Introduction

Projections show that there will be 9 billion people in the world by 2050, but we are not gaining additional resources like land or water. The Food and Agriculture Organization (FAO) estimates that we need a 70% increase in food production to feed all those people. This entails growing, harvesting, distributing, and consuming the food in a more efficient way. Also with increasing concern on food safety and cost of fresh fruits and vegetables, it's important to know the source of your food. A kitchen garden ensures safe, inexpensive, regular and handy supply of fresh vegetables and also allows for the adoption of technologies and skills, which can keep pace with growing population and food demand.

8.2 Objectives

- The overall objective of this training is to equip participants with knowledge to produce safe and healthy vegetables at the household level using adoptive kitchen garden technologies.
- Train participants to understand the concept of kitchen gardening and link it to their main farm production.

8.3 Course Outcomes

i) Participants will understand how to establish a kitchen garden

ii) They will know the various kitchen garden technologies

iii) Participants will appreciate benefits of a kitchen garden

iv) Participants will understand the concept of good agricultural practices (GAP)

v) Participants will acquire knowledge and skills in proper management of kitchen gardens

vi) Participants will acquire knowledge and skills on selecting crops to grow in a kitchen garden and how to rotate them.

8.4 Training Outline

- Definition of kitchen garden
- Why kitchen garden?
- Kitchen garden technologies
- Requirements to construct multi-storey gardens
- Kitchen garden management practices

Training Notes

8.5 Definition

A kitchen garden is a place where crops are grown mostly for family consumption to supplement what is grown on the main farm. It can be of any convenient size (depending on family size) of plot within the homestead. Planning of what to grow in a kitchen garden is vital. It should comprise daily food crops depending on family needs. Planting should be staggered to have constant supply throughout the year.

8.5.1 Why Kitchen garden?

- Uses locally available materials
- Can supply the household with fresh vegetables throughout the year
- Can achieve dietary diversification
- Have low input hence suitable for households where labour is constrained e.g., households of people with disability, HIV, orphans and old age.
- Can be a source of income.
- Requires little water

8.5.2 Kitchen garden technologies

Some of the Kitchen garden technologies include:

1. Multi-storey gardens
2. Zai pits
3. Mandala gardens
4. Moist beds
5. Raised beds
6. Hanging gardens
7. Hydroponics
8. Recycled tire gardens
9. Cone garden / conical gardens
10. Three in one or integrated fish farming

8.5.3 Multi-storey gardens

A multi-storey garden is a type of kitchen garden with vertical reorientation, either with different layers of growing media or uniformly structured growth platform. They are broader at the base and narrower at the top. Each of the layer is planted with the relevant crop for family consumption.

Requirements for constructing a multi-storey garden

- Minimum plot area 2ft X 2ft
- 4 Poles 2M long each when using back polythene
- 2M black polythene tubes 1000 gauge, UV- treated shade net, gunny bags
- Manure ratio of 1:1
- Top soil
- Ballast
- Seedlings

8.5.4 Procedure for constructing the multi-storey garden

- Consider an area of a convenient size for family needs.
- Place the hollow tin at the centre of the area.
- Secure the four poles at each corner of the square area when using black polythene.
- Insert the polythene tube 60" wide around the four poles.
- Fill the hollow tin with the ballast and cover the tin.
- Mix manure, top soil and fertilizer thoroughly and then put the mixture between the hollow tin and the polythene paper.
- Gradually fill in the mixture making sure not to interfere with the tin
- Lift the tin without moving from the centre position and refill with ballast.
- Do not compact it as you fill.
- Fill the soil and manure mixture until the polythene is full.
- Water the hollow tin through the ballast.
- Leave it overnight to set
- Make holes spaced at 1ft by 1ft diagonally.
- Plant the seedlings and make the soils around each.

8.5.5 Bag gardening

Bag gardening will help solve problem of limited land space because of vertical farming consequently leading to more crops per meter square produced with limited amount of water. Its benefits include:

- Limited use of land and water
- Less labor
- Bag is reusable up to 10 years - Why? Explain UV-treatment!
- Sides and top of bag are all used.
- The bags are for both commercial and domestic use
- Plant more than one crop per bag

Requirements for a vertical bag garden?

- Bags, Soil, Manure, Seedling, Slow release fertilizer
- Trichoderma for seedbed and root drenching
- Beneficial Fungi (Bacillus, Met 69, Met 62, Trichoderma)
- Crop protection
- Space
- There are different sizes of bags

i) Large Size

- Can be erected with or without columns depending on soil drainage.
- Carries 100 seedlings.
- Amount of soil and manure/compost mixture in the bag is 17 wheelbarrows without vertical column and 14 wheelbarrows with vertical column.
- Ground space is 3m2.

ii) Medium

- Can be erected with or without columns depending on soil drainage.
- Carries 85 seedlings.
- Amount of soil and manure/compost mixture in the bag is 12 wheelbarrows without vertical column and 9 wheelbarrows with vertical column.

iii) Small bag

- Is erected without vertical column due to size.
- Carries 40 seedlings.
- Amount of soil and manure/compost mixture in the bag is 1 wheelbarrow.
- In a sack of 90 kg size, mix three wheelbarrows of well-prepared animals manure or compost and 5 wheelbarrows of top soil. Mix the two contents thoroughly before you used the mixed soil to fill the sack. The compost must be well decomposed. It is recommended to know your nutrient status before adding fertilizer because different regions and soils have varied fertility.
- Add lime/ash - 5kg to the soil if the pH is low (below 6.0).
- Mix everything well together.
- Start filling the bag.
- Ensure the base is upright at each step.
- Fill the bag half way and with the aid of open ended container, place at the centre and fill with gravel till top of the bag. This will ensure proper drainage.
- Once the bag is filled, water well before transplanting or planting seeds.
- Shade the bags if in dry areas to reduce heat stress and water loss from the bags.
- Watering should be done every 2-3 days interval or as need arises.

Figure 9: Steps followed when making sack garden (a-i)

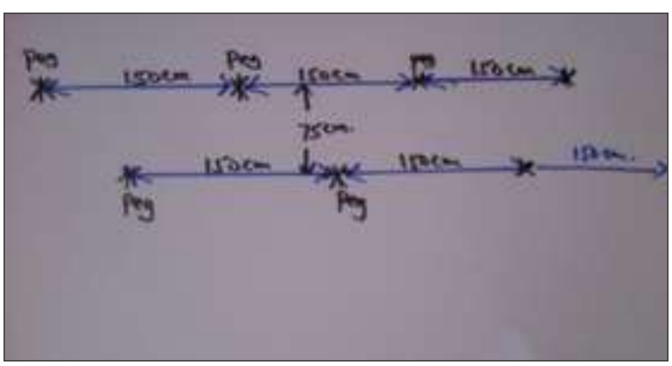
- Crops which can be grown in bags include; Leafy vegetables such as Sukuma wiki, amaranth, nightshade, spinach, spider plants and herbs.
- If bag gardens are being used for a 'home garden' then more than one type of crop can be planted in the same bag.
- Good agricultural practices in preparation and management of bags.
- Test your soils to know its fertility before adding lime and or fertilizer.
- Only plant hardened seedlings.
- Monitor you crops for pests.
- Provide good drainage in the bags. Some soils compact and reduce water penetration. Place gravel at the centre of the bags to enhance water penetration.

8.5.6 Zai pits

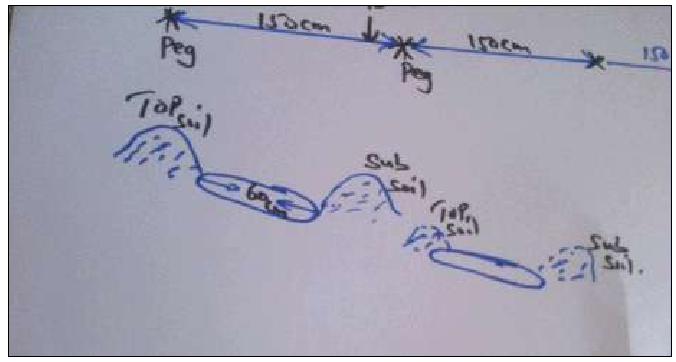
- Many farmers in Kenya do not have access to irrigation and mainly rely on rainfall for their crop production. This subjects them to recurrent problem of insufficient and unreliable rainfall leading to low crop production or total crop failure.
- • Zai pits are recommended for relatively low rainfall areas or where moisture conservation is required to enable crop survive drought.

How to make Zai pits

- Select part of a farm that is neither too steep nor very flat. If too steep make terraces first.
- Mark the field at an interval of 150cm within the rows and 75cm between the rows. 150cm markings in one row should be alternate to the next row.



- Dig a hole 60cm in diameter placing top soil (first 20cm) on uphill side and sub soil on downhill side.



Mix top soil with a bucket of well decomposed manure and return to hole ensuring the hole is not refilled to the top so that some space remains to collect and store runoff water.

8.5.7 Kitchen garden management practices

To make kitchen gardening successful, and to give best production results, the following things are important: - good agricultural practices, field hygiene, proper pesticide handling, site selection, seed bed preparation, nursery establishment, watering / irrigation, transplanting / planting plant, weeding, fertilizer or manure application, pest and disease control and harvesting.

a) ***GAP guidelines*** – good agricultural practices refer to the adoption and use of best possible sustainable production practices by the farmer, balancing between the needs of the crop and maintaining and improving the immediate farm and surrounding natural environment (soil, air and water).

b) ***Field hygiene*** – Field hygiene refers to specific practices the farmer undertakes during the farming period to prevent the introduction and spread of pests/ disease, weeds and harmful substances which may adversely affect crop production, quality and even introduce harmful substances which would affect the health of consumers of the produce. Examples of such include E. coli (bacteria) and pesticide residues.

c) ***Pesticide use and handling*** – pesticides are required to help in pest and disease management but its use can lead to effects on farmers, consumers and environment. Use of pesticides calls for handling as indicated in the instruction label.

Tables 6: Natural enemies of different pests in some of horticultural crops

Crop	Pest/Disease	Beneficial Organism
Kales / Sukuma Wiki	Diamond Back Moth, Aphids, Thrips, Caterpillars, Bacterial Rot	Lady Bird, Aphidias, Black Ants
Spinach	Red Spider mites, Caterpillars, Powdery Mildew, Blight	Phytoseilus, Metarhizium
Spider Plant (Dek), Black Night Shade (Osuga), Jute Mallow (Apoth), Amaranth (Ododo), Cow Pea (Boo), Crotalaria (Mitoo)	Diamond Back Moth, Aphids, Cartepillars, Thrips, Nematodes Wilts (Fusarium and Bacterial Wilt), Red Spider Mite, Fire Beatles	Lady Bird, Aphidias, Black Ants, Phytoseilus, Hover Fly
Capsicum, Chilies, Egg Plant, Tomatoes, Pumpkins, Onions	Red Spider mites, Caterpillars, Powdery Mildew, Blight, Thrips, White Flies, Bacterial Wilt, Fusarium wilt Bulb rot, Nematodes, Downy mildew, cut worms, bollworms	Lady Bird, Aphidias, Black Ants Phytoseilus, Hover Fly, Trichoderma,

8.5.8 Site Selection in kitchen gardening

If you already have a kitchen garden you may not need to choose a new site, it's enough to improve the old site. If you are making a new garden, there are many factors to consider:

- Well drained sandy loam soil is best
- Avoid sites with poor field history e.g disease infestation, low fertility, acidic soils flooding, etc
- It should be close to a water source for ease of watering
- Avoid steep grounds prone to run off in wet weather
- Nurseries should be placed in full sunlight. Shading by trees result in delayed or poor seed germination.
- Dip deep to bring up the sub soil
- Create a fine tilt by mixing well-decomposed manure and working it in.
- In wet areas or wet weather, raise the beds to 15cm in height to improve drainage
- In the dry areas, sunken beds are preferred as they trap moisture.
- On sloppy ground, beds should run along the counters to prevent erosion.

8.6 Seed Establishment

Make drills of 2cm depth cross the bed and 10-13cm apart
Sparsely / thinly drill your seeds within the drills and cover lightly. If sowing is done while soil is dry, kindly compact the soil to improve on seed-soil contact. Water your bed until it is well soaked. Thereafter, watering will depend on the weather conditions and soil type.

8.7 Crop Rotation

Grow crops in rotation to prevent buildup of pests and disease which reduce yield i.e. plant vegetables of different families in succession, as illustrated below:

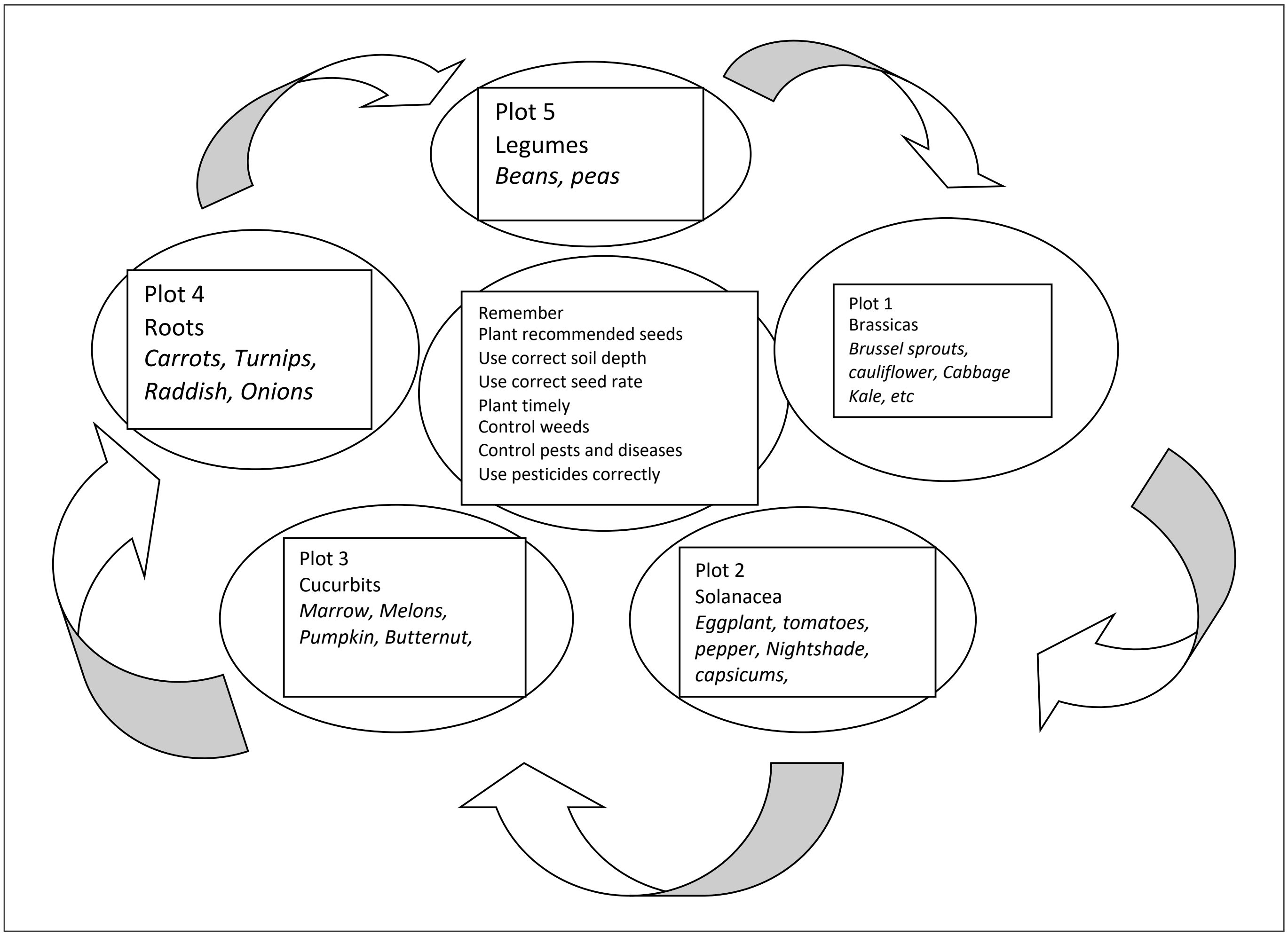


Figure 10: Simple crop rotation plan

8.7.1 Fertilizer / manure application

i) ***Spreading*** - spread well–decayed compost over the surface of the soil then dig to the depth of 20cm/8ft. At a rate of 8kg/m2. The rate is adequate for most crops. This is the easiest method but requires high amounts of compost manure.

ii) ***Direct placement*** – Here the amount of compost used is less. You put manure in the planting holes.

iii) ***Application of compost*** - The most appropriate time to apply compost is during the planting of the crop. However, compost making can be undertaken at any time of the year.

iv) ***Soil analysis*** - When using inorganic fertilizers, it is important first to do soil analysis to know the type and quantity of fertilizer to use. Over application of inorganic fertilizers can be harmful to the environment. Some of the commonly used fertilizers are DAP, CAN and NPK.

8.7.2 Nursery establishment and management

A vegetable nursery is a place or an establishment for raising or handling of young vegetable seedlings until they are ready for more permanent planting. Some vegetable seeds are small and therefore require special care during their early growth period.

Nursery bed preparation steps

i) Select a site with good drainage and fertility (high organic matter).

ii) Dig the site well to remove all weeds.

iii) Construct raised seedbeds of 1 m wide where no eggplant, potato, or tomato has been grown for at least 3 years.

iv) Incorporate 5 kg/m2 of good compost into the bed.

v) If possible, solarize the planting bed to kill diseases.

vi) Raise beds to 15 – 20 cm from the ground.

vii) Length of beds is varied but width is restricted to 1M.

viii) When having more than one bed, leave a space of 30 -45 cm between two beds which helps in weeding, nursery care against diseases and insect pest and also for draining out the excess rain water from the nursery beds.

ix) The beds should be prepared in the east and west direction and line should be made from north to south direction on the beds.

x) To plant seeds in the nursery (onion, tomatoes, and kales), make lines 2-3cm deep and 5-7cm apart and drill the seeds not very densely spaced.

xi) Cover the seeds with light fine soils and water using a watering can.

xii) To avoid damping off problem, drench the soils with Trichoderma during the first watering (Trichoderma is mixed with water at a rate of 1ml of Trichoderma to 1 litre of water).

xiii) Mulch the nursery using dry straw or grass to maintain moisture and soil temperature. Mulch should be removed immediately after germination is complete.

xiv) Tomatoes and kales are ready for transplanting 4 – 6 weeks after planting and onions after 6 – 7 weeks. But, it is important to observe physical appearance and size of seedlings before transplanting.

xv) Timely transplanting is important because late and early planting can lead to poor establishment and death of plants in the field.

xvi) Keep seedlings under shade in the early growth period but harden them before transplanting.

xvii) Transplant during cool hours of the day.

8.7.3 Insect-pest repellent plants

Planting and managing of insect pest repellent plants within or between the main crops is one of the strategies of reducing the insect-pest population in the vegetable farms.

This **list of pest-repelling plants** includes plants used for their ability to repel insects, nematodes, and other pests. They have been used in companion planting as pest control in agricultural and garden situations, and in households.

Certain plants have shown effectiveness as topical repellents for haematophagous insects, such as the use of lemon eucalyptus in PMD, but incomplete research and misunderstood applications can produce variable results.[1]

The essential oils of many plants are also well known for their pest-repellent properties. Oils from the families Lamiaceae (mints), Poaceae (true grasses), and Pinaceae (pines) are common haematophagous insect repellents worldwide.[1]

Plant	Pests
Artemisias	Repels ants, cabbage looper, cabbage maggot, carrot fly, codling moth, flea beetles, whiteflies, the Cabbage White, and Small White, as well as mice
Basil	Repels flies, including mosquitoes the carrot fly, asparagus beetles and whiteflies
Borage	Repels tomato hornworm and cabbage worms[2]
Castor bean	Repels moles
Catnip	Repels ants, flea beetles, aphids, the Japanese beetle, squash bugs, weevils, the Colorado potato beetle, the cabbage looper, and cockroaches. May attract cats.
Chamomile	Repels flying insects
Chives	Repels carrot fly, Japanese beetle,[2] and aphids[3]
Chrysanthemums	Repel roaches, ants, the Japanese beetle, ticks, silverfish, lice, fleas, bedbugs, and root-knot nematodes
Citronella grass	Repels insects, may deter cats
Citrosa	Proven not to repel mosquitoes
Clovers	Repel aphids and wireworms
Common lantana	Repels mosquitoes
Coriander	Repels aphids, Colorado potato beetle, and spider mites
Cosmos	Repel the corn earworm
Crown imperial	Repel rabbits, mice, moles, voles and ground squirrels
Dahlias	Repel nematodes
Dill	Repels aphids, squash bugs, spider mites, the cabbage looper, and the Small White
Epazote	Repels spider mites, thrips aphids, and whitefly
Eucalyptus	Repels aphids, the cabbage looper, and the Colorado potato beetle
Fennel	Repels aphids, slugs, and snails
Fever tea	Repels mosquitoes
Four o'clocks	Attract and poison the Japanese beetle
French marigold	Repels whiteflies, kills nematodes
Garlic	Repels root maggots, cabbage looper, Mexican bean beetle, and peach tree borer.
Geraniums	Repel leafhoppers, the corn earworm, and the Small White
Hyssop	Repels the cabbage looper and the Small White
Larkspurs	Repel aphids
Lavender	Repels moths, scorpions, water scorpions, fleas, and flies, including mosquitoes
Leek	Repels carrot fly

Plant	Pests
Lemon grass, L balm, L thyme, Lime basil	Repels mosquitoes
Lettuce	Repels carrot fly
Mexican marigold	Repels insects and rabbits
Myrrh	Repels insects
Narcissus	Repel moles
Nasturtiums	Repel squash bugs, aphids (though there is conflicting information with some sources stating it attracts aphids), many beetles, and the cabbage looper
Onion	Repels rabbits, the cabbage looper, and the Small White
Oregano	Repellent to many pests
Parsley	Repels asparagus beetles
Peppermint	Repels aphids, cabbage looper, flea beetles, squash bugs, whiteflies, and the Small White
Petunias	Repel aphids, tomato hornworm, asparagus beetles, leafhoppers, and squash bugs
Pitcher plants	Traps and ingests insects
Radish	Repels cabbage maggot and cucumber beetles
Rosemary	Repels cabbage looper, carrot fly, cockroaches and mosquitoes, slugs, snails, as well as the Mexican bean beetle
Russian sage	Repels wasps
Rue	Repels cucumber and flea beetles
Sarracenia pitcher plants	Are especially proficient at trapping yellow jacket wasps
Spearmint	Repels fleas, moths, ants, beetles, rodents, aphids, squash bugs, and the cabbage looper
Spiny amaranth	Repels cutworms
Stone root	Repels mosquitoes
Summer savory	Repels bean beetles
Tansy	Repels ants, many beetles and flies, squash bugs, cutworms, Small White, and Cabbage White
Thyme	Repels cabbage looper, cabbage maggot, corn earworm, whiteflies, tomato hornworm, and Small White
Tobacco	Repels carrot fly, flea beetles and worms.
Tomato	Repels asparagus beetles
Venus flytrap	Ingests insects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9 ORGANIC MANURES

9.1 Introduction

Organic manures or fertilizers are important alternatives to inorganic fertilizers. They include animal manures, compost, green manures and vermi manure. Besides being affordable and available at the farm level, their application leads to improved soil structure and the ability to retain soil moisture.

9.2 Objective

The objective of training extension agents and farmers on organic manures is to equip them with knowledge and skills of improving soil fertility and crop yields through the use of sustainable and environment friendly organic sources soil nutrients.

9.3 Course Outcome

Participants are expected to understand:

- Benefits of organic manure
- How to make good compost
- Methods of applying organic manure

9.4 Training Outline

- Benefits of manure

a) Types of organic manure
b) Compost manure
c) Composting materials
d) Farm yard manure
e) Manure application

Trainer's Note

9.5 What is Manure?

Manure is organic matter that is used as organic fertilizer in agriculture derived from the decay of plants and animals.

9.5.1 Why manure?

i) Reduce mass and volume – lower hauling costs
ii) They are available at the farm and are usually cheaper than commercial fertilizers
iii) Increase crop yield and are sustainable
iv) No transportation costs are involved when using green manure
v) They condition the soil by improving the structure and texture
vi) Improve nutrient qualities – the nutrients from compost are released slowly and steadily
vii) Increase water retention of soil

9.5.2 Disadvantages of using organic manure

- It is only ready availability for farmers with livestock
- Weed problem can be aggravated because manure may contain plant seed that are not easily degradable
- Use of organic manure is labour– intensive

9.6 Composting

Composting is deliberate accumulation of organic materials in a place so that they decompose and produce plant nutrients. It takes place under controlled conditions in heaps or pits to produce compost which is a slow release fertilizer.

9.6.1 Composting materials

Compost can be made from any organic material, such as green vegetation, ash or charcoal dust, animal manure, refuse and paper, twigs and branches, dry grass, water and measuring stick. It is important to note that very coarse materials should not exceed 10% of the materials to be composted. Straw should be left in the field to start rotting before adding to the heap Avoid making compost in water logging areas

9.6.2 Procedure for building compost heap

1. Select a location close to where the heap will be located. The compost should be protected from wind, sunlight and water.
2. Measure out an area 1m wide and 1 m long. Similar area must be allowed for turning the heap.
3. Loosen the soil where compost is to be made. This will allow close contact of the material to be composted with the ground.
4. Lay down a foundation of twigs and small branches, which will allow drainage and ventilation.
5. Then sprinkle some water on this layer.
6. For second layer, add coarse plant material like dry grass and straw, chopped into length of 5-12cm.
7. This layer should be about 15 cm thick; sprinkle water on the layer.
8. The third layer is for animal manure. Add a 5cm deep layer of manure, which is sprinkled with a mixture of urine, earth and wood ash if possible.
9. Add a fourth layer of fresh but wilted plant material. Green weeds, leguminous forage and Tithonia are good materials.
10. This layer should be 15-20cm.
11. Sprinkle a mixture of ash or charcoal with a little top soil or old compost.
12. Add more layers by starting again with dry grass, then animal manure, green plant material and topsoil. Remember to sprinkle water on each layer. Build up the heap to a height of 1.5m
13. The process of composting can be checked regularly using dry stick driven diagonally into the compost heap. If the stick is warm it indicates that the process of composting is still going on. If the stick is dry add more water.
14. After three weeks the lower layers of material composted is likely to have decomposed. At this time the heap is ready for turning, which is repeated every 3 weeks. Use the stick to monitor the progress of decomposition. When the stick feels cold then the decomposition process is complete.

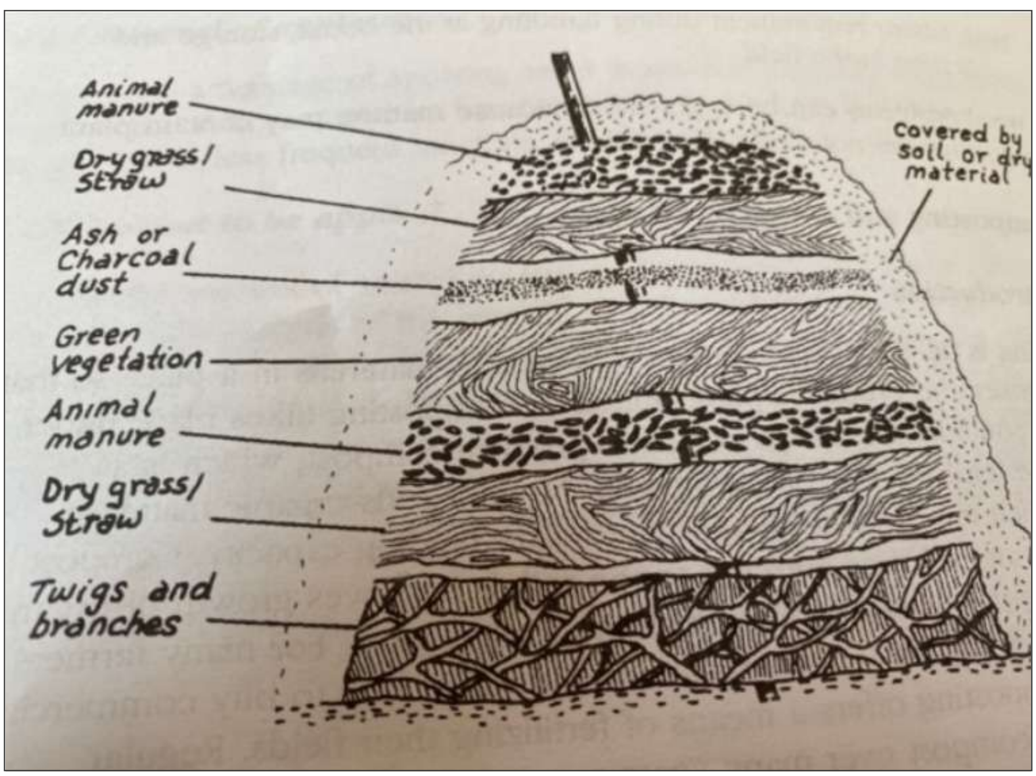

Figure 11: A typical arrangement of compost heap

9.6.3 Application of manure

- **Spread -** spread well-decayed compost over the surface of the soil then dig to the depth of 20cm at a rate of 8kg/m2
- **Placement -** Put compost/manure per hole where crop is planted.

9.7 Farm Yard Manure

This is decomposed animal waste products such as urine, excreta and droppings from poultry and their beddings.

9.7.1 Why farm yard manure

- They are available at the farm and are usually cheaper than commercial fertilizers
- Applying manure over a long period of time improves humus content of the soil
- Ability of soils to store and release nutrients improves following the applications of the manures. The soil capacity for water retention is also improved
- Crop yield is increased and can be sustained.

9.7.2 Procedure

- A bedding of grass is provided in the houses of domesticated farm animals such as goats, sheep, fowls and cattle.
- The animals will deposit their droppings and urine on the bedding materials
- After some time, which may vary from days in pig houses to months in poultry units, these beddings are replaced with new in a specially prepared shaded place, and new layers of used beddings are continually added until a heap formed.
- In the course of time, decomposition and mineralization of these materials take place, through activities of certain bacteria, resulting in rich farm yard manure.


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10 INTEGRATED PEST MANAGEMENT

10.1 Introduction

The term integrated pest management (IPM) was first used in agriculture beginning in the 1970s in response to growing knowledge about the negative side effects of pesticide overuse. The approach emphasizes the integration of pest biology and cultural practices in controlling insect pests in crops. This unit is intended to equip the users with knowledge and skills in improving crop yields through pest & disease management using suitable techniques and methods in a manner that maintains pest populations at levels below what can cause economic injury.

10.2 Objectives of the Training on IPM

- To enhance the capacity of participants to reduce pest population below economic injury levels.
- To equip participants with knowledge on management of insect pests by not only killing them but by preventing feeding, multiplication and dispersal.
- Participants to understand use of eco-friendly methods, which will maintain the quality of environment (air, water, wildlife and plant life)
- To equip participants with knowledge of reducing post-harvest losses of cereals and pulses using cost effective storage solution without the use of pesticides.

10.3 Course Outcome

Participants are expected to understand:

- Pest host interaction
- Key diagnostic pointers
- Predisposing factors for pest outbreaks
- Pest disease cycle

10.4. Training Outline

- Definition of IPM
- Pest control methods
- Benefits of IPM
- Designing IPM program
- What is needed for IPM program to be effective?
- Key pests & diseases
- Hermitic Storage Technology (HST) - use of hermitic bags

Trainer's Notes

10.5 What is IPM?

Integrated Pest Management (IPM) is a sustainable approach to pest management which combines the use of cultural practices, physical, biological and chemical control methods on pests and diseases. IPM should not be confused with organic practices. It does not discourage spraying chemicals; it promotes spraying with selective pesticides only when the crop needs it, which generally means that less pesticide is used. A pest is any living organism which causes damage to crops and livestock. It could be plants, animals, insect and fungi or bacteria.

10.5.1 Pest control methods

i) **Cultural Control**

Any activity aimed at manipulating crop environment to discourage pest establishment. It includes crop rotation, ploughing, planting drought tolerant varieties, using the right spacing and seed rate, early planting and mulching.

ii) **Physical/mechanical control**

Is the mechanical approach of handling the pest through use of traps, stickers and barriers.

iii) **Biological control**

It is the use of living organism or their extracts to control pests. It includes use of predators, parasitoids, parasites, beneficial fungi and bacteria and plant extracts. For instance, predatory or parasitic insects and mites known as 'beneficials' or 'good bugs' may help to control chewing and sucking insects that affect the quality and productivity of crops by killing them or disrupting their breeding cycle.

iv) **Chemical control**

Involves the use of compatible pesticides in the management of pests. It is used in IPM when biological and cultural control has not been enough to protect the productivity of the crop. Where chemical control is required, selective insecticides are chosen which target the pest, leaving the beneficial population unharmed.

10.5.2 Why IPM?

- Environment friendly
- Guarantees safe foods
- Conserves natural enemies to pest
- Ensures human safety against harmful chemicals
- Manages pest resistance to pesticides
- Improves on farm diversity
- Commercial pesticides are too costly for most peasant farmers

10.5.3 Designing an IPM program

A good IPM program should address the following aspects:

i) What would I do?

ii) What do I know about the pests?

iii) Where am I getting the problem from? – Neighbour's poor practices on my farm

iv) What practices increase or reduce pest on my farm? (Get a history of the farm with regards to the problems)

v) What are the control measures at my disposal? (Based on observation made or farm evaluation, prescribe most efficient combination of control methods which are sustainable, economical and practical to that area)

vi) What can I do about my planting materials? (Asses if the problem is from planting material and alternative ways of managing the problem)

vii) How can I encourage biological control for this pest to establish on the farm?

10.5.4 What is needed for IPM program to be effective?

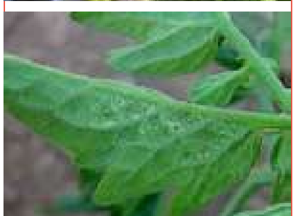
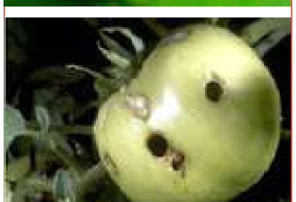
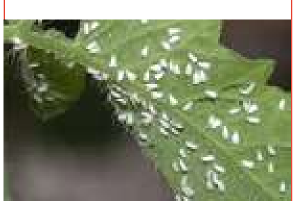
- Accurate pest and natural enemy identification (Predators / parasitoids)
- Understanding of pest life cycle
- Understanding the effects of pest damage to the crop
- Knowing how different pest control measures will affect the pest and natural enemies

10.5.5 Key Pests & Diseases

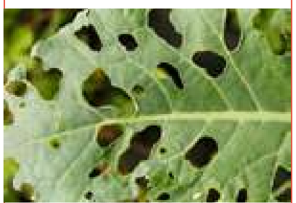
Key pests and diseases in farms include Aphid, Red spider mite, Thrips, White flies, Caterpillars, Mealy bugs, Termites, Rodents, Nematodes, Weevils, Blight, Rust, Fusarium wilt, Bacterial wilt, Downey, mildew and Anthracnose

10.6 Pests - Identification, Life cycle, Ecology and Control

Table 7: Pest affecting different horticultural crops, their damage features and controls

Pest	Crops affected	Features and damage	Controls
Red spider mites ***(Tetranychus evansi)***  	Tomatoes and spinach, spider plant, water melons and night shade	• Adult tomato red spider mites are small in size with eight legs. • They can vary in colour from light orange to deep orange red or brown. • Males are much smaller than females and are a more elongated and triangular in shape • The tomato red spider mite can be found on both sides of leaves but it prefers the undersides near the leaf veins. • Feeding causes leaves to become yellowish white and mottled. • Produces webbing especially on the undersides of leaves.	• Good farm hygiene practice - "Come clean, Go clean" • Ensure all visitors are instructed in and adhere to your hygiene requirements • Monitor your crop regularly • Practice crop rotation. • Spray with Achieve – Bio fungicide • Spray with miticides when there is need.
Bollworm ***(Helicoverpa armigera)***  	Tomatoes and chilies	• Has so many host plants and can be classified as a general pest. • It attacks different crops differently and thus earned itself many common names; tobacco bud worn, maize ear worm and tomato fruit worm. • Adult is a nocturnal moth having greyish – brown forewings. • Mature larvae vary in colour depending on food source (green, pink, brown or black) and can be recognized by white bands which are punctuated by breathing pores.	• Remove weeds by weeding. • Scout the crop regularly to detect pest presence early. • Spray with approved pesticides.
White flies 	Spider plant, night shade, tomatoes, water melons	• Usually occur in groups on the underside of leaves. • The body is yellowish but the insects look white because of wax covers. • Produce honey dew which black mold grows on. • High populations may cause the leaves to yellow and shrivel.	• Remove host plants. • Encourage natural enemies. • Spray with insecticides.

Pest	Crops affected	Features and damage	Controls
Aphids  	Sukuma wiki, spider plants, night shade	• Appear in many colours ranging from black, brownish, green, grey, • Size ranges between 1.5mm – 3mm. • They suck plant sap and cause the plants to stunt. • Produce honey dew which contaminate the plant through growth of sooty mold.	• Aphids have many natural enemies; use less harmful chemicals to encourage populations of these natural enemies • Use approved pesticides
Thrips 	Skuma wiki, chilies,	• Adult bean thrips have a uniformly dark, grayish black body. • Feeding by flower thrips causes scars and blemishes on leaves and pods. • Heavy thrips feeding causes flower abortion and flower malformation • French bean pods become scarred (having a rough silvery surface) and malformed and are not marketable.	• Regularly monitor crop for early detection. • Use blue sticky traps • Use approved pesticides (Appendix 1)
Broad mites 	Tomatoes, chilies, capsicum	• Tiny and not easily seen without aid of magnifying lens but damage is significant • Discoloration, necrosis of tissues and deformation of affected parts. • Young leaves are stunted, deformed, fail to elongate and finally may wilt and dry. • Stems of terminal shoots become slightly swollen, roughened • A bronzed dusty appearance may occur on affected plant parts. • Attacked fruits become deformed and show white to tan or brown scars on the skin.	• Do regular monitoring for early detection. • Do effective crop rotation with non-host crops • Avoid introducing infested plant material into the crop, either with seedling plants • Apply predacious mites - Amblyseius species. • Spray the crop with Sulphur. • Use approved pesticides.

Pest	Crops affected	Features and damage	Controls
Caterpillars 	Spinach, skuma wiki, spider plant, night shade.	• Ragged holes their feeding activity leaves in plant foliage. • Black frass on leaves.	• Hand picking and dropping in soapy water to suffocate. • Regular scouting. • Spray of bacillus thuringiensis. • Spray with approved chemicals.
Root Knot Nematodes 	Passion fruits, Tomatoes, Gooseberry, night shade	• Formation of galls or knots on roots. • Yellowing of leaves. • Stunting and eventual wilting of affected plants	• Crop rotation. • Use of tolerant rootstocks. • Maintain high organic matter. • Use approved pesticides
Weevils 	Maize, Rice sorghum, wheat	• Make holes on grain	• Use hematic bags • Store grains in tightly sealed glass, metal, or sturdy plastic containers (not bags)Regularly clean pantry cracks, crevices, and shelves. • Use approved pesticides
Rodents 	Maize, Rice wheat, sorghum	• Consume grains in store	• Use rat reppellant • Store grains in tight sealed glass or metal containers • Use chemical control as a last resort

10.6.1 Diseases

Table 8: Diseases affecting horticultural crops, symptoms and control

Disease	Features/Symptoms and damage	Controls
Bacterial spot *(Xanthomonas vesicatoria)*  	• Small brown – black spots that are surrounded by a yellow hallo. • Infects leaves, stems and flowers and defoliation is slowly.	• Plant clean seeds. • Plant resistant varieties. • Do regular fungicide sprays
Early blight *(Alternaria solani)* 	• Dark brown, irregular spots appearing on lowest oldest leaves. • Infects leaves, stems and fruits.	• Space plants correctly. • Weed the fields regularly. • Practice crop rotation. • Do regular fungicide sprays.
Late blight *(Phytophthora Infestans)* 	• Earliest symptom is leaf stems bending downward followed by greasy, gray-green areas on leaves. • Underside of leaf may develop a whitish mold. • Entire plant turns black and dies within days if no control measure is taken	• Avoid overhead irrigation. • Give plants correct spacing- no overcrowding. • Maintain field hygiene. • Plant clean seedlings • Do proper scouting and know how to identify it. • Do regular preventative sprays. • Remove any volunteer tomato or potato plants. • Practice effective crop rotation.
Septoria leaf spot *(Septoria Lycopersici)* 	• Gray – brown areas on oldest lower leaves initially with gray centres and darker borders. • Centres of discoloured areas may have many small black spores.	• Crop rotation. • Weed the crop. • Maintain correct plant spacing. • Spray with approved pesticides.

10.7 Agroecological and Innovative Way of Grain Storage *(Hermitic Storage Technology)*

Hermetic Storage Technology (HST) is the latest innovation to reduce post-harvest losses, raise the incomes of smallholders and make the country food secure. It has been promoted as a proven safe and cost-effective solution for households for the storage of dried maize, red beans, cow peas, green grams, sorghum, millet, chick peas and other cereals. Hermetic storage bags preserve the dried cereals and pulses without the use of any pesticide dust. They are special gunny bags with inner liners. The WPP bag protects the inner liners that give the best hermetic properties to block gases and water vapour. Once the hermetic bag is closed as per the instructions provided, oxygen and other gases are prevented from entering or exiting.

10.7.1 Why hermetic bags?

- Improved storage allows farmers to reap the benefits of improved prices by delaying sales until prices rise.
- Loss of weight during storage: there is no moisture loss when dry cereal are sold in hermitic bags
- Food and financial security: Farmers reduce post-harvest loses improving households and national food security and maintaining nutritional value of cereals
- Families also save on the cost of buying cereals at higher prices when they harvest
- This protects the dried grains and pulses from damage that mostly occurs during post-harvest storage. The stored grain can last up to two years and the bag is reusable.
- Food safety: no pesticides are used to preserve the cereals and pulses hence safe food for consumption.

10.7.2 Where to buy the bags

The high-quality brands available include Purdue Improved Crop Storage (PICS), GrainPro-Super Grain, Zero Fly, Agro-Z and Elite bags.

10.7.3 Recommended cereals for Hermitic bags

Dried maize, Red beans, Cow peas, Green grams, Sorghum, Millet and other cereals and legumes but not groundnuts

10.7.4 Procedure for storage

1. Sort the pulses /grains to be stored and remove any impurities like stones, wood splinters, crop residues, etc.
2. Make sure the grains are properly dried to 13.5 percent moisture content before storage in bags.
3. Check the inner and outer layers of the purchased HST bags for holes or tears. (Do not use defective liners)
4. Place the HST bag together with the inner liners
5. Pour the little quantity of grains and adjust the bag to remove any folds
6. Fill with the rest of the grains to be stored up to 2/3 or 70 percent of the bag
7. Pack the grain tightly and remove all air pockets from the top of the liner
8. Twist the remaining part of the liner, bend the twisted inner liner part and close it using a smooth tie
9. Close the second liner similarly and one liner at a time
10. The outer bag is also closed in the same way as the inner liners with a smooth tie;
11. Store the closed bags on-farm in a cool and dry place preferably on a pallet or a raised flat structure that will keep the bags away from ground moisture
12. The room/store must be secured from rodents by using mesh on the windows and ventilators
13. When preparing to sell, remove the grains and pulses from the HST bags and pour into a normal bag of 90kg for transporting from the market
14. Fold the empty HST bag and keep it safely for the use in the next season.

Note:

- Do not wash or perforate the bag. Do not add any pesticide to the grain stored in the HST bag. Store in a cool, dry place whenever possible. Avoid exposure to the sun.
- HST bags contribute to smarter, healthier, and wealthier families consuming safe grains and pulses stored in a safe environment.
- Hermetic bags are not suitable for storing seeds because seeds are living and hermetic bags deprives seeds of oxygen.

11 PRINCIPLES OF SOIL HEALTH MANAGEMENT

11.1 Introduction to soil health

Soil is home to a complex assemblage of organisms that interact to significantly impact both aboveground and belowground processes. This community of organisms which have all or part of their lives in the soil plays a key role in soil function by providing the foundation for such critical processes which include; soil structure development, decomposition and nutrient cycling, bioremediation, and promotion of plant health and diversity. It's therefore imperative to maintain soil health for sustainable agricultural production.

11.2 Objective of the Training Soil Health

To equip extension agents and farmers with skills necessary for improving and maintaining soil fertility, soil physical and chemical properties and optimal production of crop yields.

11.3 Course Outcome

- After the training, participants will be able to know the basic steps of soil sampling, soil composite preparation and quantity of soils needed for analysis.
- After the training, participants will be able to carry out simple soil pH testing and reading of the pH level of any given soil.
- After the training, participants will be in a apposition to know qualities of a good soil

11.4 Training Outlines

1. Introduction to soil health management
2. Definition of soil and soil health
3. Soil health assessment
4. Composition of healthy soil
5. Soil health principles
6. Soil health management practices
7. Constraints in attaining healthy soil
8. Benefits of soil health to sustainable agriculture
9. Factors affecting nutrient availability

Trainer's Notes

11.5 Soil

Soil is the upper layer of earth in which plants grow or it can also be defined as a mixture of organic matter, minerals, gases, liquids, and organisms that together support life.

11.5.1 Soil health definition

Soil health is the capacity of soil to function as a living system, with ecosystem and land use boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health. Healthy soils maintain a diverse community of soil organisms that help to control plants. Soil health has been defined as the "the continued capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, promote the quality of air and water, and maintain plant, animal and human health.

11.6 Soil Health Assessment

Soil health is an assessment of how well soil performs all of its functions now and how those functions are being preserved for future use. Soil health cannot be determined by measuring only crop yield, water quality or holding capacity, or any other single outcome. Soil health cannot be measured directly, so we evaluate indicators.

Indicators are measurable properties of soil or plants that provide clues about how well the soil can function. Indicators can be physical, chemical, and biological properties, processes, or characteristics of soils. They can also be morphological or visual features of plants. Indicators can be assessed by qualitative or quantitative techniques.

Useful indicators of soil health:

- Measure changes in soil functions,
- Encompass chemical, biological, and physical properties,
- Are accessible to many users and applicable to field conditions, and
- Are sensitive to variations in climate and management.

11.6.1 Indicators of healthy soil

- Soil organic matter => nutrient retention; soil fertility; soil structure; soil stability; and soil erosion
- Physical: bulk density, infiltration, soil structure and macrospores, soil depth, and water holding capacity => retention and transport of water and nutrients; habitat for soil microbes; estimate of crop productivity potential; compaction, plow pan, water movement; porosity; and workability
- Chemical: electrical conductivity, reactive carbon, soil nitrate, soil pH, and extractable phosphorus and potassium => biological and chemical activity thresholds; plant and microbial activity thresholds; and plant available nutrients and potential for N and P loss
- Biological: earthworms, microbial biomass C and N, particulate organic matter, potentially mineralizable N, soil enzymes, soil respiration, and total organic carbon => microbial catalytic potential and repository for C and N; soil productivity and N supplying potential; and microbial activity.

11.7 Composition of a Healthy Soil

A healthy soil should have the following;

1. **Moisture –** Should retain adequate water for plant growth. It does not become waterlogged, but should slow the rate at which water leaves the soil.
2. **Mineral composition -** This refers to the proportions of different types of particles in the soil. A healthy soil should contain a mixture of clay and sand, allowing for a medium level of drainage,
3. **Gases -** Effective exchange of gases between the soil and the atmosphere makes soil microorganisms to thrive. For this to happen, the soil should have a loose structure.
4. **Organic matter –** Healthy soil should be high in organic matter.
5. **Microorganisms –** They keeps soils in good condition. Healthy soil should be high in microorganisms which include fungi, bacteria and insects.

11.7.1 Soil health principles

Principles for improving soil health and sustainability include

1. Use of plant diversity to increase diversity in the soil.
2. Managing soils more by disturbing them less.
3. Keeping plants growing throughout the year to feed the soil.
4. Keeping the soil covered as much as possible.
5. Integrating livestock to recycle nutrients and increase plant diversity.

11.7.2 Soil health management practices

1. Reduce inversion tillage and soil particles transfer - Excessive tillage is harmful to soil health as it reduces the soil coverage provided by crop residues, leaving soil more exposed to erosion.
2. Increase organic matter inputs - Organic matter inputs must meet or exceed the losses of organic matter due to decomposition or other processes.
3. Use cover crops - Cover crops contribute numerous benefits to soil health which include reduced risk of erosion, enhancing organic matter content and sustaining and increasing population of soil beneficial organisms among others.
4. Reduce pesticide use - Beneficial organisms that contribute to biological control or pest organisms can be harmed by the application of broad-spectrum insecticides.
5. Provide a habitat for beneficial organisms – Soil health management methods include the use of insectary plants, hedgerows, cover crops, and water reservoirs to attract and support populations of beneficial organisms such as insects, spiders, amphibians, reptiles, bats, and birds that parasitize or prey on insect pests.
6. Rotate crops - Diverse crop rotations will help break up soil-borne pest and disease life cycles and improve crop health. Rotations can also assist in managing weeds.

7. Managing nutrients - Carefully planning the timing, application method, and quantity of manure, compost, and other fertilizers will allow you to meet crop nutrient demands and minimize nutrient excesses. Maintaining a soil pH appropriate for the crop to be grown will improve nutrient availability and reduce toxicity.

You can maintain or increase soil organic matter more easily when you use reduced-tillage systems, especially no-till. The decreased soil disturbance keeps biological activity and organic matter decomposition near the surface and helps maintain a soil structure that allows rainfall to infiltrate rapidly. Leaving residue on the surface, or applying mulches, has a dramatic impact on soil biological activity. It encourages the development of earthworm populations, maintains soil moisture and moderate's temperature extremes. Compared with conventional tillage, soil erosion (water, wind or tillage) is greatly reduced under minimum-tillage systems, which help keep organic matter rich in the topsoil.

Other practices that reduce soil erosion, such as contour tillage, strip cropping along the contours and terracing, also help maintain soil organic matter. Cover crops also help maintain soil organic matter in resource-scarce regions that lack possible substitutes for using crop residues for fuel or building materials.

Use of rotations of grass, legume or a combination of grass and legume forage crops, or crops with large amounts of residue is also important in maintaining good soil health. It is recommended to leave residues from annual crops in the field, or, if removed for feed, composting or bedding, they should be returned to the soil as manure or compost. Raising animals or having access to animal waste from nearby farms gives a wider choice of economically sound rotations. Those that include perennial forages make hay or pasture available for use by dairy and beef cattle, sheep and goats, and even poultry.

11.7.3 Constraints to attaining Healthy soils

The following factors affect soil health, reducing its ability to support plant life leading to erosion, compaction, nutrient imbalance, pollution, acidification, water logging, loss of soil biodiversity and increased salinity.

i) The effect of mono-cropping on soil health

Monocropping is the practice of growing the same crop on the same plot of land, year after year. This practice depletes soil of nutrients (making the soil less productive over time), reduces organic matter in soil and degrades soil health. Soil scientists have also discovered that monocropping alters the microbial landscape of soil, decreasing beneficial microbes and causing poor plant growth over time.

ii) Synthetic fertilizers negatively impact soil health

All plants need nitrogen (N), phosphorus (P) and potassium (K) for healthy growth and productivity. These macronutrients (in addition to other macro and micronutrients) form the basis of healthy soils. Research has found that synthetic nitrogen fertilizer application decreases soil's microbiological diversity (that is, bacteria, fungi, etc.) and/or alters natural microbiological composition in favor of more pathological strains.

iii) Pesticide residues in soil

Pesticides are chemicals that are used to control weeds (herbicides), insects (insecticides) and fungi (fungicides) in food, fiber and wood production. They degrade the soil by killing soil microorganisms and non-targeted plants.

iv) The food print of crop production

Other types of pesticides may have similar effects on soil microbiology, impacting nitrogen-fixing microbes important to soil health and fertility. Soil fumigants are a type of pesticides designed to kill organisms in the soil before farmers start to plant. Fumigants kill nearly all soil organisms — not just the harmful ones — including beneficial bacteria, fungi and other organisms that help maintain healthy soils.

v) Factory farm waste contaminates soils

Animal waste from concentrated animal feeding operations (CAFOs), also known as factory farms, spread on agricultural fields can contain harmful microbes and antibiotic and other pharmaceutical residues, which can lead to antibiotic-resistant bacteria in soils.

vi) Tillage, soil compaction and erosion

Mechanical tillage and the use of heavy farm equipment can cause both soil compaction and soil erosion if soils are not managed effectively. Soil compaction is caused by use of heavy farm machinery and tilling when soils are too wet; compaction has become an increasing problem as farm equipment has gotten increasingly heavier.

vii) Soil tillage, climate change and soil carbon sequestration

Soil stores a tremendous amount of carbon; nearly 80 percent of the carbon in terrestrial ecosystems is in soil. Local loss of soil-sequestered carbon has global consequences. Scientists estimate that approximately one-third of carbon dioxide (CO2) emissions (a major contributor to climate change), are from the clearing of forests and the cultivation of land for agriculture.

11.7.4 The Benefits of sustainable agriculture to soil health

Here are just some of the major benefits that sustainable agricultural practices have on soil health:

- Improved carbon sequestration — regenerative agricultural techniques, like cover cropping, can help build soil and sequester carbon.
- Improved water retention — healthy soils with high organic matter retain more water.
- Less need for pesticides — healthy plants grown in biologically diverse soil with plenty of microbes are less susceptible (or attractive) to plant pests and better able to defend themselves from attack.
- No need for synthetic fertilizer — using sustainable soil-improvement techniques can eliminate the need for synthetic, fossil-fuel-based fertilizers.

11.7.5 Factors affecting nutrients availability

Nutrient availability in soil is influenced by many, often interrelated factors. These include the parent material, particle size, humus content, pH, water content, aeration, temperature, root-surface area, and mycorrhizae development.

Soil fertility is greatly influenced by five broad factors: parent material, climate, biota, time and topography. Two properties that have a profound impact on the soil's water holding capacity, nutrient retention, nutrient supply and drainage are soil structure and soil texture.

Among these are soil factors, such as pH, available nutrients, texture, organic matter content and soil-water relationships; weather and climatic factors, including temperature, rainfall and light intensity; the crop and cultivar; postharvest handling and storage; and fertilizer applications and cultural practices.

11.8 Addressing Soil Acidity

There are a number of factors that contribute to soil acidity at the farm level:

- Replacement of basic nutrients (calcium, magnesium and potassium) by hydrogen through soil erosion, leaching and crop removal.
- Use of acid-forming fertilizers e.g., the conversion of ammonium (NH_4^+) nitrogen to nitrate (NO_3^-) nitrogen in the soil (nitrification), which produces significant amounts of acid (H^+).
- Parent rock material

11.8.1 Effect of soil acidity on crop yield

Soil acidity is one of the most important factors limiting crop yield.

- Soils with pH <5.0 have high exchangeable aluminium (Al), which causes toxicity to most crops
- High exchangeable aluminium (Al) damages roots, decreases water and nutrient uptake, and increases drought risk, and hence reduces crop yield

11.8.2 Levels of soil acidity

Acidic soils are classified by severity of acidity (Table 9).

Table 9: Grading of Levels of soil acidity at the KARI-Kabete

Degree of Acidity	pH Range
Extremely Acidic	<4.5
Strongly Acidic	4.5-5.0
Moderately Acidic	5.0-6.0
Slightly Acidic	6.0-6.5
Near Neutral	6.5-7.0
Source: KARI, 2002	

11.8.3 Crop tolerance levels to soil acidity

Different crops have various degrees of tolerance to acidity. For instance, chilies, sweet potatoes and Irish potatoes do well in soils with pH values below 5.5. Most of the horticultural crops, such as onions, spinach, carrots, cabbages and cauliflower only grow well in soils with pH values above 6.0. Maize performs well in the medium tolerance range of 5.5-6.0 pH value. When crops are grown in soils with pH values below the lower limit, they give low yields. This can only be improved by applying inputs including fertilizer, lime, compost and manure.

11.8.4 Relationship between nutrient availability and soil pH

The availability of essential plant nutrients varies with soil pH. Different crops require different soil acidity levels to optimally absorb nutrients from the soil (Table 10).

Table 10: Soil pH range for optimal nutrient absorption

Crop	pH Required
Maize	5.5-7.0
Beans	6.0-6.6
Wheat	6.3-6.5
Sorghum	6.5-7.5
Cassava	5.5-8.0
Sunflower	>6.0
Sweet Potatoes	5.0-7.0
Irish Potatoes	5.8-6.5
Banana	5.0-6.5
Tobacco	6.0
tomatoes	5.5-7.0
Spinach (Swiss chard)	6.0-7.0

11.8.5 Soil health amendments to address acidity

Ways of reducing soil acidity include:

- Application of lime
- Use of organic materials
- Breeding for acid tolerant crop varieties – this does not reduce soil acidity, but confers tolerance to a crop.

a) Use of lime to amend soil health

Liming raises the soil pH from acidic status to a near neutral level. The benefits of liming acidic soils include:

- Improves the uptake of N, P and K. However, note that the availability of micronutrients decreases as pH increases
- Stimulates biological activity in soils leading to more vigorous root systems.
- Improves legumes symbiotic nitrogen fixation;
- Reduces the possibility of Mn^{2+} and Al^{3+} toxicity
- Improves physical condition (better structure); better drought tolerance
- Improves palatability of forages
- Provides an inexpensive source for Ca^{2+} and Mg^{2+} when these nutrients are deficient at lower pH;

Determining lime requirements for acidic soils

The optimum pH for a soil depends on the type of crop to be grown. The amount of lime recommended is the amount of lime needed to reach the target pH for the most acid-sensitive crop. Once a given soil reaches the desired soil pH, it should remain at that level for an average of two years without the need to lime. Lime should be applied if the soil pH is more than 0.2 units below the target soil pH.

How to calculate lime requirement?

Mehlich Buffer pH Lime requirement
$Y = 16.988 - 2.722X$
Where Y= tons per ha; X = soil pH

The quality of the liming material is paramount.

- The $CaCO_3$ equivalency (e.g., > 80%), depending on the Ca content of the starting material.
- The fineness factor (e.g., > 70%)
- The moisture content (e.g., < 5%).

Application of lime to the soil

- Application of lime at 6t/ha will require another application 3 years later
- Application of lime at 4t/ha will require another application 2.5 years later
- Application of lime at 2t/ha will require application every two years

Table 11: Relative neutralizing values of some liming materials.

Liming Material	Relative Neutralizing value, %
Calcium Carbonate	100
Dolomite Lime	95-108
Calcitic Lime	85-100
Baked oyster shell	80-90
Marl	50-90
Burned Lime	150-175
Burned Oyster shells	90-110
Hydrated Lime	120-135
Basic Slag	50-70
Wood Ash	40-80
Gypsum	None

Some challenges in use of lime by smallholder farmers

- Limited knowledge and awareness of importance of lime
- Limited financial resources to purchase lime and other inorganic inputs
- Large quantities are required for application per unit area
- Few agro-dealers stock lime as it is bulky
- It expensive to transport the bulky amount of lime required per unit area
- Scarce pelleted lime in the Kenyan market; hence the powder form that is commonly applied is difficult to apply as it easily blown away by wind
- Lime application is labour intensive

b) Use of organic materials to amend soil health

During decomposition of organic matter, there is release and synthesis of organic compounds which combine with aluminium (Al) to form solid-organic material phase leading to reduction of Al solubility. Organic farmers seek to “build the soil” or enhance its inherent fertility by using crop rotation, animal and green manure, tillage practices and cover crops. Crop rotation and tillage practices provide appropriate opportunities for pest control while minimizing erosion.

Organic farmers use natural materials, which exploit biological processes to supply nutrients needed in the soil. Organic fertilizers are needed in larger quantities than are conventional fertilizers because their nutrient concentrations tend to be lower. Organic fertilizers can be more expensive, bulkier and less uniform than conventional counterparts. Some of the common sources of organic nutrients include:

- **Potassium (K):** manure, alfalfa meal, kelp meal, greensand, wood ash, potassium sulfate, and granite dust.
- **Sulfur:** acid rain, manures.
- **Calcium:** lime, colloidal phosphate, bone meal, gypsum, and wood ashes.
- **Magnesium:** dolomitic lime and langbeinite.
- **Micronutrients:** mineral weathering, manure, compost, and liming amendments.

Table 12: Some of the commonly used organic fertilizers

Fertilizer Type	Description	Comments/Issues
Alfalfa meal or pellets	Contain around 3 percent nitrogen and are commonly used as an animal feed.	Commonly used for high-value horticultural crops but rather expensive for field crops.
Ash	Wood ash (0–1–3) contains P and K, is a good source for micronutrients and acts as a liming agent.	Commonly used in gardens; avoid over-application which can cause alkalinity and salt build up; avoid ash from treated wood or from the burning of manure.
Biological amendments	While not fertilizers per se, there are a number of biological amendments used to promote biological activity or microbial associations between plants and soils with the intent of increasing plant nutrient uptake.	A separate article covering this is under development.
Bone meal	Typically, a mixture of crushed and ground bone that is high in phosphorus. N contents vary depending upon handling. Range from 4:12:1; 1:13:0; 3:20:0.5.	Permitted as a soil amendment but cannot be fed to animals in certified production. Blood, bone and meat meal are prohibited in many countries in Europe and Japan because of BSE transmission risk.
Blood meal	Dried blood, is a soluble source of nitrogen. Typical N:P:K contents are 13:1:0. Solubility can vary. Should be used carefully, release of ammonia can burn plants and lead to loss through volatilization.	Use limitations are the same as bone meal above. Recently Canada, with the support of IFOAM, proposed to prohibit cattle wastes as fertilizer at the UN Codex Alimentarius session in Montreal, 2004. Allowed under National Organic Program (NOP) regulation.
Calcium sulfate (Gypsum)	$CaSO_4.2H_2O$. Contains about 23% Ca, is a mined deposit that is used to reclaim alkali soils, lower soil pH, and adjust cation balance.	Good source for sulfur; useful for alkaline soils with high sodium content. Avoid gypsum from recycled sheetrock.
Cocoa Shells	Cocoa shells (1:1:3) are available in some regions. They are used as a source of potassium and are popular due to their slow release properties.	Also used as a mulch.
Dolomitic lime (Calcium-magnesium carbonate)	$CaCO_3$–$MgCO_3$ is about 24% Ca and 20% Mg, is a very effective lime source. Over application is perceived to be a problem in horticultural systems. Under application is an issue in some field crop systems. Has a lime equivalent of 1900 lb/ton.	Labs following the cation balance theory avoid the use of dolomitic limes, KCl, and oxide forms of trace elements.

Fertilizer Type	Description	Comments/Issues
Feather meal	(13:0:0) a by-product of the poultry processing industry, which contains 15% N as non-soluble keratin has been promoted as a slow release N source.	Feather meal can transmit the Avian flu, A(H5N1) virus, which is relatively easily transmissible to animals and people.
Fish emulsion	(Ranges in content from 4:1:1 to 9:3:0); suitable for foliar feeding of starts and the spot treatment of transplants; is reputed to prevent stress, stimulate root growth and provide cold protection.	Fish emulsion may be fortified with chemical fertilizer, so be suspicious of any product with a phosphorus content in excess of 4%. Fish products may also contain synthetic preservatives, stabilizers and other products prohibited under the NOP. Fish meal can also contain high levels of PCB's.
Granite dust	Granite dust is available in some regions. It is used as a source of potassium that is popular due to its slow release properties.	Availability varies regionally.
Greensand (Glauconite)	A mined sandstone deposit (typically 0:0:3 or 0:0:6) used as a source of potassium. Also contains iron, magnesium, silica and other trace minerals.	Is a common ingredient in potting mixes.
High calcium lime (Calcium carbonate)	Limestone containing 0–5% magnesium carbonate.	Rapid reacting due to high solubility, valued source of Ca and liming where magnesium abundance is a concern and soil is not alkaline.
Hydrated lime	High quality $Ca(OH)_2$ is a dry powder produced by reacting quicklime with a sufficient amount of water to satisfy the quicklime's natural affinity for moisture.	The National Organic Standards Board approved use of calcium hydroxide as a component of Bordeaux mix and lime sulfur for fungicide use, but does not allow its use as a soil amendment.
Manures and composts	Nutrient contents vary widely; it is recommended they be applied on the basis of phosphorus need. Use as an N source leads to over application of P.	Manure- and compost-based P has high plant availability, ranging 70–100% available. Compost, if produced according to NOP requirements, can be applied any time during the growing season. Animal manure can only be used on crops for human consumption if it is incorporated into the soil at least 120 days prior to harvest for crops that contact the soil or 90 days prior to harvest for crops that do not contact the soil.
Potassium sulfate	K_2SO_4 is a mined fertilizer not widely available. It has been used as a food preservative.	This is allowed under the NOP rules if you can prove you are using a mined source that has not been treated with acid or any other chemical reaction to make the potassium more available. This is a good choice for high Mg soils, but it is fairly reactive and must be used carefully.
Rock phosphates	Rock phosphates are frequently divided into hard rock and colloidal or soft rock forms. Rock phosphate typically has lower availability than colloidal P, which is low (2%) compared to materials like bone meal (11%). Marine sediments are typically ground and cleaned. Availability is low where soil pH is above 6 and biological activity is low. Addition of manures can increase solubility. Contains Calcium and acts as a liming agent.	Phosphate rock is most effective at supplying P in soils with low pH (less than 5.5) and low calcium concentrations. Phosphate rock applications made to soils with pH greater than 5.5 may not be effective because of reduced solubility.

Fertilizer Type	Description	Comments/Issues
Sea weed and Kelp	(Ranges from 1:0.2:2 to 1.5:0.5:2.5) Also high in micronutrients, Fe, Cu, Zn, Mo, Bo, Mn, Co. and Alginic acid (26%). Is used as a soil conditioner. Several kinds of sea weed and kelp are on the market. Kelp meal can be applied directly to the soil or in starter fertilizer.	Can be high in salts and metals. Other reputed benefits are hormones or hormonal activity. Claims to protect plants from stress: cold, drought and insect pressure. Expensive, so best suited for high value crops.
Seed meal	(Ranges from 6:1.5:2 to 6:2:2); cotton seed and soybean seed meal have been popular.	Now that generically modified crops are so wide-spread sourcing GM free meal can be difficult. Check with your certifier about the needed documentation.
Sodium nitrate	(16:0:0) Historically an important component of fertilizers, and a raw material for the manufacture of saltpeter. It is a mined product that is about 16–20 percent nitrogen and highly reactive. It acts more like a synthetic fertilizer and can cause sodium buildup in the soil. Can contain medium to high levels of Boron.	The NOP stipulates that the nitrogen obtained from sodium nitrate must account for no more than 20 percent of the crop's total nitrogen requirement. This can be used cautiously when rapidly available nitrogen is needed. It is prohibited by the Farm Verified Organic and Organic Crop Improvement Association-International Federation of the Organic Agriculture Movements accredited levels of certification. European organic standards consider it to be the equivalent of a synthetic fertilizer because it is highly soluble and leaches readily from the soil. Check with your certifier before using.
Soybean meal	(8:0.7:2) Useful to augment N and P.	Often used as a feed additive; medium N release rate; may inhibit germination of small seeds. Check with your certifier before using, due to widespread use of GM soybeans.
Sulfate of potash (sul-po-mag and K mag or langbeinite)	(0:0:21 with 11 Mg) Naturally occurring crystalline product commonly used to supply potassium.	This and calcium sulfate are allowed under the NOP if you can prove you are using a mined source that has not been treated with acid or any other chemical reaction to make the potassium more available. Potassium sulfate is the better choice for high Mg soils, but it is fairly reactive and must be used carefully.

c) Other methods to build soil health naturally include:

- **Bare fallow**

  Bare fallow can be used with fallow periods occurring between harvested crops. Fallows commonly occur over winter in temperate zones or during the dry season in Mediterranean or tropical zones. Use of bare fallow to accumulate water and, at times to control weeds only works to enhance the soil where it concentrates resources enough to increase overall crop productivity. If bare fallow is used, soil erosion must be prevented.

- **Crop rotation**

  Crop rotation varies plant species in time and space and is an important strategy for organic farmers. Goals are to keep the soil surface covered with a growing crop for most of the year. Key elements of rotations include the breaking of disease and pest cycles and the inclusion of soil building cover crops or cropped fallow periods. By selecting effective cover crops or perennial crops farmers can maintain or increase soil organic matter content and nutrient availability during periods when cash crops are not grown. For most organic farmers, fertility is based on the rotation and not the amendment.

- **Cover crops**

  Cover crops include annual, biennial, or perennial herbaceous plants grown in pure or mixed stands. Annual covers occupy the rotation for part of the year. Perennial crops may be referred to as ley or pasture phase or as a plant-fallow. Cover crops provide soil cover and can help loosen compacted soil through the growth of roots. They enhance soil physical condition and improved water filtration. Legume cover crops provide nitrogen while non-legumes can increase nutrient availability to subsequent crops by taking up nitrogen, phosphorus, and potassium that might otherwise leach or become unavailable to plants.

- **Crop diversification**

  Diversification through rotation and use of covers or lay crops can reduce crop insect pests and diseases, if the cover crops are not alternate hosts. Both covers and perennial ley covers help maintain or increase soil organic matter if they are allowed to grow long enough to produce sufficient biomass. These also help prevent soil erosion caused by both water and wind, and suppress weeds. The management of residues within rotations can be quite sophisticated.

11.8.6 Breeding for acidic tolerant crop varieties

Plant breeding programmes have been applied to develop germplasm that are tolerant to aluminium (Al) toxicity. These include:

- A multidrug and toxic compound extrusion (MATE) gene in sorghum and in maize ZmMATE1gene, that transports citric acid, has been noted to confer Al tolerance
- Introgression of such genes into Al sensitive cultivars have been shown to improve grain yield performance in acid soils.

It is worth noting that breeding does not reverse soil acidity; it produces plants that are tolerant to the acidic condition of the soil.

12 FARMERS SEED SYSTEMS: SEED PRODUCTION AND STORAGE

12.1 Introduction

Seed is the least costing input but one that determines the yield of a crop. Most of the seeds used in Kenya for crop production is produced by small scale farmers. Therefore, it is important to provide farmers with knowledge and skills that will assist them in producing quality seeds and in sufficient quantities for increased food security.

12.2 Objective of the Training on Seed Production and Storage

To build capacity of trainers and farmers on quality seed production.

12.3 Course Outcome

After the training, participants are expected to:

- Have increased awareness on seed production and storage principles
- Increase the quantities of seeds that they produce and store
- Exchange information freely on quality seed production and storage

12.4 Training Outline

a) What is seed?
b) Types of seed
c) Seed systems
d) Quality aspects of seed
e) Seed bulking
f) Seed storage
g) Seed Classes
h) Seed Maintenance

Training Notes

The seed production toolkit is intended to support trainers and farmers to acquire the knowledge they need to deliver quality seed and increase seed production for a variety of crops.

12.5 What is Seed?

A seed is a part of plant that grows into a new plant.

12.5.1 Types of seed

1. **True seed** - Fertilized mature ovule embryonic plant part covered in a seed coat. True seed is developed in the sexual reproduction system. The unit of reproduction is of a flowering plant capable of developing into another such plant. These fall into two categories self and cross-fertilizing. Self-fertilizing crops (e.g legumes-beans) produce genetically similar offspring unless a mutation occurs. In the cross-fertilizing crops (e.g maize, amaranth) wind and insects aid random fertilization consequently changing genotypes and producing plants that are genetically different from the parents.
2. **Vegetative seed** - Means by which plants are raised asexually from parts of roots, tubers, stems or bulbs. Plant parts used for vegetative propagation are called planting materials. In vegetative propagated plants (sweet potatoes, cassava) there is no fertilization therefore the genotypes remain fixed.

Advantages normal seed

- Rapid multiplication is possible
- Allows for quick formation of new varieties
- Easy to carry and transport
- Cheap to produce
- Easy method of planting

Disadvantages of normal seed

- High chances of contamination of a variety
- Deterioration can easily happen in open pollinated varieties if poorly maintained

Advantages of vegetative seed

- Chances of variety contamination are low
- Can be used for seedless crops and varieties
- Quick method of propagation for plants that take several years to flower
- Can be used when seeds are difficult to use
- Produces identical qualities as the parents
- Has desirable characters of the plant (fruit, taste, colour are maintained)

Disadvantages of vegetative planting materials

- Variety development not easy
- Transmission of diseases easy
- Low chances of dispersal
- Mechanization cannot be easily used during planting

12.5.2 Farmers' seed systems

Seed system definition-the channel through which farmers get seed. Effective seed systems have the potential to increase production quickly and economically. There are 3 types of seed systems:

- Traditional, local or informal seed system. In this system seed production is integrated into crop production. Farmers select seed from the crop usually intended for food. Seed production activities are not regulated by any formal organization or institution but guided by customs and traditions of the community.
- Formal-government system-The activities in this system are Scientific plant breeding, Formal seed production, Seed quality control and formal seed marketing and distribution networks. It operates under institutional rules and regulations such as seed law, phytosanitary law and plant variety protection law. formulated by the government. The national regulatory institution for the seed industry in Kenya is The Kenya Plant Health Inspectorate Services (KEPHIS)
- Integrated- a combination of the formal and local. Improved varieties are introduced and the produced using formal system guidelines while building on farmers' knowledge and capacities, but without the involvement of regulators

What are the advantages and disadvantages of traditional and formal seed systems?

Advantages of the systems

i) Traditional / informal seed system

- Preserves genetic diversity
- Easy to disseminate seed
- Seed prices lower than in formal system

ii) Formal seed system

- Seed quality is assured
- Development of improved varieties faster
- Large amounts of seed produced
- Good maintenance of varieties

iii) Integrated seed system (combination of traditional and formal seed systems)

- Distribution of new varieties faster
- Seed quality is high but not assured
- Good maintenance of variety

Disadvantages

i) Traditional seed system

- Quality not assured
- Quantities produced specific to community
- Maintenance of varieties poor

ii) Formal seed system

- Seed dissemination is limited
- Prices are high
- Some of the technologies involved are not farmer friendly eg UA Kayongo (Imazapyr)

iii) Integrated seeds system

- Seeds produced through this system not recognized by regulators

12.5.3 Aspects of seed quality

- **Genetic** – presence or absence of contamination from other varieties in a crop or seed lot. Farmers would prefer to have uniform variety during production of crops intended for commercial purposes. varieties can degenerate (change) over time especially after much recycling of seed.

- **Germination/vigour -** ability of seed to germinate well and have high vigour. It is a requirement that good seed should germinate well and be strong when emerging. poor seed will result in low plant density. Knowing the germination rate before planting helps the farmer to calculate and adjust the seed rate accordingly. For example, if the germination rate is 50% a famer will need to double the seed rate to get the correct plant population. Farmers should therefore conduct germination tests before planting. The major factors that affect germination are, temperature, moisture content of seed and humidity. Other factors may include storage, dormancy and the inbuilt genetic ability of a species.
- **Health -** presence or absence of seed borne/transmitted diseases. Seed diseases can be caused by bacteria, fungi and viruses. Seed that is already affected by disease at planting will produce a poor crop. The presence of seed borne diseases cause varieties to degenerate quickly.
- **Physical appearance of seed (cleanliness) -** presence or absence of unwanted substances (other seeds, chaff, weed seeds) in a seed lot. Seeds should be clean to attract good prices. Buyers would not like to pay for dirt in seed. Seeds are transported over long distances and therefore the presence of weed seed in a seed lot can be a means of dispersing unwanted weeds.

12.5.4 Seed bulking

What is seed Bulking-Seed increase or producing seed in large volumes. It is the means through which rare plant population are conserved. Why seed bulking:

- To conserve rare species
- To increase seed of parents during breeding

Factor to consider when bulking seed

1. Land selection – determined by
   - Isolation distances for the crop in question (distances that will not allow pollen contamination for seed crop in relation to similar crop in the vicinity) e.g. maize crop located at least 200m from the next maize crop (Table 11).
   - Rotation; use a crop of a different family to avoid

     i) disease and insect infestation,
     ii) volunteers that would contaminate the variety
   - Quantity of seed required to be bulked

2. Descriptor (listed/known characteristics of a variety that makes it unique from others) of seed crop to guide in removing rogue plants

3. Seed agronomic practices

iv) **Fertilizer and seed rates must be applied as recommended**. Farm yard manures, compost can also be used to improve the fertility of the soil. But it is recommended that nitrogen application of chemicals and manure should be used moderately. High amounts of nitrogen produce vegetative growth and high yields but may result in large seeds that are not hardy and that cannot withstand hard conditions during storage or emergence. Phosphorus and potassium in sufficient amounts are good for the development of hardy seeds.

v) **Spacing -** right spacing should be maintained (correct plant population),

vi) **Weed control –** the seed crop plot must be kept weed-free. Remove weeds that resemble the main seed crop. These may cross fertilize with the seed crop and change the variety in the subsequent generations of affect the taste of the crop in cases of cereals e.g finger millet. several weeding methods should be applied e.g. use of mulching, uprooting the weeds, hard sharp sticks/metal, panga, hoeing

vii) **Crop protection -** protection of seed crop is a very important stage in the seed production cycle. Sucking, chewing and piecing insects should be controlled in all stages of growth of a seed crop. At the lowering stage, most of the pests lay their eggs in the flowers and this grows together with the pods. Constant spraying of seed crop with biodegradable pesticides at flowering is mandatory. Seed transmitted diseases should be controlled to protect the quality of the next generation of seed. Use of disease free seeds and fields is key in controlling seed transmitted diseases. Planting early and timely harvesting are strategies that can be used to avoid pests and diseases.

viii) **Field inspections -** A seed grower should know how to inspect the seed crop. the objective of field inspection is to identify any plants that are different from the variety being grown. These are called off types and should be removed before flowering of the seed crop. This activity helps identify diseases early for timely action in controlling them. Suggested walking patterns are given in figure 12 and 13.

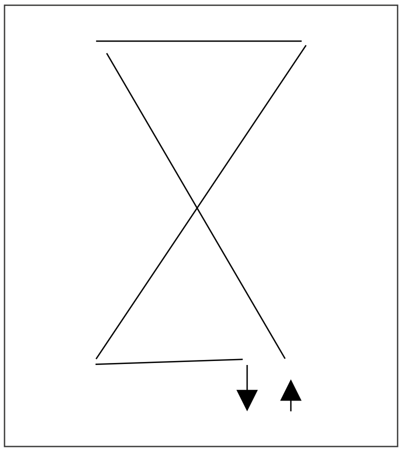


Figure 12:Observation of 60-70% of the field

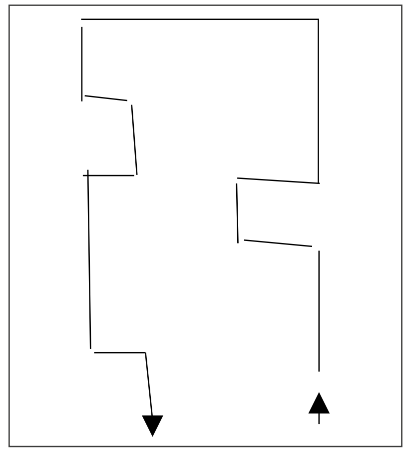


Figure 13: observation of 85 % of the field

ix) **Harvesting** - timing is of essence at this stage. Seed harvesting should be done at the appropriate time to avoid wastage when harvesting is delayed and high seed moisture content when harvested early. Seed with high moisture content is prone to damage during processing and this can lead to disease infection.

Table 13: Field and laboratory recommendations for seed production

Crop	Isolation meters minimum	Off types of other varieties	Fertilization mechanism
Maize	200	1	Cross (wind)
Finger millet	4	5	Self
Sorghum	200	1	Semi-cross (wind)
Bambara nuts (Njugu mawe)	100	-	Semi-cross (insects)
Cowpea	25	0	Semi cross (insects)
Groundnut	25	-	Self
Sesame (Simsim)	300	-	Semi-cross insects
Soybean	4	1	Self
Beans	25	1	Self
African night shade (Sucha)	50	-	Self
Spider plant (Tsitsaka)	200	-	Cross (insects)
Amaranth (dodo)	300	-	Semi-cross
Pumpkin	200	-	Cross Insects
Tomato	50	5	Self

12.5.5 Seed storage

What is seed storage - It is a systematic way of preserving seed such that the rate of deterioration is slowed down. This is usually done in a controlled environment to enable the seed to retain its viability (germination and vigour) for long periods after harvesting.

Why seed preservation - We preserve seed to maintain physical and physiological (germination and vigour) quality especially aspects before planting. Note: if the seed harvested is poor because of bad field conditions e.g high moisture at harvest, low germination, low vigour and poor seed health, even the best storage practices cannot improve the shortcomings. Other benefits of seed storage include the need for repeated production within a short span especially when it is in large quantities thereby cutting costs.

Storage structures and materials

Different methods are used to preserve seed

- Traditional/agro-ecological seed preservation

  Cow dung, leaf extracts, wood ash, smoke tunnels/aerials, cow dung slurry, cow urine, common salt, powders of various plant materials, leaf extracts, earthenware pots, calabash, gourds, solid wall bin.

- Modern method of seed preservation
  - **Chemicals** - dusting products, slurry and liquids.
  - **Non-chemical** - use of cold rooms, moisture absorbing materials such as silicon, drying beads, air tight containers/bags – Farmers are not advised to store seeds in hermatic bags. Hermatic storage of seeds is a very specialized field which includes storage in hermatic bags, tins, and aluminium foils.

Advantages and disadvantages of modern and traditional/agro-ecology seed preservation methods

Advantages of traditional/agro-ecology preservation methods

- Has no side effects
- Cheaper/low cost
- Easy to use
- Requires little special technology

Advantages of modern seed preservation methods

- Highly efficient in seed preservation
- Can preserve large quantities the seeds at a time
- Can preserve seed for a long period of time

Disadvantages of traditional/ agroecological seed preservation methods

- It cannot store seeds for long time without losing viability
- Cannot store large quantity of seeds

Disadvantages modern seed preservation methods

- They are expensive to install and to run
- Requires special technology and skills to run e.g. cold rooms
- Chemical methods risky to the health and environment of users

Environment suitable for seed storage

- **Optimum temperatures for storage –** the lower the temperature the longer the storage period and vice versa
- **Optimum relative humidity (RH) of each seed in question** - the lower the relative humidity the longer the seed will be able to store

Factors responsible for successful seed storage are:

- Crop species
- Initial seed temperature
- Environmental factors (T, RH),
- Seed moisture content
- Seed packaging

Storage pests

- The main storage pests of crop seeds are insects and weevils

12.5.6 Seed classes

What are seed classes: These are the generations involved during seed multiplication. It indicates the generation distance of the seed from the original seed produced by the plant. They are referred to as high for the first three and low for the latter.

What dictates the level of seed classes - Method used in bulking seed (seed selection, rogueing intensity and isolation distances applied)

How many times should a farmer recycle seed - Open pollinated species are recycled fewer times (e.g., 5 times) because the chances of contamination are high, but self-pollinated species can be recycled many times (e.g., 8 times). The formal seed system in Kenya allows for a maximum of 5 cycles/generations from breeder seed to certified generation 2.

12.5.7 Seed variety maintenance

Why maintain seed variety

- To retain the characteristics desired for crop variety
- To uphold the identity and purity of the cultivar
- To rejuvenate a variety after enough recycling has been done
- To restore a degenerated variety to its former self

How to maintain a seed variety: The simplest method is called mass selection which can be done in two ways (Figure 14 and 15).

Positive mass selection-Pick the best plants when compared with the neighbouring plants and use them as seed.

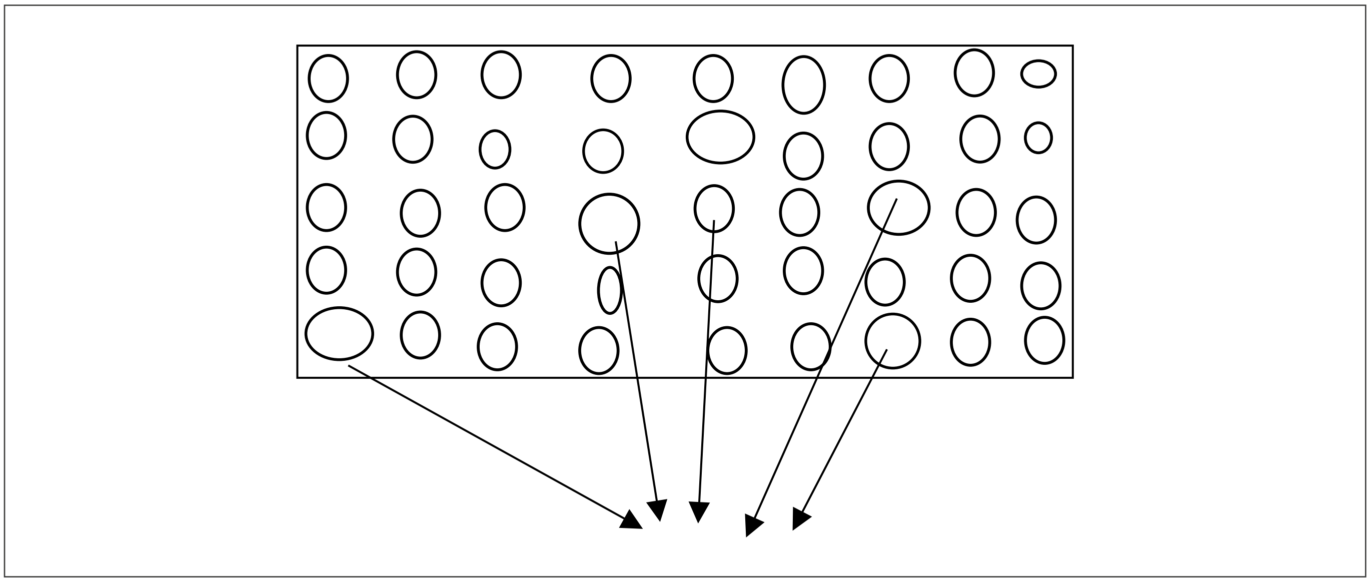


Figure 14: Positive mass selection- seed from the best plants are selected and used for next seasons planting

Negative mass selection-remove off types and leave the rest of the plants for seed production

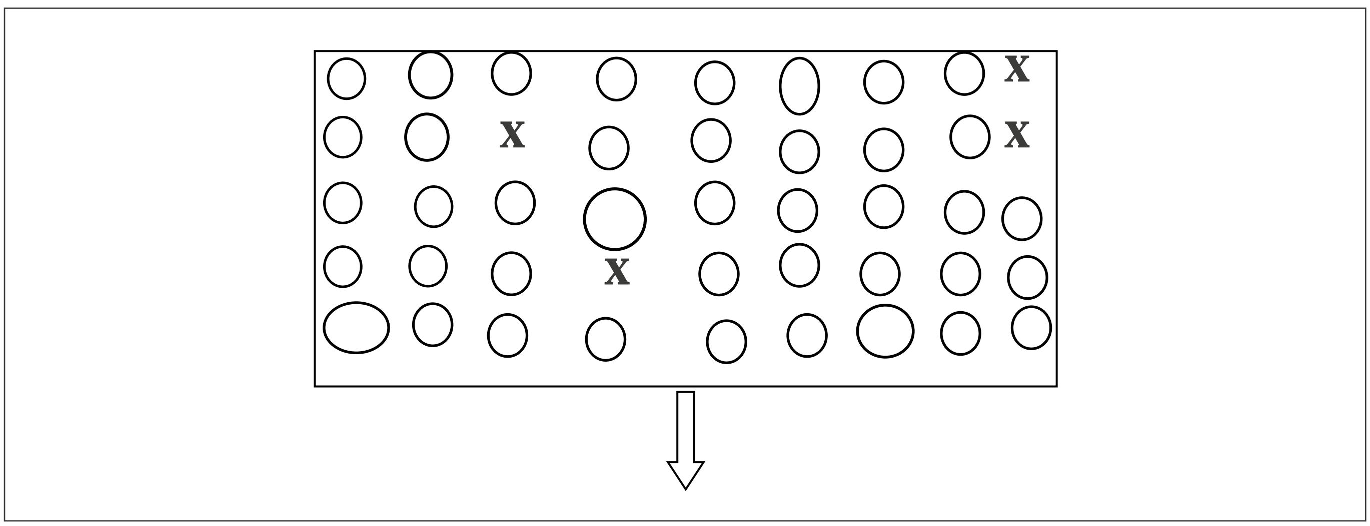


Figure 15: Negative mass selection-bad looking plants (off types) are removed and the reaming plants are used for seed

ACRONYMS

- KEPHIS-Kenya Plant Health Inspectorate Services

REFERENCES

- Conny Almekinders and Niels Louwaars (1999). Farmers' seed Production. New approaches and Practices. Intermediate Technology. Publications United Kingdom Trowbridge

- Jump up to:a b c d e Maia MF, Moore SJ (March 2011). "Plant-based insect repellents: a review of their efficacy, development and testing". Malaria Journal. 10 Suppl 1 (Suppl 1): S11. doi:10.1186/1475-2875-10-S1-S11. PMC 3059459. PMID 21411012.

- Jump up to:a b c d e f g h i j k l m n Hummel, K. Use plants for pest control. Archived 2015-02-14 at the Wayback Machine Coles County Yard and Garden. University of Illinois Extension.

- Jump up to:a b c d e f g h i j k l m n o p q r s t u v w x y z aa ab ac "Companion Planting" (PDF). Cornell Cooperative Extension. Chemung County. May 1999. Archived from the original (PDF) on May 29, 2014.

- Jump up to:a b c d e f g h Clarke, C. Indoor pest-repellent plants. SFGate: San Francisco Chronicle.

- Jump up to:a b c Plants help keep mosquitoes away. Colorado State University & Denver County Extension Master Gardener. 2010.

- "Mosquito Plant, Pelargonium Citrosum - The Citrosa Plant". 2015-06-08. Retrieved 2016-09-26.

- Diana Beresford-Kroeger. A Garden for Life: The Natural Approach to Designing, Planting, and Maintaining a North Temperate Garden. p. 171. ISBN 9780472030125.

- Chiasson, H.; Bostanian, N. J.; Vincent, C. (August 2004). "Acaricidal properties of a Chenopodium-based botanical". Journal of Economic Entomology. 97 (4): 1373–1377. doi:10.1093/jee/97.4.1373. ISSN 0022-0493. PMID 15384350.

- Chiasson, H.; Vincent, C.; Bostanian, N. J. (August 2004). "Insecticidal properties of a Chenopodium-based botanical". Journal of Economic Entomology. 97 (4): 1378–1383. doi:10.1093/jee/97.4.1378. ISSN 0022-0493. PMID 15384351.

- "12 plants that repel unwanted insects". 2014-10-02. Retrieved 2017-10-19.

- http://ipm.ucanr.edu/PMG/GARDEN/FLOWERS/nasturtium.html

- "5 Herbs That Keep Bugs Away". 2017-07-08. Retrieved 2018-08-04.

- Stephen Muliokela (1997) Zambia seed Technology handbook. Ministry of Agriculture Food and fisheries

- Seeds and Plant Varieties (Seeds) Regulations, 1991 Seed Chapter 326

Practical
ACTION

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