Agroecology Initiative

INITIATIVE ON Agroecology

Protocols for innovative agroecological soil, water and integrated pest management practices:

Management techniques, trials establishment and monitoring

July 2024

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Protocols for innovative agroecological soil, water and integrated pest management practices:

Management techniques, trials establishment and monitoring

Kiambu and Makueni Agroecology Living Landscapes in Kenya

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List of Abbreviations and Acronyms

AE-I .... CGIAR Initiative on Agroecology

ALL .... Agroecological Living Landscape

CIFOR-ICRAF .... Center for International Forestry Research and World Agroforestry

CIRAD .... French Agricultural Research Centre for International Development

CSHEP .... Community Sustainable Agriculture Healthy Environmental Program

DNRC .... Drylands Natural Resources Centre

EIPMA .... Effective IPM Association

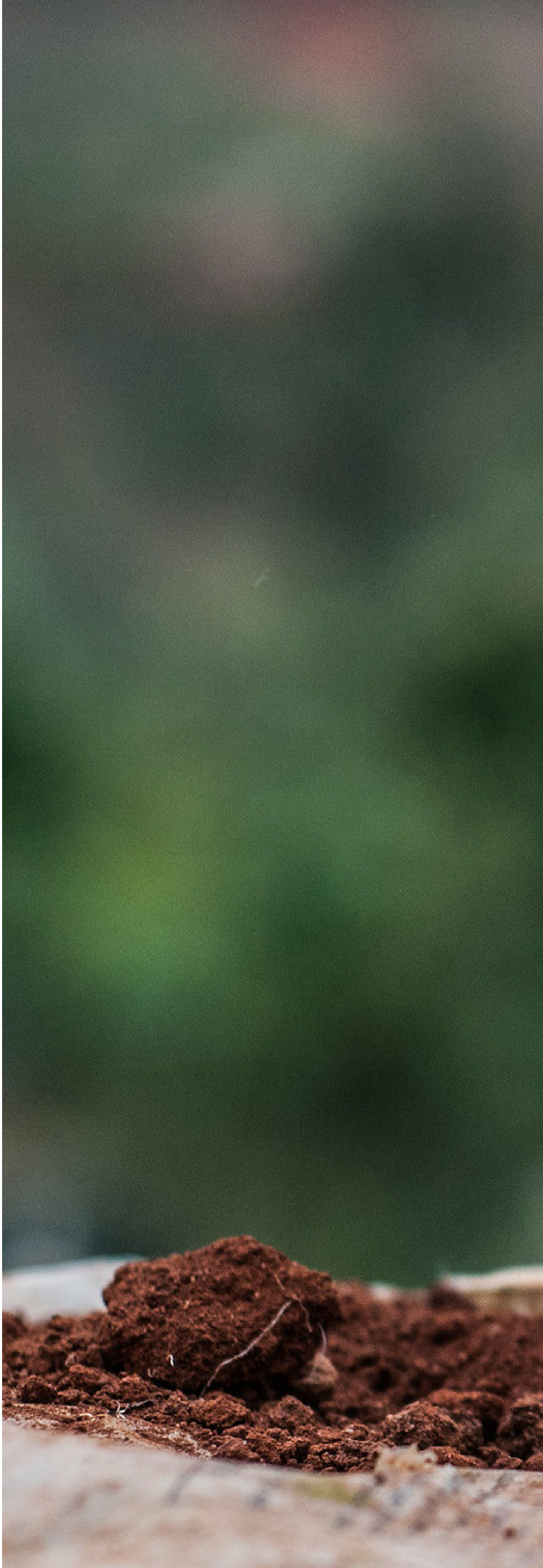
FAW .... Fall armyworm

IITA .... International Institute of Tropical Agriculture

IPM .... Integrated Pest Management

PELUM .... Participatory Ecological Land Use Management

TPP .... Transformative Partnership Platform



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Preface

This technical guide seeks to help farmers and other land managers to better understand the technicalities of a range of innovative agroecological practices, and to share the acquired and applied knowledge with other interested farmers. The guide outlines the central technical aspects of selected innovative agroecological practices and procedures for setting up, implementing, and monitoring the testing of the selected innovative practices.

This guide has been designed within the CGIAR Agroecology Initiative (AE-I). The Agroecology Initiative promotes the application of contextually appropriate agroecological principles by farmers and communities in various contexts, with support from other food system actors. Following a purposive engagement process that led to the participatory formulation of visions for an agroecological future, and a vision-to-action plan, the AE-I team and local partners co-designed innovative agroecologically-based on-farm practices. These practices were subsequently trialed by participating farmers to monitor and investigate their performance.

This manual covers technical aspects for the specific practices that AE-I partners co-designed in the agroecological living landscape (ALL) in Kiambu and Makueni Counties, Kenya. It includes six different practices that are listed under three focus areas, namely soil management, water management, and integrated pest management (IPM). It is structured in four main chapters. The first three address the basic techniques, skills, and materials required for the practices under each focus area, along with introductions of the respective practice's specific functions and benefits. They also provide details about the establishment of field trials for experimentation. The fourth chapter is dedicated to guiding the development of contextually suitable, co-created and participatory trial monitoring and data collection, recording, and analysis approaches.

The manual aims to i) guide users on the technical aspects of specific contextually suitable and co-designed agroecology practices; ii) guide users on trial plot establishment, management, monitoring, and data collection; iii) empower users to find, test, and improve on the application of available innovative agroecological solutions; and iv) encourage users to share and co-create knowledge with other farmers and food system actors to scale suitable agroecological alternatives.

Hezekiah Korir / IITA

1. Introduction

The CGIAR Initiative on Agroecology (or Agroecology Initiative, AE-I) is a collaborative partnership of eight entities of CGIAR, as well as the Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF), and the French Agricultural Research Centre for International Development (CIRAD) under the auspices of the Agroecology Transformative Partnership Platform (TPP). The Initiative is funded by the CGIAR System Council with its first phase (2022–2024) being implemented in eight countries – five in Africa, two in Asia, and one in the Americas. The Agroecology Initiative primarily aims to promote the application of contextually appropriate agroecological principles by farmers and communities in various contexts, with support from other food system actors. The AE-I operates through so-called agroecological living landscapes (ALLs) in each country. The ALLs are geographically bound landscapes in which smallholder farmers, agroecology practitioners, researchers, and other development actors identify, test, and promote on- and off-farm agroecological innovations across sectors and scales.

In Kenya, the AE-I team includes researchers from CIFOR-ICRAF, the Alliance of Bioversity International and CIAT, as well as the International Institute of Tropical Agriculture (IITA) and WorldFish. The AE-I team has fostered the emergence of two ALLs together with territorial and country-level partners: one in Kiambu, and another in Makueni County. The Initiative's interaction and engagement with the ALLs is organized via central points referred to as 'ALL host centers': the Community Sustainable Agriculture and Healthy Environment Program (CSHEP) in Ndeiya, Kiambu County, which focuses on organic agriculture; and the Drylands Natural Resource Centre (DNRC) in Mbumbuni, Makueni County, focusing on permaculture. The ALLs host centers represent and provide a physical space where food system actors can meet, interact, and co-create knowledge.

Drawing on a comprehensive co-creation process (see Fuchs et al., 2023a), which included a detailed assessment of existing agroecological practices (see Kuria et al., 2023), the AE-I team held co-design workshops on testing innovative agroecological practices in the Kiambu and in the Makueni ALL host centers. During the workshops, participating farmers and other food system actors identified, prioritized, and selected one practice in each of the three focus areas of soil, water, and integrated pest management (IPM). The methodical and iterative process included presenting scientific insights on existing and contextually appropriate practices, along with insights into farmers' experiential options and relevant selection criteria, leading to a collaborative prioritization (see Fuchs et al., 2023b). While it is important to highlight that many agroecological practices have multiple purposes and could be listed under several focus areas, the workshop participants chose one specific practice for each focus area (see Table 1).

Table 1: Summary overview of the innovative practices and their controls in the Kenyan ALLs

ALL location	Focus area	Test crop	Test plot (innovation)	Control plot (farmer practice)
Kiambu	Soil	Spinach	Compost manure	Combination of manure and fertilizer
	Water	Spinach	Mulch	Without mulch
	Integrated pest management	Cabbage	Plant-based biopesticide (chili)	Other biopesticides or chemical pesticides
Makueni	Soil	Beans-maize intercrop	Farmyard (animal) manure	None; or a combination of manure and fertilizer
	Water	Beans-maize intercrop	Terraces with planted edges	Terraces with bare edges
	Integrated pest management	Beans-maize intercrop	Plant-based biopesticide (neem)	None; or chemical pesticides

This guide provides specific knowledge and practical insights that can support farmers and other food system actors to better understand the technicalities of the selected practices, and that can help them to share the acquired and applied knowledge with other interested farmers. It outlines the technical aspects of the selected agroecological practices and the procedure for setting up, implementing, and monitoring the testing of the selected innovative practices.

The manual aims to:

- Guide users on the technical aspects of specific contextually suitable and co-designed agroecology practices, namely preparing and using compost manure, mulching and plant-based biopesticides.
- Guide users on trial plot establishment, management, monitoring, and data collection to gain scientific insights into the performance of the selected innovative practices against conventional alternatives in their own context.
- Empower users to find, test, and improve on the application of available innovative agroecological solutions.
- Encourage users to share and co-create knowledge with other farmers and food system actors to scale contextually suitable agroecological alternatives for socioeconomic, and ecological benefits.

This guide consists of four main chapters.

1. The first chapter focuses on the co-designed practices in the **soil management** focus area:

The first sub-chapter describes:

- the basic techniques and skills required to make and apply compost-based manure as a soil-management practice;
- the benefits, preparation of compost manure, characteristics and storage of mature compost manure; and
- how to establish on-farm trials to test performance of the compost manure.

The second sub-chapter describes:

- the different techniques and skills required to make and apply farmyard manure as a soil-management practice;
- the benefits, different modes of preparation, characteristics and storage of farmyard manure; and
- how to establish on-farm trials to test performance of the farmyard manure.

2. The second chapter focuses on the co-designed practices in the **water management** focus area:

The first sub-chapter describes:

- the technical aspects of mulching, i.e. where it is needed, and its benefits and limitations;
- the selection of mulching materials, and their application and maintenance; and
- how to set up on-farm trials to test the effectiveness of mulching.

The second sub-chapter describes:

- the technical aspects of terrace establishment;
- the benefits and limitations, and maintenance; and
- how to set up on-farm trials to test the effectiveness of terraces.

3. The third chapter focuses on the co-designed practices in the **integrated pest management** focus area, including both the chili- and the neem-based bio-pesticides, which describes:

- the basic techniques and skills required to implement IPM;
- the benefits of IPM, and the different IPM methods with focus on plant-based biopesticides;
- the common plant-based extracts that are used to manage pests in crops, and how to prepare them; and
- how to establish on-farm trials to test chilli-based biopesticide as an IPM strategy.

4. The last chapter describes:

- contextually suitable, co-created and participatory trial monitoring and data collection, and
- options and modalities for documentation of and record keeping about the practices under trial.

2. Co-designed practices in soil management

2.1 COMPOST MANURE

Basic techniques and technical skills required to implement the practice

Introduction

Composting is the process of aerobic or anaerobic transformation of organic materials of plant or animal origin into humus through natural decomposition. Compared with uncontrolled decomposition of organic material, decomposition in the composting process occurs at a faster rate, reaches higher temperatures and results in a product of higher quality. Key points are highlighted in bold type.

Benefits/advantages of compost manure

- Improves plant growth and health.
- Provides plant nutrients in a stable organic form.
- Increases plant rooting depth.
- Improves physical, biological, and chemical soil properties.
- Reduces erosion.
- Conserves water.
- Reduces weed germination.
- Moderates soil temperature.

Compost manure preparation

Materials required

- Dry materials, e.g. maize stover, dried grasses, dried leaves, maize husks, rice straw, or hedge cuttings (for hedge cuttings, materials with low carbon-to-nitrogen ratios such as Tithonia diversifolia (before seed-set)[1] are preferable).
- Green plants, e.g., Tithonia diversifolia, fresh grass, green leaves from trees such as Calliandra calothyrsus, Leucaena leucocephala or Sesbania sesban.
- Already composted manure (starter).
- Wood ash.
- Topsoil.
- Water.
- Kitchen waste.

Tools and equipment

- Panga (a machete commonly used in farming activities in Kenya, especially to cut maize stover or tree branches).
- Fork jembe (a local type of garden hoe).
- Spade.
- Watering can.
- Wheelbarrow.
- Banana leaves.
- Tape measure.
- Thermometer stick.

Site selection

- It should be near the place where the compost is to be used. This saves time and labor in terms of the transport of organic material and compost.
- The site should be away from streams, ponds, drainage ditches, wells or any groundwater.
- Consider the direction of the prevailing wind- manure can produce a strong odor during decomposition and should be on the leeward side of the site.
- Accessibility – the site should be accessible.
- A compost heap should always be made outside and not too close to houses. The heap is likely to attract a number of pests, such as mice, rats, termites and other insects.
- The compost heap should be under shade.

Composting procedure

- There should be enough space around the heap to enable the compost to be turned over or examined. A space about 2 to 3 times that of the heap itself is the most practical.

Heaping process

- Start by clearing the spot/location where the compost (heap) is to be made. This should be about 1.2 m (width) and 1.5 m (length) and depends on the amount of composting material you have.
- Use a sharp object (e.g., a panga) to cut/chop your dry materials into segments. Aim for a length of approximately 20 cm. This action will assist in improving the airflow within the pile and make the process of turning the pile easier.

1 *Tithonia diversifolia* can be invasive, so avoid incorporating such species if seeds have set.

- Add a layer of about 10 cm of tough organic material (dry materials) which is difficult to decompose: At the bottom of the pit, place about 10 cm thick of fibrous materials (dry materials from plants that have already seeded) which are difficult to decompose. Examples of dry materials include twigs, straw, hay, maize stalks; dried grasses, dried leaves, maize husks, rice straw, or hedge cuttings. This will help air to easily enter the heap and any excess water to flow away more quickly. Sprinkle water evenly on this layer.

Note: Care should be taken to ensure that the organic materials used are neither diseased, nor showing any form of disease infestation. This is because in case the disease-causing organisms were not destroyed, then there is likelihood of their re-introduction in the compost and a possibility of a later spread when the compost is applied in the field. At all times, it is important to avoid questionable plant materials, such as invasive weeds and weed seeds, diseased plants, plants treated with persistent herbicides, invasive plant species, certain kitchen scraps like citrus peels and onions, wood and leaves with high tannin (e.g. pine [*Pinus patula*], eucalyptus species).

- Add a layer of about 10 cm of fresh organic material, which decomposes easily. The Tithonia diversifolia will be placed after the first layer because it easily decomposes. It should be chopped into small pieces to increase the rate of decomposition.

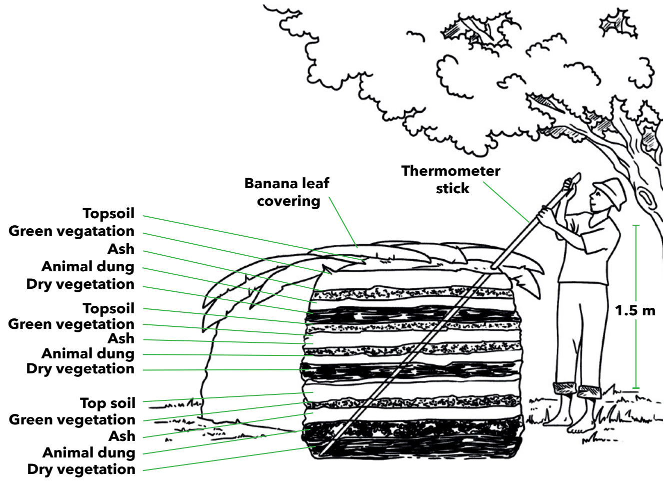
The ***note*** above applies here too.

- Add a 2-cm layer of animal manure, compost or slurry from a biogas tank. This should be included to provide food for the decomposers. The function of this layer is to add nitrogen to enable the microorganisms to function well, and to add phosphate and other plant nutrients. Sprinkle water on this layer to keep the pile moist.
- Apply dust or wood ash to the above layer enough just to cover it. The ash contains calcium and potassium that help in regulating to around pH 6. Sprinkle water on this layer to keep the pile moist.
- The next 15–20cm layer is of green vegetation, such as green plants (preferably leguminous) and kitchen waste that decompose easily. Sprinkle water on this layer too to keep the pile moist.
- On top of this, sprinkle a 2-cm layer of topsoil (or ready-made compost). The soil should be collected from the top 10 cm of clean (moist) soil (e.g., from under trees). This ensures that the right microorganisms are brought into the heap. Sprinkle water on this layer too to keep the pile moist.

Mixing of ready-made compost with organic materials can also be done to introduce the organisms to the heap. The soil not only prevents ammonia produced from escaping but also keeps heat in the heap. Sprinkle water on the whole heap.

- Repeat the process of piling up successive layers starting with the dry material (*difficult to decompose*), followed by *easily decomposable organic material* (e.g. *Tithonia* diversifolia), then animal manure or compost or slurry, then dust/wood ash, followed by green vegetation and lastly, topsoil until the pile is about 1.5m high. Put a final layer of topsoil 5cm thick and cover the whole pile with dry vegetation or banana leaves.
- Drive a dry sharp stick about 2m long into the pile at an angle. Ensure it passes through the pile from the top to the bottom. This stick assists in showing whether the pile is dry or wet and also acts as a thermometer.

Figure 1. Compost preparation using the pile method



Source: Modified from IIRR, 1998.

After initial heaping:

- After approximately three days, decomposition should have commenced within the pile, and when you withdraw the stick, it should feel warm.
- Periodically, remove the thermometer-stick to monitor the pile's progress.
    - If the stick is dry, it's an indication that the pile requires moisture, so be sure to sprinkle water on the pile.
    - Conversely, if the stick feels cold or displays the presence of a white substance, this suggests that decomposition has halted, and the process should be restarted.
- During decomposition the heap has to be turned over regularly, in order that it remains well aerated, and all the material is converted into compost.
    - The first turning over of the heap should be done after 2 to 3 weeks.
    - The second turning overtakes place after 3 weeks and it may even be necessary to turn the heap over again for a third time.
- Repeat the moisture test and the temperature test a few days after each turning over operation.

Figure 2. Turning over of the compost heap

Source: Modified from FAO, n.d.

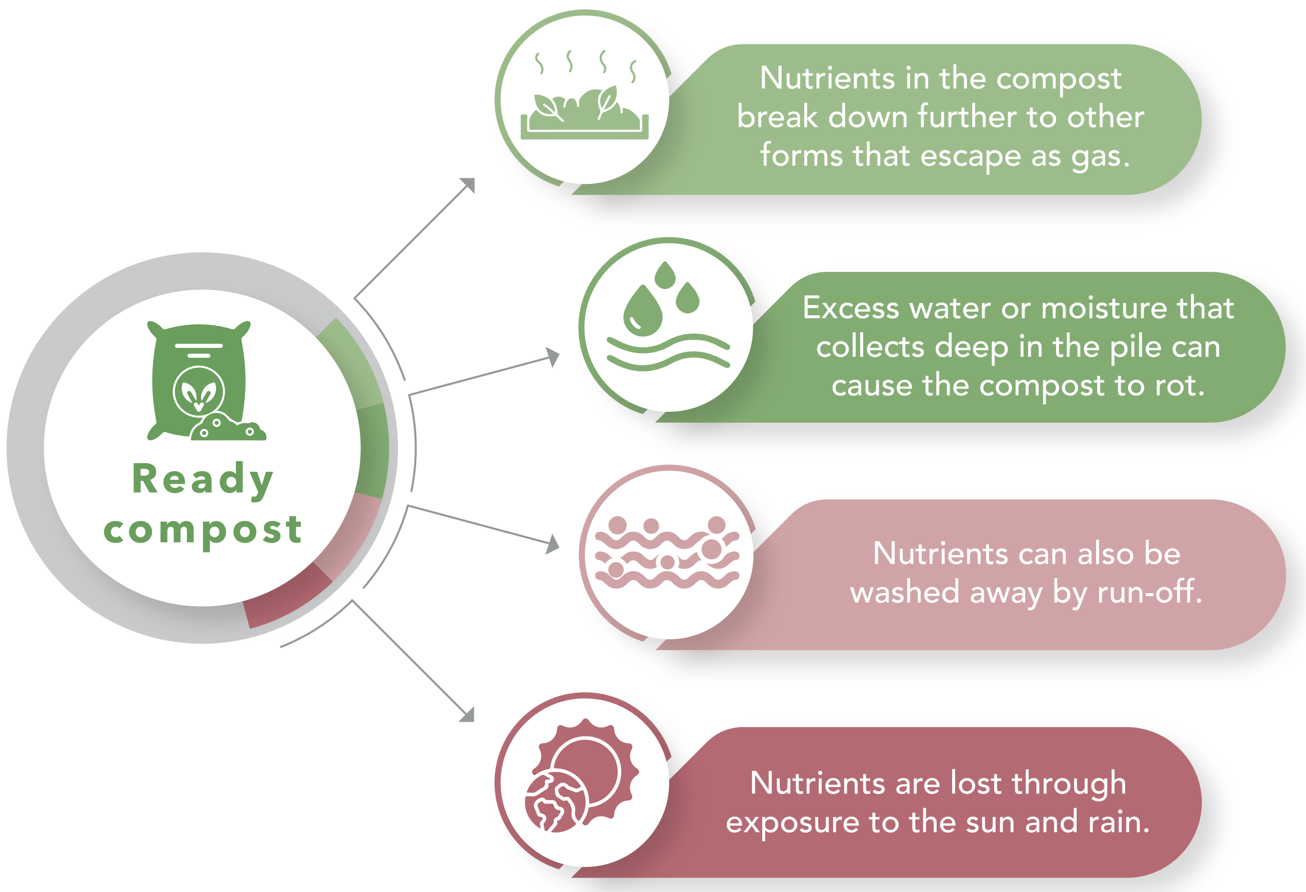
Characteristics of mature compost

- Decomposition is complete if the plant material has changed into an unrecognizable crumbly, dark-brown mass and the waste particle size is reduced.
- It should not be sticky or greasy.
- The volume of the heap reduces. When the waste material is composted, the compost heap height will be reduced by about 30 %.
- To confirm its readiness, continue to monitor the temperature of the pile. If the stick feels warm when you remove it, it indicates that the pile is still in the composting process, and the compost is not yet ready.
- Mature compost should emit a pleasant, earthy smell, which is a good indicator of its maturity and suitability for use on your farm. There should not be any smell of ammonia.

Storage of mature compost

- Compost can be stored for a long time. Compost is at its best for 3 – 4 months after it has matured (however, the longer it is stored, the more nutrients it loses).
- Compost should be stored properly so that it does not spoil.
- Compost should be stored in a shade covered with a layer of topsoil, banana leaves or polythene to regulate and maintain temperature and moisture levels.
- Sacks or storage bags can be used for long storage.

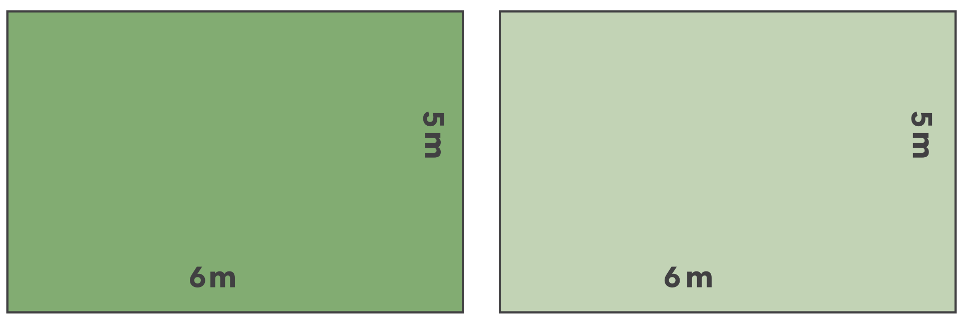
Figure 3. Nutrient-loss pathways in the compost



Trial establishment for testing compost as a soil management strategy

Trial setup

- Collect soil samples according to standard sampling procedures[2] from the fields to determine nutrient levels.
- Establish two plots: a control and a test plot.
- Each plot (test and control) to measure 6 m x 5 m (30 m²) as shown below.
- As a recommendation, the two plots should be located side by side to minimize the effect of farm variations.
- Prepare the plots before the onset of rain.
- The orientation of the plots/beds should across the slope in case of a sloping land
- For the test plot, apply compost in the planting holes and thoroughly mix with the soil at the rate of 4 t/ha (12 kg per plot), while for the control, adopt the normal farmer practice.



2 The samples are to be taken in a 'W' pattern sample points using a trowel to a depth of 15 cm, put in a bucket, mixed into a composite and a representative sample of about 500 g taken. The samples should be well labelled with proper details involving dates of sampling, locality, name of the farmer, plot, crop, practice, etc.

- Transplant spinach (Spinacia oleracea) seedlings from a previously prepared nursery, at the spacing of 30 cm x 30 cm.
- Transplanting should be done late in the evening when the temperature is low.
- The soil should be wet before uprooting them from the nursery to prevent root damage.
- Plant the seedlings in the beds at the same depth they were previously growing at while in the nursery.

Box 1: Vegetable nursery bed establishment

Nursery site selection

- Locate the nursery bed close to the main field to minimize damage to seedlings during transportation.
- Locate it near a water source.
- Shield it from strong winds.
- Avoid water-logged areas.
- Avoid slopy areas to prevent soil erosion and loss of seedlings.

Nursery bed preparation

- Dig the nursery area to a depth of at least 15 cm.
- Remove stones and clots from the bed and level it.
- Spread mature compost or farmyard manure and mix it into the soil. These should be of very fine particles.
- Raise the beds 15-20 cm above the ground.
- Make the nursery bed approximately 1 meter wide for easy access to all parts of the bed.
- The length of the nursery bed depends on the size of the field to be planted.
- Leave a space of about 40 cm between nursery beds to facilitate management operations such as weeding and disease control.
- ***Note:*** The nursery bed should be oriented to run from East to West direction, and lightly covered on top. This helps avoid direct sunlight in early stages of seedling growth.

Planting seeds

- Make rows of about 15 cm apart using a string to ensure straight lines.
- Create shallow furrows, no deeper than 2 cm, along the marked lines.
- Sow the seeds singly along the rows and cover them with a thin layer of soil.
- Ensure to use high-quality and/or certified seeds.
- Cover the nursery bed with mulching materials, preferably dry grass.
- Water the nursery thereafter; and keep them moist throughout but avoid over-watering as this may lead to rotting of roots and diseases incidences.
- Watering is better done in the morning, afternoon and evening; and only morning and evening depending on the stage of growth of the seedlings.
- Inspect the nursery after 4-5 days to check if the seeds are germinating then remove grass mulch.
- Regularly employ the most appropriate measures to control weeds*, pests and diseases. Weeds can often be hand-picked, and pests/diseases sprayed using the most appropriate pesticides (biopesticides).
- Monitor the nutrient requirements and supplement accordingly with the most appropriate organic fertilizers
- About 3 weeks after seedling emergence, slowly start hardening off the seedlings by slowly removing the shading, reducing the frequency/intervals of watering and the amount of water used in preparation for transplanting.
- On average, under proper management, vegetable seedlings are ready for transplanting 21–30 days after sowing.

** In some instances, nutrient demands ensue and this needs to be arrested as quickly as possible. Caution should be taken not to apply too much of fertilizers to cause overgrowth, etc. and to avoid contact with the plants due to scorching aspects.*

Trial management

Weeding

Weeds compete with the crop for growth factors like nutrients as well as harboring pests and diseases. They should therefore be controlled. Since spinach roots are shallow and easily damaged, care must be taken when weeding.

Pest management

Plant-based biopesticides will be used to manage pests once pests are noticed on the crops.

2.2 FARMYARD MANURE COMPOST

Basic technical skills to implement the practice

Introduction

Farmyard manure is an organic fertilizer made from the waste products of farm animals, predominantly cattle, but also goats, sheep or chicken, among others. This manure, which includes dung and urine, in the case of cattle, is rich in essential nutrients that are crucial for plant growth.

Benefits of farmyard manure

- Helps to improve the soil structure.
- It expands the capacity of the soil to hold more water, water infiltration and minerals.
- It also boosts the soil's microbial activity, which improves mineral delivery and plant nutrition.
- Manure increases plant productivity.
- Composted manure can improve enzyme activity and bacterial diversity in soils.
- It plays a crucial role in eliminating harmful ammonia gas from manure.
- It also eliminates harmful pathogens and weeds.
- It provides a generous amount of organic matter to the soil.
- Adding cow manure compost breaks up the compacted soil and improves the aeration of the soil.
- Composted cow manure also contains beneficial bacteria, which convert nutrients into readily accessible forms.
- The nutrients can be slowly released without burning tender plant roots.
- Composting cow manure also produces fewer greenhouse gases, making it environmentally friendly.

Composting techniques

Material requirements

- Animal manure.
- Beddings from the animals' shed.

Site selection

- Composting should take place on an area that drains well but where runoff or leachate will not reach the waters of the state.
- The pad ideally should drain into a containment pond. The site may not be located along surface waters of the state, on soil textures coarser than a sandy loam or within a flood plain.
- Ideal areas are well-drained, have slopes of 2 to 4 percent, consist of concrete or packed soil or gravel and drain into a containment pond.

Method of preparation of farmyard manure compost

Pit method

- In this method, the manure is stored in a pit with non – absorbent bottom and sides.
- The pit is provided with a bund at the rim of the pit to prevent the surface run-off of water during rainy season.
- The dimensions of the pit can be variable depending on the quantity of dung, urine and litter produced on the farm per day.
- The losses also occur in this method due to exposure to sun and rain, but it is relatively a better method than the heap method.

Rex Maina

Figure 4. Flow chart showing the process of farmyard manure preparation using the pit method

Site selection
- Select a location near the homestead for making the farmyard manure.

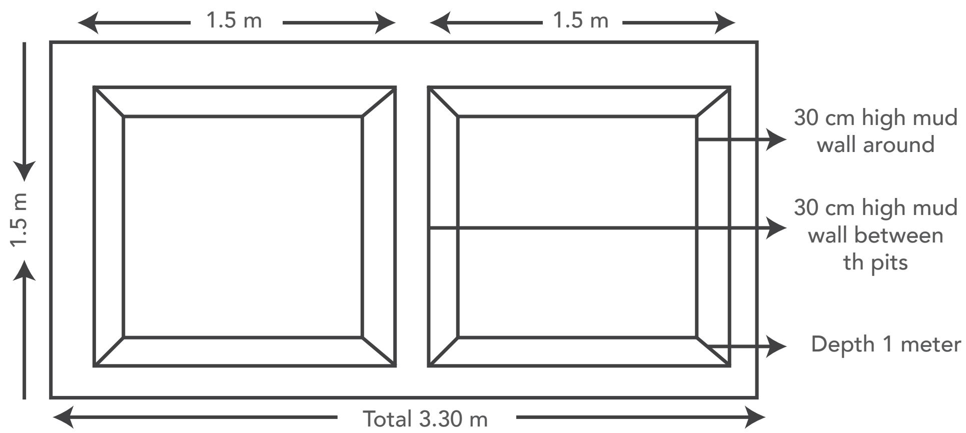
Pit Excavation
- Excavate two pits.
- Size of each pit should be 1.50 meters long by 1.50 meters wide by 1.00 meters deep, with about 30-centimeter distance between them.
- The walls of the pit should be sloped to prevent soil from breaking away and filling the pit.

Shade
- Make a hut over the pits with bamboo nets, hut-making materials, or tin so that sun or rainwater cannot enter.

Filling the pit
- Fill the pit with the cattle dung and animal beddings.
- The litter in the first pit will turn into manure within one to one and half months depending with the type of the animal manure and weather conditions during decomposition.

Turning
- Make a hut over the pits with bamboo nets, hut-making materials, or tin so that sun or rainwater cannot enter.

Figure 5. Designing the two pits for manure preparation



Heap method

- Manure is heaped on the ground, preferably under the shade of a tree.
- Cover with a layer of litter /ash / earth to prevent the loss of moisture and to avoid direct exposure to sun.
- Put up a small bund around the base of the heap to protect against surface run-off washing out the manurial ingredients.
- Cover the exposed portion of the heap with banana leaves or any other available material.

Note:

- The maximum losses of nutrients occur in this method of storage, resulting in poor quality manure.
- Direct exposure to the vagaries of climate such as sunshine and rainfall causes looseness and dryness of manure, which hastens the losses of nutrients and rapid oxidation of organic matter.

Figure 6. Manure preparation using the heap method

Photos: Peter Bolo / CIAT

Covered pit method

- Of all the methods described, this is the best method.
- In this method, the bottom and sides of the pit are made non-absorbent by granite stone lining.
- The pit is also provided with a bund of 1½ feet height to prevent surface flow of water (rainwater) and a suitable cover by way of roofing with locally available materials such as banana leaves.
- Organic matter and nutrient losses can be effectively controlled in this method of storage in order to obtain better quality manure.

Application

- Add the appropriate amount of the mature composted farmyard manure to the soil (approximately 4 tons of well decomposed manure is required per hectare depending on the nutrient quantity in the manure, soil nutrient status and crop type.
- After planting is completed, add water to the plant. This water will lead the plant to absorb the nutrients in the farmyard manure compost along with water.

Caution when using farmyard manure

- Manure left unincorporated for even a couple of days can lose a significant part of its nitrogen content through volatilization.
- Fresh manure can possibly transmit pests and disease to crops, so fresh manure should not be used as a side-dress fertilizer.
- Use of raw manure can sometimes increase weed problems. Some manure contains weed seeds from bedding materials. This problem can be eliminated if using composted manure.
- Fresh manure can burn seedling roots. Manure should be tested before applying to soil.

Trial establishment for testing farmyard manure as soil management strategy

Soil and manure nutrient analysis

- Collect soil samples from the fields and send soil samples to a laboratory for analysis to determine nutrient levels and pH.
- Sample the manure and send for analysis of the nutrient composition

Trial setup

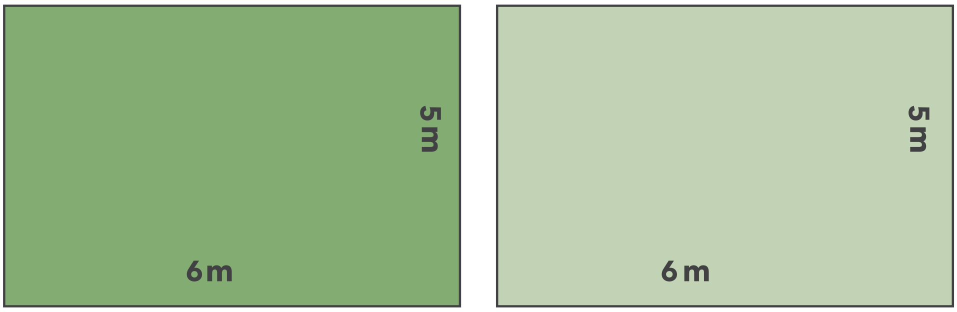
Tools and equipment required

- Tape measures.
- Plot tags.

Process

- Prepare the land before the onset of the rains.
- Collect soil samples according to standard sampling procedures[3] from the fields to determine nutrient levels.
- The trial should consist of two plots (test and control). As a recommendation, the plots should be located close to each other to prevent any disparities. The orientation of the plots/beds should be across the slope in case of sloping land.
- Each plot (test and control) should measure 6 m x 5 m (30 m^2) as shown below.

The test plot should receive farmyard manure at the rate of 4 t/ha (12 kg per plot) while the control plot should receive the usual farmer practices of soil management.



Planting

- Intercrop the maize and beans from the local varieties adapted to the region (i.e., maize varieties *Kinyaanya*; and beans *Katumbuka* for Makueni County).

Spacing

- Maize: plant maize seeds singly at 75 cm x 25 cm.
- Beans: plant beans between the maize rows at an interrow spacing of 10 cm.

Trial management

Weeding

- Weeding should be done depending on the weed pressure.

Pest management

- Use plant based biopesticide to manage pests once pests are noticed on the crops.

3 The samples are to be taken in a 'W' pattern sample points using a trowel to a depth of 15 cm, put in a bucket, mixed into a composite and a representative sample of about 500 g taken. The samples should be well labelled with proper details involving dates of sampling, locality, name of the farmer, plot, crop, practice, etc.

3. Co-designed practices in water management

3.1 MULCHING

Basic techniques and technical skills required to implement the practice

Introduction

- Mulch is any organic or non-organic material that is used to cover the soil surface to protect the soil from being eroded away, reduce evaporation, increase infiltration, regulate soil temperature, improve soil structure, and thereby conserve soil moisture.

Mulching materials

- Different materials are used, including organic mulch that is either living or dry (e.g., from grass, straw, hay, bark, or leaves)

Where is mulching suitable?

- Drought and weed prone areas.
- Low to medium annual rainfall areas.
- Dry soil conditions/areas.
- Soils with good drainage.

Table 2. Benefits and limitations of mulching

Advantages/benefits	Limitations
○ Reduces weed infestation.	○ Crop residues are also needed as fodder.
○ Enhances soil structure and microbial activity.	○ Plant material may sprout and become weedy.
○ Provides nutrients to the crops when they decompose.	○ May create conditions for increased pests and diseases.
○ Increases soil organic matter.	○ Dried material may be a fire hazard.
○ Protects soil from wind and water erosion.	○ Difficult to spread on steep slopes.
○ Improves infiltration of rain and irrigation water.	
○ Reduces evaporation, enhancing efficient water use.	
○ Reduces surface run-off velocity thereby reducing erosion.	

Selection of mulching materials

What to consider

- Materials which easily decompose will protect the soil only for a short time but will provide nutrients to the crops while decomposing.
- Hardy materials will decompose more slowly and therefore cover the soil for longer.
- Always use materials that are free from weeds, pests and diseases.
- The materials should have a high water-retention capability and be permeable.
- Where soil erosion is a problem, slowly decomposing mulch material (low nitrogen content, high C/N) will provide long-term protection compared to rapidly decomposing material.

Mulch material: Use locally available materials.

- Cover crops
- Crop residues
- Grass
- Pruning material from trees

Preparation: Dry the mulch material to reduce moisture content and facilitate easier application.

Figure 7. Mulch application in vegetables in Kiambu ALL

Photos: Beatrice Adoyo / CIFOR-ICRAF

Mulch application: key things to consider

Table 3. Key aspects of mulch application

What to consider	How to do it
Depth of mulch	Apply a layer of mulch that is approximately 5-10 cm thick. This can be done gradually.
Spacing	Ensure that there is sufficient space between the mulch and the plant to facilitate air circulation and minimize pest attack (cutting insects) on the plant.
Timing	If possible, the mulch should be applied before or at the onset of the rainy season, as then the soil is most vulnerable.

Note:

- If the mulch layer is not too thick, seeds or seedlings can be directly sown or planted in between the mulching material.
- On vegetable plots, it is best to apply mulch only after the young plants have become somewhat hardier, as they may be harmed by the products of decomposition from fresh mulch material.
- If mulch is applied prior to sowing or planting, the mulch layer should not be too thick to allow seedlings to penetrate it.
- Mulch can also be applied to established crops and is best applied directly after digging the soil.
- It can be applied between the rows, directly around single plants (especially for tree crops) or evenly spread on the field.
- Increase the thickness of the mulch when the weather is too dry and reduce it when it is too wet.

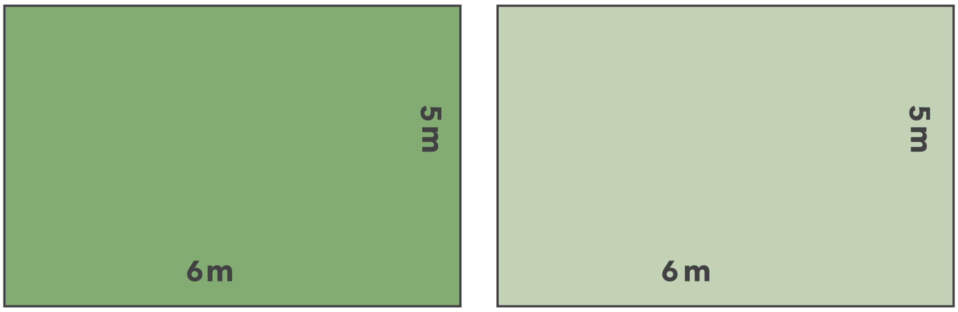
Maintenance of mulch material

- *Regular Inspection*: Check the mulch layer periodically to ensure it hasn't thinned or shifted.
- *Weed Management:* Monitor for weed growth at the mulch edges and remove any weeds promptly.
- *Irrigation Management:* Adjust irrigation practices based on soil moisture levels under the mulch.

Trial establishment for testing mulching as a water-management strategy

Trial setup

- Collect soil samples according to standard sampling procedures[4] from the fields to determine nutrient levels.
- The experiment should consist of two plots each measuring 6 m x 5 m (30 m²) (test and control plot).
- The orientation of the plots/beds should be across the slope if on sloping land.
- The inter-row spacing for spinach should be 30 cm, with an inter-plant distance of 30 cm within the same row.



- Grass hay should be used as mulch for the test plot while for the control plot, it will be the farmers' normal practice in relation to soil-water management.
- The mulch materials are to be applied to the plots by hand per treatment after transplanting by measuring the thickness of 5-10 cm (2-4 inches).
- The materials should be applied both in between the rows and around the crops.

3.2 TERRACES

Basic technical skills to implement the practice

Introduction

Terrace farming refers to the technique of creating flat, levelled steps or terraces on sloping land to facilitate agricultural cultivation. By constructing these terraces, farmers transform steep slopes into manageable and productive farmland. Based on the benefits of terrace farming, the Agroecology Initiative strives to co-create knowledge on communal challenges to agroecological transition.

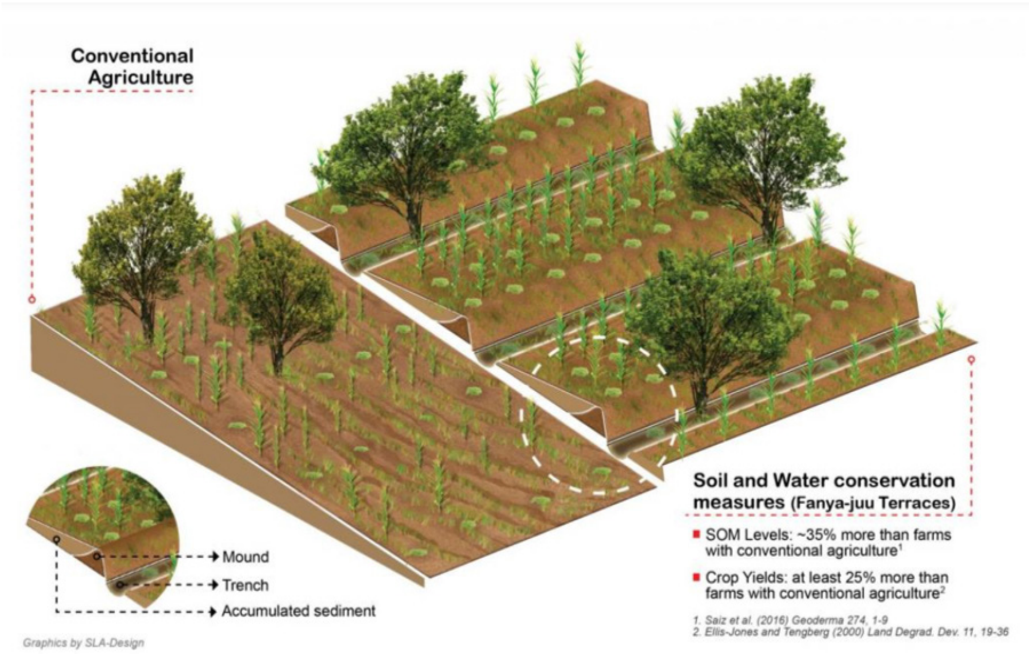
Contexts where terraces can be useful

- Slopes with erodible soils
- Where other farming practices such as contour farming and crop rotation are not sufficient measures to prevent soil loss.


Hezekiah Korir / IITA

4 The samples are to be taken in a 'W' pattern sample points using a trowel to a depth of 15 cm, put in a bucket, mixed into a composite and a representative sample of about 500 g taken. The samples should be well labelled with proper details involving dates of sampling, locality, name of the farmer, plot, crop, practice, etc.

Figure 8. Illustration of the *Fanya-juu* terraces



Source: Shisanya, 2017

Benefits of terraces

Soil conservation: The terraces act as physical barriers, preventing erosion and ensuring long-term soil fertility.

Water management: The terraces in terrace farming allow for efficient water management. They slow down water runoff, promoting water infiltration and reducing the risk of soil erosion.

Increased agricultural productivity: By creating level steps, terrace farming optimizes the distribution of sunlight, water, and nutrients to crops. This results in improved yields and enhanced agricultural productivity. Additionally, terrace farming allows for diverse crop cultivation, making efficient use of limited land resources.

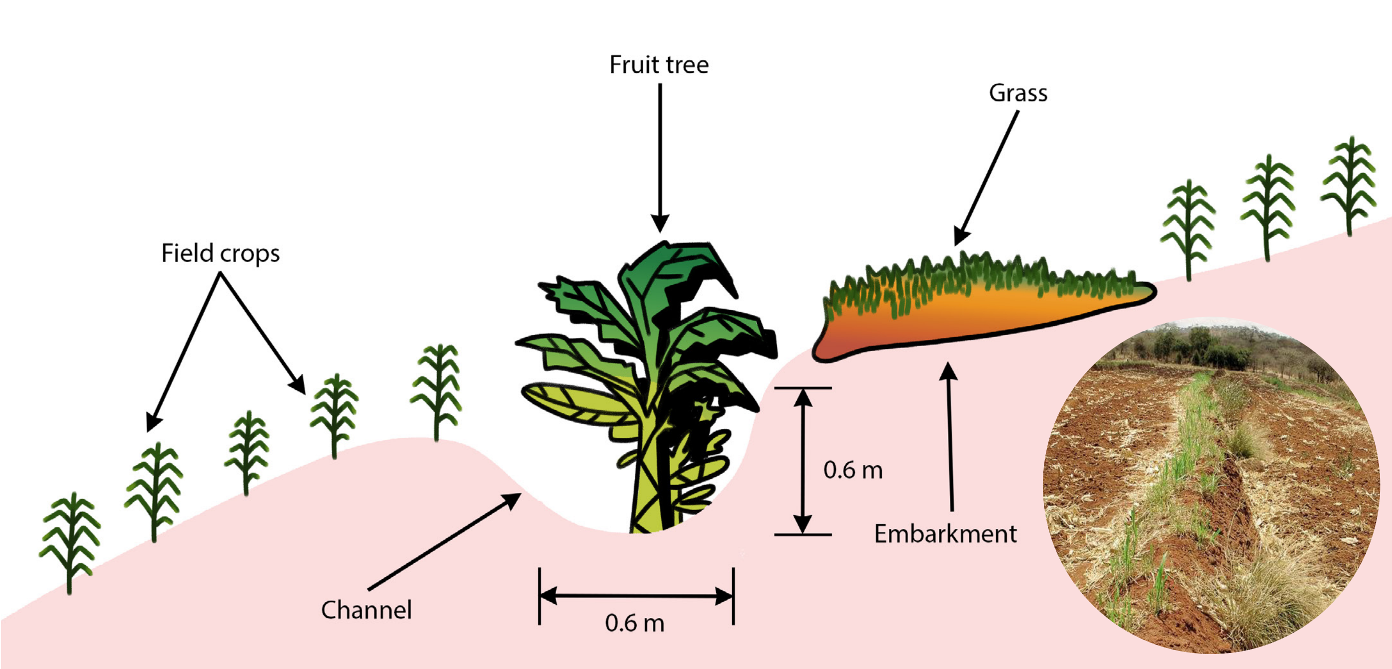
Environmental sustainability: Terrace farming promotes sustainable agriculture by minimizing the negative impacts of farming on the environment. It reduces soil erosion, conserves water resources, and preserves biodiversity by creating habitats for various plant and animal species.

Maintenance of terraces

The terraces must

- be spaced correctly,
- have adequate ridge height,
- have adequate channel cuts to provide the necessary water storage,
- have properly-sized outlets, and
- be planted with grasses such as Napier grass on the terrace edge to help stabilize them.

Figure 9. Maintenance of terrace edges with grass bunds, e.g. Napier grass



Source: Modified from Mati, 2006

Consequences of abandoned terraces

- Deterioration of soil quality.
- Higher risks for soil erosion.

Trial establishment for testing terraces with planted edges as water management strategy

Baseline soil sampling

Soil samples should be collected from each farm and sent to the laboratory for determination of physico-chemical and nutrient levels analysis.

Trial setup

- Collect soil samples according to standard sampling procedures[5] from the fields to determine nutrient levels.
- The trial should consist of two plots. As a recommendation, the plots should be located side by side to prevent any disparities. The orientation of the plots/ beds should cross the slope in case of sloping land.
- Each plot (test and control) should measure at least 6 m x 5 m (30 m^2) as shown below.

The test plot should comprise an area within the terraces having the edges planted with Napier grass while the control plot should comprise the normal farmer terrace management (commonly left bare or planted with trees on the terrace edges).

Planting: The maize and beans should feature in the intercropping pattern.

Spacing

Maize: Inter row spacing (75 cm) and intra-row spacing (25cm).

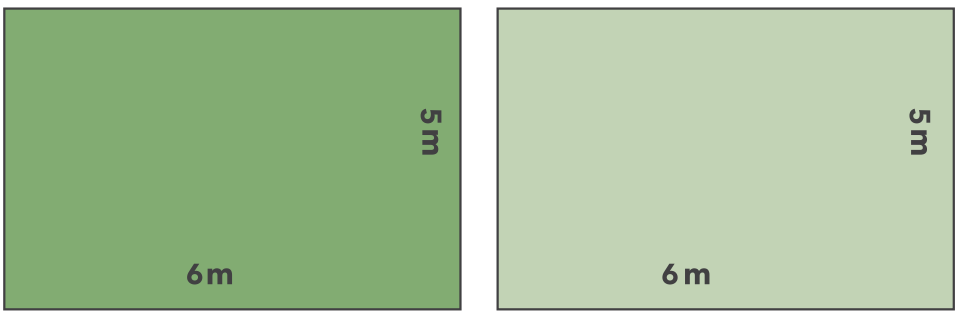
Beans: between the maize rows (approx. 37.5 cm) and 10 cm within the row.

Trial management

Compost/manure application: Apply a uniform amount of compost/manure for both test and control plots: 1-2 handfuls per hole.

Weeding: Weeding should be done frequently depending on the weed pressure.

Pest management: Use IPM techniques to manage pests once they are observed on the crop.



5 The samples are to be taken in a 'W' pattern sample points using a trowel to a depth of 15 cm, put in a bucket, mixed into a composite and a representative sample of about 500 g taken. The samples should be well labelled with proper details involving dates of sampling, locality, name of the farmer, plot, crop, practice, etc.

4. Co-designed practices in integrated pest management

4.1 BASIC TECHNIQUES AND TECHNICAL SKILLS REQUIRED TO IMPLEMENT THE PRACTICE

Introduction

Integrated pest management (IPM) is an ecosystem-based approach to pest management that combines several approaches to ensure an ecologically sound ecosystem. IPM addresses challenges in food systems holistically. Pest management creates a more balanced ecosystem by manipulating the pest population to maintain them below the economic injury levels. This is unlike the concept of pest control. IPM's great impacts are on the accumulation of small actions that reduce pest numbers below an economically damaging level, since it is not necessary to eliminate all pests.

Benefits of IPM

- Key benefits of IPM are that they reduce losses from pests, reduce the risk of pest resistance developing and optimize use of inputs. This increases farm productivity.
- Caution should be taken in the selection of pest management approaches to be incorporated.
- Since each approach presents potential adverse impacts to health, safety precautions should be taken during the preparation and application of any type of pesticides.

IPM methods

IPM consists of key methods of pest management which include:

- Cultural methods: These include crop rotation; push-pull farming techniques (using repellent "push" plants and trap "pull" plants); mulching, using clean planting materials; timely planting, composting, weeding, irrigation, pruning; fallows to break pest cycles and crop hygiene maintenance.
- Physical methods: These involve reducing pest population by using devices which affect the pests physically or alter their physical environment. These practices include using barriers and traps (i.e., yellow and blue traps), shade nets, knocking pests off plants with water jets, soil solarization or heat treatment, and behavioral methods: These latter use natural and/ or artificial signals, such as pheromones, kairomones, and sounds or vibrations to interfere with fundamental pest behavior, such as feeding and mating. They include using repellent plants (e.g., Mexican marigold [Tagetes minuta], chili pepper [Capsicum annuum L.), onions [Allium cepa], and Sodom apple [Solanum incanum]).
- Chemical methods: These involve many types of compounds which can:
  - repel or confuse pests,
  - interfere with insect molting processes or development,
  - be broadly toxic to living systems (some botanicals and most conventional insecticides).
- Biological control methods: These deploy other living organisms (natural enemies) to control pests. They include predators, such as ladybirds, or praying mantises; parasites such as Aphelinidae (parasitic wasps); pathogens such as Bacillus thuringiensis; and pest competitors (e.g., lady beetles, hoverflies and lacewings).

Plant-based or botanical biopesticides are a particular kind of biological control method (and are sometimes listed under chemical methods): These include aloe (*Aloe vera* or *Aloe secundiflora*), banana (*Musa ssp.*) peel, chili pepper (*Capsicum annuum L.*), garlic (*Allium sativum*), Melia (*Melia azedarach*), Mexican marigold (*Tagetes minuta*), neem (*Azadirachta indica*), onions *(Allium cepa)*, pawpaw (*Carica papaya*) leaves, pyrethrum (*Chrysanthemum cinerariifolium*), Sodom apple (*Solanum incanum*), Tephrosia (*Tephrosia vogelii*), and Tithonia (*Tithonia diversifolia*). The modes of action and target pest/insects of some of the plants are listed in the table below.

Table 4. List of plant-based biopesticides and their use

Plant	Active ingredient/mode of action	Target pests
Aloe (*Aloe vera* or *Aloe secundiflora*) 	Aloe shavings can be used in warding off insects.	Aphids, loopers, armyworms, spider mites, thrips, leaf miners and whiteflies.
Banana peels (*Musa* ssp.) 	Banana peels contain high concentration of potassium and tannins making it unappealing for the insects.	Aphids and Ants.
Chili pepper (*Capsicum annuum* L.) 	Capsicin is the active ingredient in chili peppers. Chilies act as a stomach poison, antifeedant and repellent.	Aphids, loopers, armyworms, spider mites, thrips, leaf miners and whiteflies.
Garlic extracts (*Allium sativum*) 	Anti-feedant (stop insects feeding), bacterial, fungicidal, insecticidal, nematicidal and repellent properties.	Ants, aphids, armyworms, and other caterpillars, whitefly, and mites, as well as fungi bacteria and nematodes.
Melia (*Melia azedarach*) 	Inhibits the larval growth of most insect pests.	Locust, ants, aphids, armyworms, caterpillars, whitefly.
Mexican marigold (*Tagetes minuta*) 	It has fungicidal, insecticidal, nematocidal and repellent properties.	aphids, blowflies, caterpillars, diamondback moths, ants, maggots, termites, flies and nematodes.

Plant	Active ingredient/mode of action	Target pests
Neem (*Azadirachta indica*) 	Azadirachtin is the active ingredient. It acts on insects by repelling them, by inhibiting feeding, and by disrupting their growth, metamorphosis and reproduction. Neem-based formulations usually do not kill insects directly, but they normally alter their behavior to reduce pest damage to crops and reduce their reproductive potential.	Aphids, loopers, armyworms, spider mites, thrips, leaf miners and whiteflies
Onions (*Allium cepa*) 	Allicin is the active ingredient in onions. Onion has anti-feedant, insecticidal and repellent properties.	White flies, ants, spider mites, thrips
Pawpaw (*Carica papaya*) 	Ripe pawpaw fruit extract may be an effective insect feeding deterrent.	Striped cucumber beetle.
Pyrethrum (*Chrysanthemum cinerariifolium*) 	Pyrethrum induces a toxic effect in insects when it penetrates the cuticle and reaches the nervous system leaving the insects paralyzed. Pyrethrum may also have a repellent effect. Pyrethrum contains a pyrethroid contact poison; the target pest must be present and hit by the spray.	Aphids, apple maggot, caterpillars, leafhoppers, whiteflies.
Sodom apple (*Solanum incanum*) 	Sodom apple fruit extracts have nematicidal compounds.	Root-knot nematodes.
Tephrosia (*Tephrosia vogelii*) 	The active ingredient in Tephrosia is rotenone. Crops that have had this extract applied show significant decreases in insect and other pest activity.	Armyworm, aphids, and mites.

Plant	Active ingredient/mode of action	Target pests
Tithonia (*Tithonia diversifolia*) 	Acts as a repellent for insects.	Aphids, weevils, termites and whiteflies.

4.2 PROCEDURE FOR PREPARING PLANT-BASED BIOPESTICIDES

Introduction

Farmers in both Kiambu and Makueni have been using a mixture of different plant extracts including chili pepper (*Capsicum annuum L.*), Mexican marigold (*Tagetes minuta*), neem (*Azadirachta indica*), Sodom apple (*Solanum incanum*), and Tephrosia *(Tephrosia vogelii)*. However, during the training workshop discussions, it was evident that the farmers were not sure which of the plant extracts in the mixture actively controlled the pests. To test the effects of plant-based biopesticides, the farmers in Kiambu selected chili pepper-based biopesticide for the management of aphids in cabbages, and the farmers in Makueni selected neem-based biopesticides for managing various pests on maize-bean intercrop.

Since the basic preparation method is similar for all biopesticides, this guide provides the steps followed in the preparation of biopesticide based on chili, neem, and a few selected other locally available plants used by the farmers.

Note: Some methods may be available that involve mixing the ingredients, however, the concentrations of active ingredients have not been tested.

Procedure

The procedure for preparing all the biopesticides included in this guide is the same and includes three main steps:

Step 1. Initial preparation of the specific plant material.

Step 2. Infusion of the plant material mix in soap solution.

- use 10 g non-perfumed soap and 1 cup of water
- stir in the soap until it makes bubbles
- cover tightly, and let it rest in a cool place for 24 hours.

Step 3. Dilution of the infused plant material

- mix in an equal amount of water (5 litres)
- shake well and strain/sieve before use.

When the biopesticides are ready, they can be sprayed on the crops. They will remain effective for 7 days after preparation. The specific instructions for how to prepare the different plant material mixes are included in the following table:

Table 5. Initial preparation of a selection of different plant material mixes

Plant material	Preparation
Aloe *(Aloe vera* or *Aloe secundiflora)*	Take 20 fresh young leaves, crush, and mix with 5 liters of water.
Chili pepper *(Capsicum annuum* L.)	Take 1 kg of hot chili pepper, grind/crush, and mix with 5 liters of cold water. Caution: Do not apply to tomatoes, cucumber, potatoes, mango, pumpkins, and any other *Solanaceae* family members. Alternative: For immediate use, boil the mixture (crushed chili pepper and 5 liter water) for 45 minutes, leave it to cool, mix with soapy water, dilute it (dilution ratio 1:1) before use.
Neem *(Azadirachta indica)*	Take 2 kg of fresh leaves or 250gm dry, ground tissue (bark, seeds, leaves, or roots) and mix with 5 liters of cold water.
Pawpaw *(Carica papaya)*	Take 2 kg of fresh young leaves, grind leaves and mix with 5 liters of water but do not boil.
Tephrosia *(Tephrosia vogelii)*	Take 2 kg of fresh young leaves or 250 g of dry, ground leaves and mix with 5 liters of water but do not boil.

Figure 10. Preparation of a plant-based biopesticide using Tephrosia

Photos: Beatrice Adoyo / CIFOR-ICRAF

Figure 11. Illustration on preparation and application of plant-based biopesticide.

Photos: Beatrice Adoyo / CIFOR-ICRAF

4.3 TRIAL ESTABLISHMENT FOR TESTING PLANT-BASED BIOPESTICIDES

Trial setup

- Collect soil samples according to standard sampling procedures[6] from the fields to determine nutrient levels.
- Send soil samples to laboratory for analysis.
- Two plots each measuring 6m x 5m (30 m^2) (test and control plot).

Planting (in Kiambu)

- Planting spacing (cabbage) to be inter-row spacing 50 cm and intra-row spacing of 40 cm planted in raised beds for ease of operations. Each bed should have three rows of cabbage.
- The orientation of the plots/beds should be across the slope on sloping land
- Use the prepared biopesticide on the test plot, and use the normal farmer practice on the control plot.

Planting (in Makueni)

- The maize and beans should be intercropped using the locally adapted varieties.

Spacing

- Maize: 75 cm x 25 cm.
- Beans: between the maize rows and planted at spacing of 10 cm between plants in row.

6 The samples are to be taken in a 'W' pattern sample points using a trowel to a depth of 15 cm, put in a bucket, mixed into a composite and a representative sample of about 500 g taken. The samples should be well labelled with proper details involving dates of sampling, locality, name of the farmer, plot, crop, practice, etc.

Spraying

- Spray the plant material extracts
  - once pest infestations have been observed on the crop[7], and
  - in fine weather - not when windy/rainy; preferably in the evening or morning hours before noon.
- Apply at weekly intervals, unless other intervals are determined according to the specific biopesticide efficacy.
- Spray early in the morning or later in the evening depending on the pest feeding time and their vulnerable growth stages and target stage of growth i.e., egg, larvae, pupa or adults.

Trial management

Compost/manure application: Apply a uniform amount of compost/manure for both test and control plots: 1-2 handfuls per hole.

Weeding: Weed frequently depending on the weed pressure.

Aphid monitoring

- Randomly select five plants in the field, tag each plant for assessing insect pest abundance, for example using a piece of wood/stick placed beside the sampled crop.
- Scout for aphids once a week before spraying plant material extracts.
- Monitor actual insect counts on each plant every two weeks just before spraying.

7 This measure avoids routine spraying and reduces the risk of any possible development of pesticide resistance.

5. Trial monitoring and recording of practices

This section describes trial monitoring and data collection in detail, regarding the documentation and record-keeping of the practices to be carried out in the trial plots.

- To monitor the effect of the practice, the farmers will have a template where they will record all the practices carried out on the plots, such as the planting dates, weeding frequency, labor, inputs, pest control, costs related to the practice implementation, etc.
- To monitor the effect of implementing the innovative practice on the household, data on the following activities/outcomes related to each innovative and control (conventional) practice will be recorded in the course of the practice implementation for each crop.
- Record all the activities/practices/outcomes done for both the test and control plot in the practice table (Annex 1).

5.1 AGRONOMIC DATA COLLECTION

Agronomic data collection for spinach

Materials needed

- Ruler/ measuring tape.
- Data collection template.
- Portable weighing scale.

Take data from each plot leaving the outermost rows at both sides of plots which will be considered as borders. Measure the growth parameters at 2-week intervals from the initial spinach harvest and record in table below:

Table 6. Data collection on the effect of mulch on growth and yield of spinach

S/No.	What to measure	When to measure	How to measure
1	Number of leaves	2-week interval	Count the number of leaves per plot.
2	Number of spoilt/ unmarketable leaves	2-week interval	Count the number of spoilt leaves per plot.
3	Leaf color	2-week interval	Record the leaf color using a leaf color chart.
4	Vegetable yield (kg)	2-week interval	Weigh the harvested spinach leaves per plot using a weighing scale.


Georgina Smith / CIAT

Agronomic data collection for cabbage

Materials needed

- Ruler/ measuring tape.
- Data collection template.
- Portable weighing scale.

Record the data on plant growth and yield as shown in Table 7 detailing what, when and how the parameter should be measured:

Table 7. Data collection on the effect of biopesticides on growth and yield of cabbage

S/No.	What to measure	When to measure	How to measure
1	Pest infestation	Weekly	Score rating (see section 5.2).
2	Leaf damage	Weekly	Score rating (see section 5.2).
3	Other pests	Weekly	Record other insect pests found on the cabbage.
4	Plant leaf color	2-week interval	Record the plant color which might range from yellow, pale green to deep green.
5	Head damage	At harvest	Score rating (see section 5.2).
6	Weight (kg or g)	At harvest	Weigh the heads of the cabbage using the weighing scale.
7	Head size (cm)	At harvest	Measure the circumference of the head using a tape measure.

Agronomic data collection for maize and beans

Materials needed

- Tape measure.
- Data collection template.
- Digital weighing scale.

Record the data on plant growth and yield as shown in Table 8 detailing what, when and how the parameter should be measured.

Table 8. Data collection on the effect of plant-based biopesticide on growth and yield of maize and beans (A= All; M=Maize; B=Beans)

S/No	What to measure	When to measure	How to measure
1	Pest infestation (A)	Maize: at V8-V10; 50 % tasseling and at grain filling stage: Beans= at branching, 50 % flowering and pod filling stage.	Score rating (see section 5.2).
2	Leaf damage (A)		Score rating (see section 5.2).
3	Depth of color (A)	Maize: at V8-V10; 50 % tasseling and at grain filling stage. Beans: at branching, 50 % flowering and pod filling stage.	Record the leaf color using the color chart (Annex 2).
4	Plant height (A)		Measure by using a meter rule by measuring from the ground to the topmost part of the plant.
5	Duration to flowering (B) and tasseling (M)	At 50 % flowering/tasseling.	Record the date when 50% of the plants flowered/tasseled.
6	Grain damage (A)	At harvest	Score rating (see section 5.2).
7	Ear (cob) length and diameter (M)	At harvest.	Measure the length of the cob using a ruler and the diameter using a tape measure.
8	Number of ears (M)	At harvest.	Count the number of cobs/ears harvested from the plot (or from the sampling area).

9	Size of kernels (M)	At harvest	Record the size of kernel as either small, medium or large.
10	Kernel filling (A)	At harvest	Record as either wrinkled, dented or flinted.
11	Number of pods (B)	At harvest	Count the number of pods per plant from a random sample of 10 plants.
12	Pod length (B)	At maturity	Measure the length of the pod using a ruler.
13	Pest pressure/ prevalence (A)	2-week interval	Record the type and severity of damage (using the severity score) by insect pest and diseases.
14	Yield (A)	At harvest	Sun-dry the maize and bean grain and weigh them with a scale.
15	Stover yield (A)	At harvest	Count the number of harvested plants, cut them and measure their field weight.
16	Maize ear and bean pod health (M, B)	At harvest	Record damaged cobs (maize) and beans and record type of damage and severity (none, low, medium, severe).

5.2 PEST DATA COLLECTION

Pest data collection on cabbage (aphid population)

- Carry out data sampling and spraying of plant extracts between 6:00 a.m. and 9:00 a.m. when the insects are least active.
- From each plot, randomly select ten plants and visually examine to record the number of aphids and leaf damage caused by aphids.
- Carefully examine the leaves and stems for the presence of aphids.
- Assess aphid infestation using visual scoring rating from 0–5; where
    - 0 = no aphid presence;
    - 1 = few individuals;
    - 2 = few isolated small colonies;
    - 3 = several small colonies;
    - 4 = large, isolated colonies;
    - 5 = large continuous colonies.
- Assess the leaf damage caused by aphids using the following ratings:
    - 0 = no damage;
    - 3 = leaves slightly cupped;
    - 5 = leaves moderately cupped with some leaf yellowing;
    - 7 = severe distortion of leaves with considerable yellowing combined with honeydew production;
    - 9 = very severe foliar distortion and yellowing combined with abundant honeydew production.
- At harvest (cabbage), determine the leaf damage for insect pest damage using a three-score category where 0= no damage, 2 = moderate damage, and 3 = severe damage.

Pest data collection on maize and beans

- Scout for insect pests once a week before spraying plant material extracts.
- From each plot, randomly select five plants and visually examine to record the types and number of insect pests; and damage caused by the insects.
- Data sampling for insect pest population and spraying of plant extracts to be done between 6:00 a.m. and 9:00 a.m. when the insects are least active.
- Carefully examine the leaves and stems for the presence of insect pests.

Record data on leaf damage (see detailed illustration for the damage to be recorded in Annex 3) using the template in Table 9.

Table 9. Leaf damage rating scale

Explanation/definition of damage	Rating
No visible leaf damage.	0
Only pin-hole damage.	1
Pin-hole and small circular hole damage to leaves.	2
Pinholes, small circular lesions and a few small elongated (rectangular shaped) lesions of up to 1.3 cm in length present on whorl and furl leaves.	3
Several small to mid-sized 1.3 to 2.5 cm in length elongated lesions present on a few whorl and furl leaves.	4
Several large, elongated lesions greater than 2.5 cm in length present on a few whorl and furl leaves and/or a few small- to mid- sized uniform to irregular shaped holes (basement membrane consumed) eaten from the whorl and/or furl leaves.	5
Several large, elongated lesions present on several whorl and furl leaves and/or several large uniforms to irregular shaped holes eaten from furl and whorl leaves.	6
Many elongated lesions of all sizes present on several whorl and furl leaves plus several large uniform to irregular shaped holes eaten from the whorl and furl leaves.	7
Many elongated lesions of all sizes present on most whorl and furl leaves plus many mid- to large-sized uniform to irregular shaped holes eaten from the whorl and furl leaves.	8
Whorl and furl leaves almost totally destroyed.	9

Note: Ratings on damage caused by fall armyworm (FAW) on corn ear and kernel where FAW is already present on plants.

Record data on ear or kernel damage before harvest and before the grain has dried off on 10 randomly selected ears from 20 randomly selected plants by using the scale indicated in Table 10.

Table 10. Maize ear and kernel rating scale

Explanation/definition	Rating
No damage to any ears.	0
Tip (<3cm) damage to 1-3 ears.	1
Tip damage to 4-7 ears.	2
Tip damage to 7 and more ears and damage to 1-3 kernels below ear tips on 1 to 3 ears.	3
Tip damage to 7 and more ears and damage to 1-3 kernels of 4 to 6 ears.	4
Ear tip damage 7-10 ears and damage to 1-4 kernels below tips of 7 to 10 ears.	5
Ear tip damage to 7-10 ears and damage to 4-6 kernels destroyed on 7-8 ears.	6
Ear tip damage to all ears and 4-6 kernels destroyed on 7-8 ears.	7
Ear tip damage to all ears and 5 or more kernels destroyed below tips of 9-10 ears.	8

5.3 INTEGRATED FARMER DATA MONITORING SHEETS

Below are the basic monitoring sheets that can be used for the specific practices included in this guide document. The monitoring practices mainly depend on the test crop, rather than the practice – unless specific additional indicators are required/desired.

Monitoring sheet for compost and mulch on spinach (Kiambu)

Name of Farmer	
Practice implementing	Compost
Crop	Spinach

	Test plot					Control plot				
Parameter	**Plant 1**	**Plant 2**	**Plant 3**	**Plant 4**	**Plant 5**	**Plant 1**	**Plant 2**	**Plant 3**	**Plant 4**	**Plant 5**
Time 1										
Number of leaves per plant										
Leaf color										
Vegetable yield (kg) per plant										
Number of naturally spoilt leaves										
Weight of the spoilt leaves										

	Test plot					Control plot				
Parameter	**Plant 1**	**Plant 2**	**Plant 3**	**Plant 4**	**Plant 5**	**Plant 1**	**Plant 2**	**Plant 3**	**Plant 4**	**Plant 5**
Time 2										
Number of leaves per plant										
Leaf color										
Vegetable yield (kg) per plant										
Number of naturally spoilt leaves										
Weight of spoilt leaves										
Time 3										
Number of leaves per plant										
Leaf color										
Vegetable yield (kg) per plant										
Number of naturally spoilt leaves										
Weight of spoilt leaves										
Time 4										
Number of leaves per plant										
Leaf color										
Vegetable yield (kg) per plant										
Number of naturally spoilt leaves										
Weight of spoilt leaves										
Time 5										
Number of leaves per plant										
Leaf color										
Vegetable yield (kg) per plant										
Number of naturally spoilt leaves										
Weight of spoilt leaves										

Parameter	Test plot					Control plot				
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
Time 6										
Number of leaves per plant										
Leaf color										
Vegetable yield (kg) per plant										
Number of naturally spoilt leaves										
Weight of spoilt leaves										

Monitoring sheet for biopesticides on cabbages (Kiambu)

Name of Farmer	
Practice implementing	IPM
Crop	Cabbage

	Test plot					Control plot				
Parameter	**Plant 1**	**Plant 2**	**Plant 3**	**Plant 4**	**Plant 5**	**Plant 1**	**Plant 2**	**Plant 3**	**Plant 4**	**Plant 5**
Time 1										
Pest infestation										
Leaf damage										
Other pests										
Plant leaf color										
Number of leaves										
Time 2										
Pest infestation										
Leaf damage										
Other pests										
Plant leaf color										
Number of leaves										
Time 3										
Pest infestation										
Leaf damage										
Other pests										
Plant leaf color										
Number of leaves										
Time 4										
Pest infestation										
Leaf damage										
Other pests										
Plant leaf color										
Number of leaves										
At Harvest										
Head size										
Weight										
Head damage										

Monitoring sheet for farmyard manure, terraces and biopesticide on maize (Makueni)

Name of Farmer

Practice implementing

Crop Maize

	Test plot					Control Plot				
Parameter	**Plant 1**	**Plant 2**	**Plant 3**	**Plant 4**	**Plant 5**	**Plant 1**	**Plant 2**	**Plant 3**	**Plant 4**	**Plant 5**
V8-V10 stage										
Depth of color										
Plant height (cm)										
Pest infestation										
Leaf damage										
50% tasseling stage										
Date at 50% tasseling										
Depth of color										
Plant Height (cm)										
Pest infestation										
Leaf damage										
Grain filling stage										
Depth of color										
Plant height (cm)										
Pest infestation										
Leaf damage										
At harvest										
Ear (cob) length (cm)										
Ear (cob) diameter (cm)										
Number of ears/ cobs per plant										
Size of grains										
Kernel filling										
Grain damage										
Yield per plot (kg)										

Monitoring sheet for farmyard manure, terraces and biopesticide on beans (Makueni)

Name of Farmer	
Practice implementing	
Crop	Beans

	Test plot					Control Plot				
Parameter	**Plant 1**	**Plant 2**	**Plant 3**	**Plant 4**	**Plant 5**	**Plant 1**	**Plant 2**	**Plant 3**	**Plant 4**	**Plant 5**
At branching										
Depth of color										
Plant height (cm)										
Level of pest infestation										
Leaf damage										
50% flowering										
Date at 50% flowering										
Depth of color (cm)										
Plant height										
Level of pest infestation										
Leaf damage										
Pod filling stage										
Depth of color										
Plant height (cm)										
Level of pest infestation										
Leaf damage										
At Harvest										
Kernel filling										
Number of pods										
Pod length (cm)										
Grain damage										
Yield per plot										

6. Concluding remarks

This guide was developed in the context of the CGIAR Agroecology Initiative in Kenya to improve access of farmers and other food system actors to practical training material about the co-designed agroecological practices. Beyond providing instructions on the practices themselves, the guide aimed to give insights into scientific research thinking and methods to support farmers to become "farmer researchers"/ citizen scientists who are skilled in the set-up and monitoring of their own innovative practices, and who can support others to do the same.

Beyond co-creating innovative agroecological farming practices, co-design also entails regular iterative engagements between the different stakeholders to jointly reflect on the performance of the practices and overall experiences made. These iterations help in the gradual adaptation of the practices and experimental design to suit the respective contexts and participants' expectations. These periodic interactions also provide an opportunity for further capacity strengthening, a platform for the development of collaborations and partnerships, and an entry point for further responsive external support.

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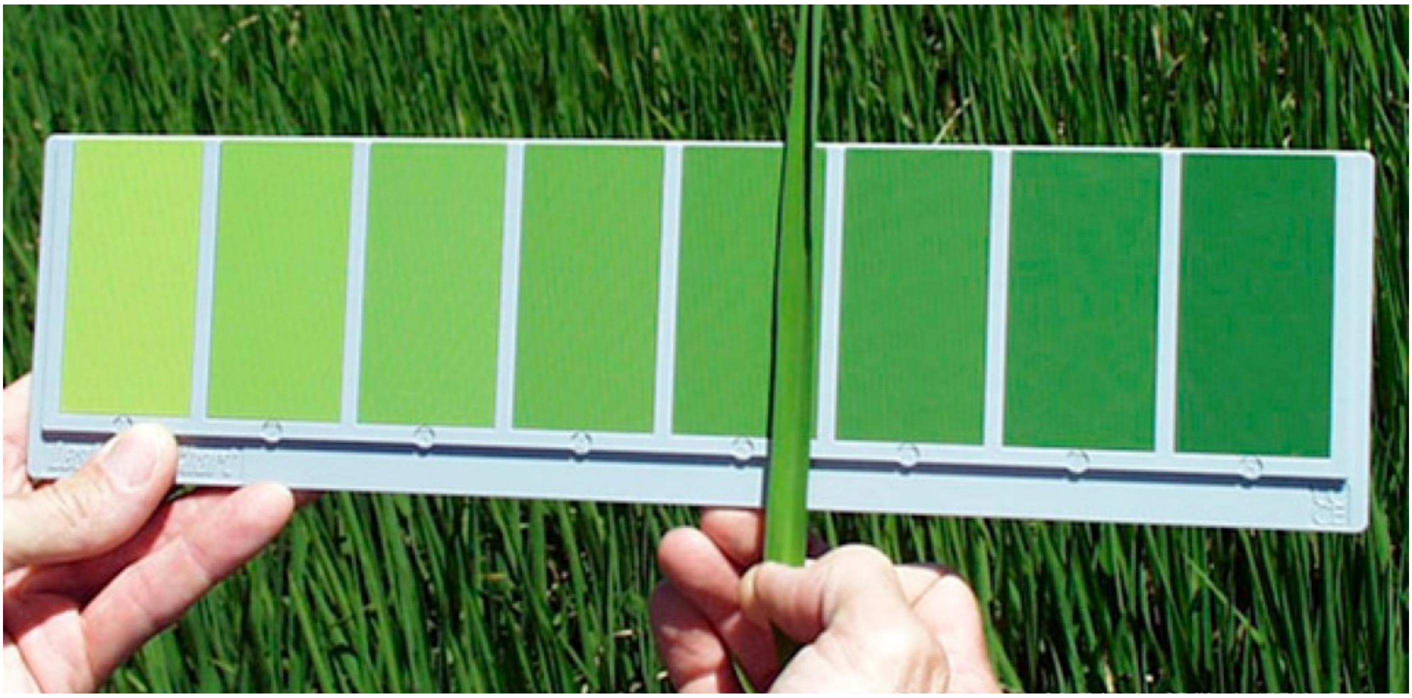
8. Annexes

Annex 1. Practice table

S/No.	Practice/Activity	Test	Control
1	History of the plot during previous cycles (at least 2 or 3 years)		
2	Inputs used (type of input, and variety [crops])		
3	Planting date		
4	Input application method		
5	Input amount		
6	Weeding frequency (collected as the dates of weeding, i.e., first, second etc.)		
7	Pest control		
8	Land topography		
9	Cost of (input, labor and transport of inputs and produce)		
10	Harvest duration and cost		
11	Any cost related to transformation / packaging of harvest		
12	Any cost related to credit/ loans		
13	Labor input for each operation (number of hours or day, and who does it, whether family or hired, man/woman/ youth)		
14	Labor cost (including in-kind payment such as food given to hired labor)		
15	Markets		
16	Any costs related to transport and marketing		
17	Cash income from sales of produce		
18	Challenges/constraints		

Annex 2. Leaf color chart



Source: The Regents of the University of California. © 2010. All rights reserved.

Annex 3. Visual pest scoring scale for screening leaf damage

The visual ratings of damage can be done based on the number and size of lesions on the leaves.

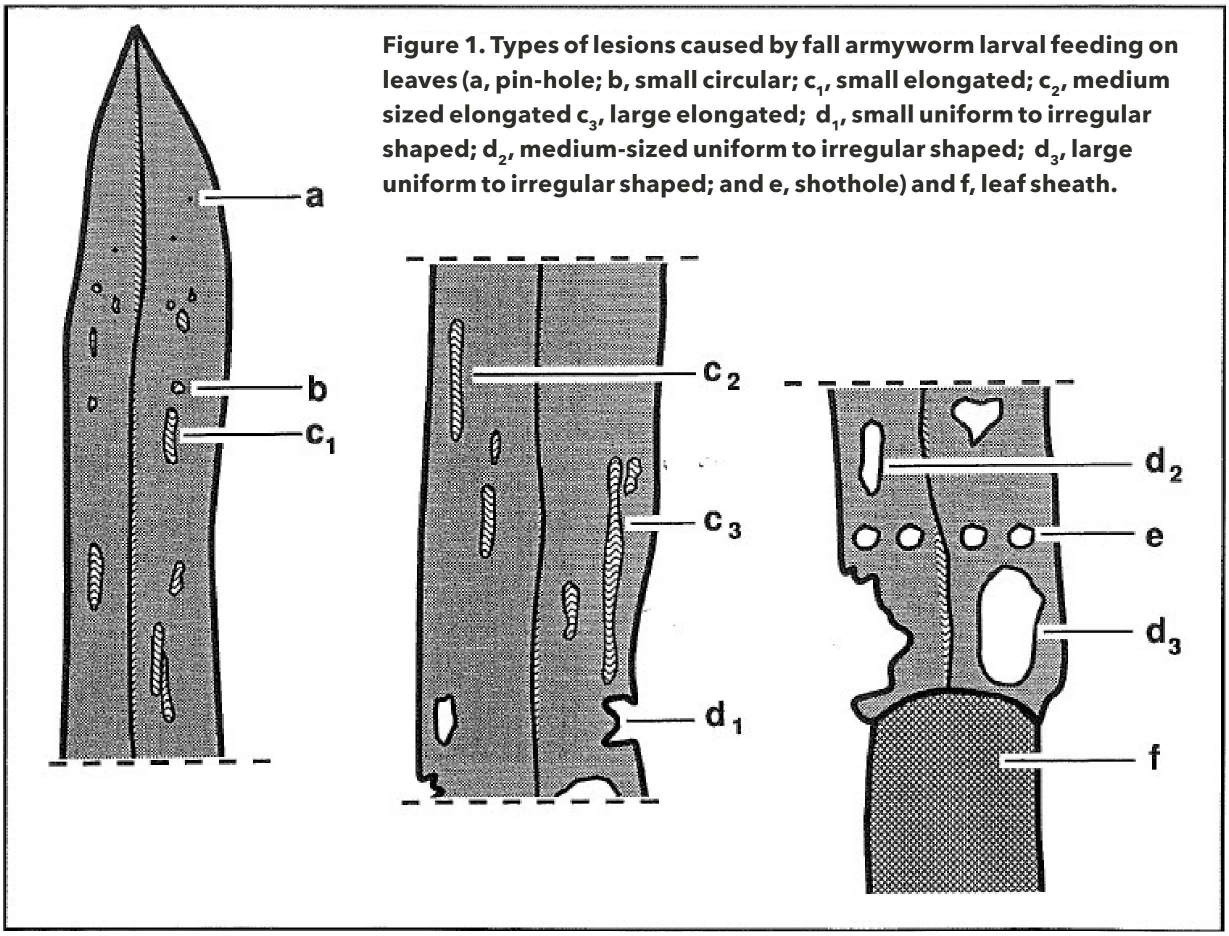


Figure 1. Types of lesions caused by fall armyworm larval feeding on leaves (a, pin-hole; b, small circular; c_1, small elongated; c_2, medium sized elongated c_3, large elongated; d_1, small uniform to irregular shaped; d_2, medium-sized uniform to irregular shaped; d_3, large uniform to irregular shaped; and e, shothole) and f, leaf sheath.

Source: Davis FM; Williams WP. 1992. Visual rating scales for screening whorl-stage corn for resistance to fall armyworm. Mississippi Agricultural & Forestry Experiment Station, Technical Bulletin 186. Mississippi State University.

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