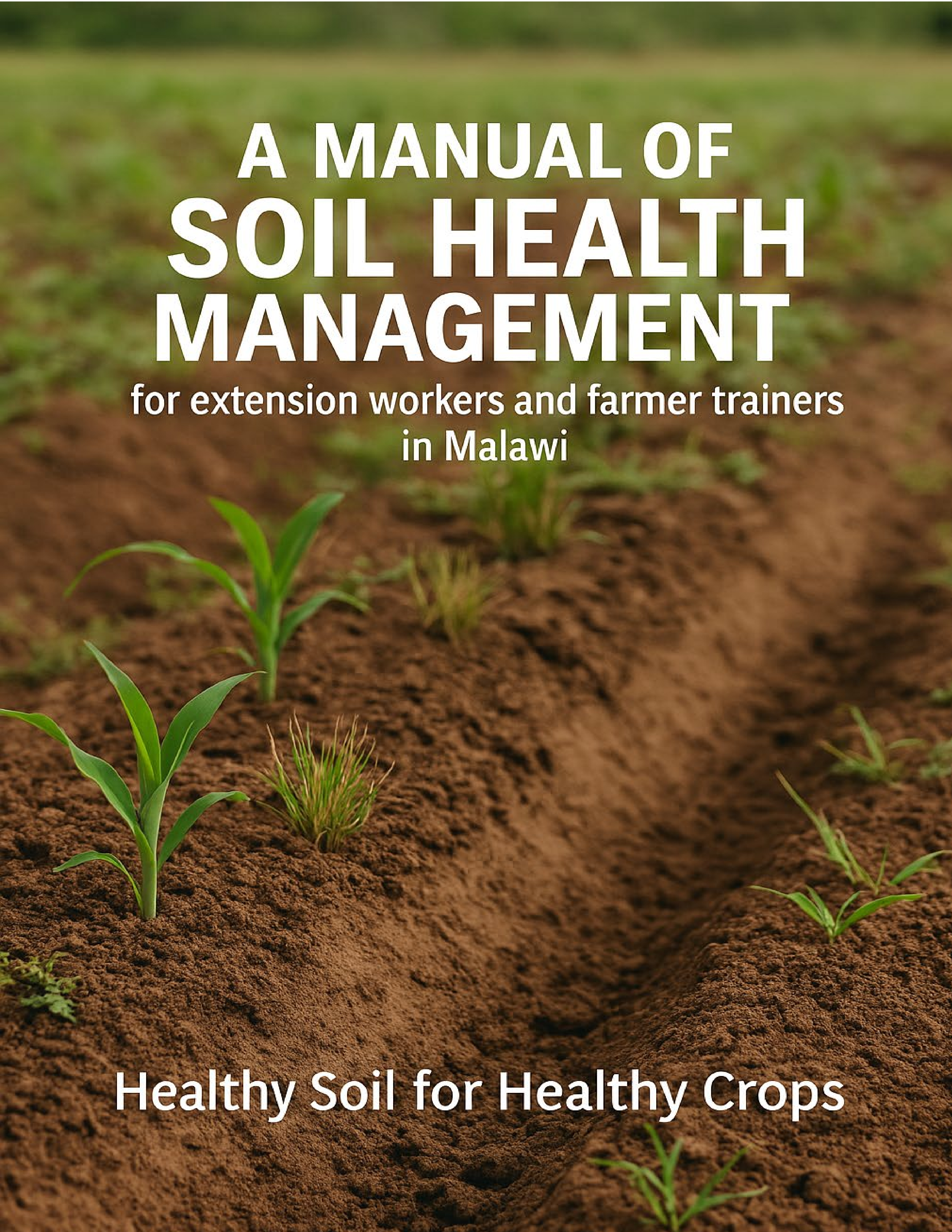

A MANUAL OF SOIL HEALTH MANAGEMENT

for extension workers and farmer trainers in Malawi

Healthy Soil for Healthy Crops

A manual of soil health management for extension workers and farmer trainers in Malawi

Theme: Healthy Soil for Healthy Crops

Kamaluddin Tijjani Aliyu[1]
Blessing Mhlanga[2]
Sileshi Gudeta Weldesemayat[3]
Jonathan Odhong[1]
Chima Rickard[4]
Wezi Mhango[5]
Christian Thierfelder[2]
Paswel Marenya[4]
Sieglinde Snapp[6]

[1]International Maize and Wheat Improvement Center (CIMMYT), Lusaka, Zambia, [2]International Maize and Wheat Improvement Center (CIMMYT), Harare, Zimbabwe, [3]Department of Plant Biology and Biodiversity Management, Addis Ababa University, Addis Ababa, Ethiopia, [4]International Maize and Wheat Improvement Center (CIMMYT), [5]Nairobi, Kenya, Lilongwe University of Agriculture and Natural Resources (LUANAR), [6]International Maize and Wheat Improvement Center (CIMMYT), Texcoco, Mexico

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Contents

Introduction

Farmers in Malawi face numerous challenges that impact both their livelihoods and the country's food security. These challenges include small and fragmented landholdings, declining yields driven by limited access to credit and agricultural inputs, as well as a growing threat of soil degradation. Healthy soils are the foundation of productive farming, yet many soils in Malawi are becoming less fertile, eroded, or depleted. Without deliberate efforts to restore and sustain soil health, crop yields and household food security will continue to decline.

Restoring soil health requires informed decision-making about agricultural practices. Yet, despite the availability of technologies that improve soil fertility and structure, dissemination to farmers has been slow and often ineffective. To address this, extension workers and farmer trainers play a pivotal role in bridging the gap between scientific research and practical, field-level application.

This manual has therefore been designed as a user-friendly, evidence-based guide to support training sessions with farmers. Its recommendations draw from studies conducted across Africa, while incorporating Malawi-specific evidence and practices.

The soil health management technologies presented in this manual are semi-site-specific, which means that they are recommended based on the conventional agroecological zone classification of Malawi. Malawi is divided into three primary agroecological zones defined by differences in soil texture, altitude, temperature regimes, as well as the amount, duration, and variability of rainfall. The zones are i) the Lower Shire Valley "**Lakeshore"**, ii) the Upper Shire **"High-altitude",** and iii) the **Mid-altitude** (Figure 1). Occasionally, the Mid-altitude plateau is further divided into a fourth category that includes the highlands. The Lakeshore encompasses the lakeshore plains and the upper Shire Valley.

In addition to agroecological zone classification, consideration of soil texture provides another practical and farmer-friendly layer for tailoring technology recommendations in this manual. Soil texture can be easily evaluated in the field using simple hand tests (described in this manual), making it a practical and user-friendly tool for guiding soil management decisions.

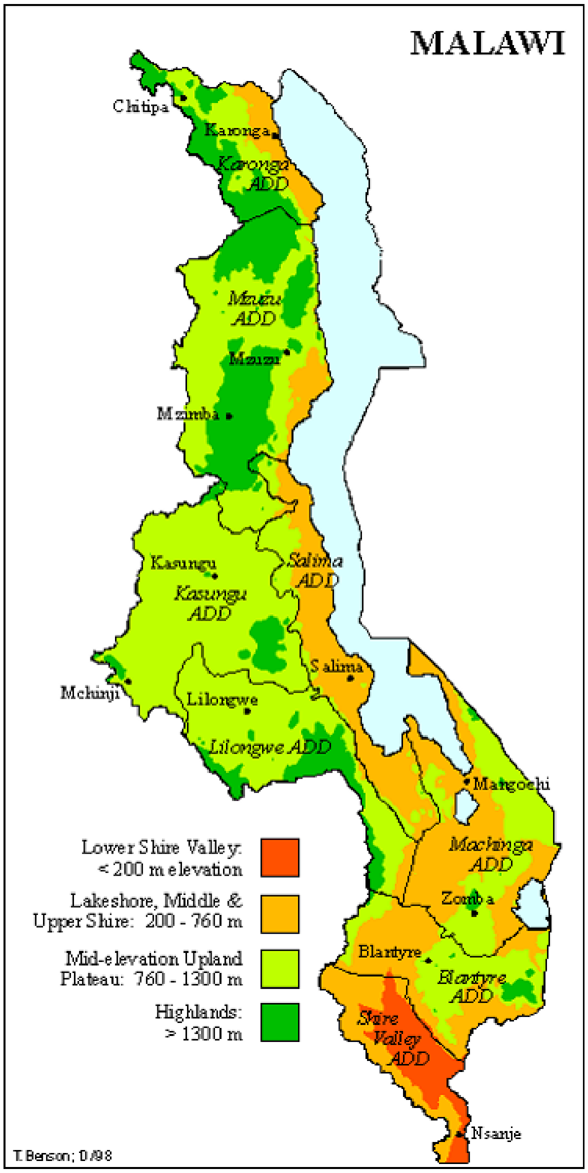


Figure 1. Classification of Malawi into agroecological zones. Adapted from: Benson et al. (2016)

The classification of soil in this manual is based on two texture categories (clayey versus sandy), chosen by experts for simplicity and clarity. These classifications also align well with local farmers' terms in Malawi, where soil is referred to as mchenga (sandy) and katondo (clayey). Intermediate texture categories were avoided to minimize confusion from multiple options.

For simplicity, this manual categorizes soils into only two groups:

- Clayey soils: defined as having more than 32% clay content and fine texture.
- Sandy soils: defined as having less than 20% clay content and coarse texture.

These two broad categories are adequate as a rough guide for farmers and extension. Refer to Module 1 for a detailed description of soil texture.

For the suitability of practices to certain agroecological zones, a specific practice is deemed to be "highly suitable" for two reasons: (1) it reduces the risk of soil degradation and (2) it increases crop yields, regardless of applicability in the agroecological zone or the soil. A practice is deemed to be "less suitable" if it provides the benefits in point (1) but to a lesser extent than the highly suitable class. A practice is deemed "unsuitable" if it neither reduces the risk of soil degradation nor increases crop yields. While these classifications involve some subjectivity, they are strongly supported by empirical evidence, including meta-analyses of soil management practices.

Table 1 presents a list of technologies, along with the corresponding agroecological zones and soil conditions, where each practice is recommended to help mitigate risks to soil health and crop productivity. For each combination of agroecology and soil texture (clay or sandy), a practice is color-coded to facilitate choices by extension agents and farmer trainers to make choices.

- Green means that the practice is suitable and highly recommended in that particular combination.
- Orange means the practice is less suitable
- Red means the practice is unsuitable.

For example, planting basins are well-suited to, and highly recommended in, clay soils along the Lake Shore, but less suitable in mid-altitude areas and unsuitable in high-altitude areas on clay soils in Malawi (Table 1).

Table 1. List of recommended soil and agronomic management interventions for the ranges of agroecological zones of Malawi

	Agroecological Zone					
	Lakeshore		Mid-Altitude		High-Altitude	
Categories of interventions	Clayey	Sandy	Clayey	Sandy	Clayey	Sandy
1. Conservation Agriculture						
Planting basins	Green	Red	Orange	Red	Red	Orange
Ripping	Green	Orange	Green	Orange	Green	Orange
Tied ridges	Red	Green	Red	Green	Red	Green
Permanently raised beds	Green	Red	Green	Red	Green	Red
2. Planting						
Planting Density						
High maize density	Red	Red	Orange	Red	Green	Orange
Low maize density	Orange	Green	Orange	Orange	Red	Red
High legume density	Red	Red	Orange	Red	Green	Orange
Low legume density	Orange	Green	Orange	Orange	Red	Red
Doubled-up legume rotation						

Pigeon pea + groundnut						
Pigeon pea + cowpea						
Pigeon pea + soybean						
Fertilizer Addition						
3. Inorganic Fertilizer						
NPK + Urea						
4. Livestock Manure						
High-quality manure (poultry/pig)						
Low-quality manure (cattle)						
Manure + fertilizer combined application						
Low-quality manure + N fertilizer						
High quality manure + N fertilizer						
5. Green Manuring						
Green manuring legumes (e.g., Tephrosia)						
6. Crop residue application						
Legume residue (pods, straw) incorporation†						
Cereal residue (e.g., maize stover) mulching‡						
7. Agroforestry						
Gliricidia-maize intercropping						
Biomass transfer						

† Legume residues should always be incorporated into the soil

‡ Cereal residues should always be applied as a mulch on the soil surface

Highly suitable

Less suitable

Unsuitable

Beyond agroecological zones and soil texture, other considerations include on-farm measurement of soil variables and socioeconomics on farms. This helps ensure that technologies and inputs can be deployed where they can effectively reduce risks to soil health and crop yields while minimizing implementation challenges. It is recommended that the practices described in this manual be tailored to local agroecological and soil conditions, as well as available resources, to maximize both effectiveness and practicality.

Module 1. Understanding your soil

Background

Soil is characterized by physical, chemical, and biological components. The primary indicators of soil physical quality include soil texture, hardness, aggregate stability, plant-available water, water infiltration rate, and adequate rooting depth. Chemical quality indicators include pH, cation exchange capacity, rates of carbon and nitrogen mineralization, nutrient availability, electrical conductivity, salinity, and toxicity. Biological quality indicators are soil organic matter, active carbon, soil protein, respiration, and the diversity and abundance of soil fauna and flora. A healthy soil can perform essential ecosystem functions, such as nutrient cycling, water filtration and retention, and carbon sequestration, while also providing habitat for diverse organisms. Several threats to soil health in Malawi include: (1) loss of organic matter; (2) erosion by wind and water; (3) acidification; (4) soil compaction; and (5) landslides of soil and rock. Understanding these threats helps us address them effectively.

This manual introduces extension practitioners to several indicators selected based on their frequency of use worldwide. These include soil organic matter (SOM), soil pH, and plant-available nutrients such as total and available nitrogen (N), phosphorus (P), and potassium (K), which can be measured in the field using handheld devices or in the laboratory through wet chemistry. Table 2 summarizes these indicators and suggests corrective actions when values fall below specific critical thresholds. These values are intended as general guidance, rather than exact prescriptions, due to a limited understanding of how they vary with soil type, climate, and management practices. Crossing these thresholds may compromise soil functions, although crop responses might still be positive. Therefore, corrective measures should be taken to prevent irreversible and catastrophic loss of soil function (see Table 2).

Soil organic matter (SOM), often measured as soil organic carbon (SOC), is the most critical and dependable indicator of soil health. It serves as both the source and sink for most nutrients. Additionally, it plays a crucial role in increasing cation exchange capacity, enhancing soil aggregation, improving water retention, and supporting soil biological activity. Furthermore, it is a critical determinant of crop response to nitrogen and phosphorus fertilization. Evidence indicates that 2% is a critical threshold for SOC, below which a significant decline in soil quality can occur, including rapid soil structure instability. In fact, SOC below 1% is insufficient for normal soil functions, including crop productivity. For example, maize yields in response to most inputs are very low when SOC is below 1%. Therefore, applying manure, planting green manure legumes, and using fertilizer trees are highly recommended to keep SOC levels above the 1% mark.

Soil pH is a key indicator of soil health. It plays a significant role in determining the availability of nutrients, microbial activity, and the decomposition of organic matter. When the soil pH, measured in water, drops below 5.5, soil functions are invariably compromised, resulting in lower responses to agricultural inputs and yields. Therefore, maintaining soil pH above this level is essential for maximizing the benefits of applying chemical fertilizers or various organic inputs.

Soil total nitrogen is an essential indicator of soil productivity and the biogeochemical cycle. Low total nitrogen levels suggest that nitrogen might become a limiting factor for productivity. However, there is no universally accepted definition of low soil total nitrogen content. According to recent work in Malawi, a threshold of 0.12% nitrogen is recommended. Nitrogen content below 0.12% is considered low in Malawi.

Available phosphorus (P) generally refers to the amount of phosphorus in soil that dissolves in water and is therefore accessible to plants. The critical P level is the point beyond which there is no significant increase in crop yield response to added P fertilizer. Since P is measured using different methods, it is hard to define a single threshold value. Soil P content below 18 mg/kg is considered low in Malawi. Therefore, Olsen P of 18 mg/kg or higher should be maintained to support soil health and crop productivity, following the corrective measures outlined in Table 2. In the following activities, practitioners are expected to learn about some soil health indicators.

Table 2. Indicators of soil health, provisional threshold levels for agricultural soils, and corrective measures

Indicator	Diagnostic tool	Threshold	Corrective measure
Soil organic carbon (%)	Portable NIR reflectometer	2.0	Apply livestock manure, compost, or legume residues; plant green manure legumes and fertilizer trees
Soil pH	Spectroscopy; wet chemistry	5.5 in water	Apply manure in areas with annual rainfall of 600-1000 mm, but apply lime in high or low-rainfall areas
Total nitrogen (%)	Spectroscopy	0.12	Apply compost or manure + N fertilizer with N:P of at least 6:1; plant green manure legumes or fertilizer trees
Available P (Olsen) (mg/kg)	Spectroscopy or wet chemistry	Olsen P < 18	Apply manure or compost; apply rock phosphate or phosphorus fertilizer
Available K	Spectroscopy	--	Apply manure, compost, or potassium fertilizers; return crop residues

Activity 1.1. Understanding soil texture

Background

Soil texture is an essential determinant of many soil functions. The suitability of practices for your field and the recommendations in this manual are based on soil texture classes.

Goal: To characterize the soil texture on a farmer's field

Time: 30 mins
What is the texture of the soil?

Steps:

- Take a handful of soil from the surface and remove any stones, roots, and non-soil materials.
- Place a small amount in your hand and add a little water at a time.
- Mix with a finger, add just enough water to make a stiff paste (like dough).
- Form a ball from the soil, then pinch it between your fingers to create a ribbon.
- Describe what you feel as you squeeze the soil: (gritty, smooth, sticky).

See how long a ribbon you can make with your soil ball. Note that the longer the ribbon, the more clay in the soil. The shorter the ribbon, the more sand in the soil (Table 3). Here in Plate 1, there is a simple description of manual soil texture evaluation.

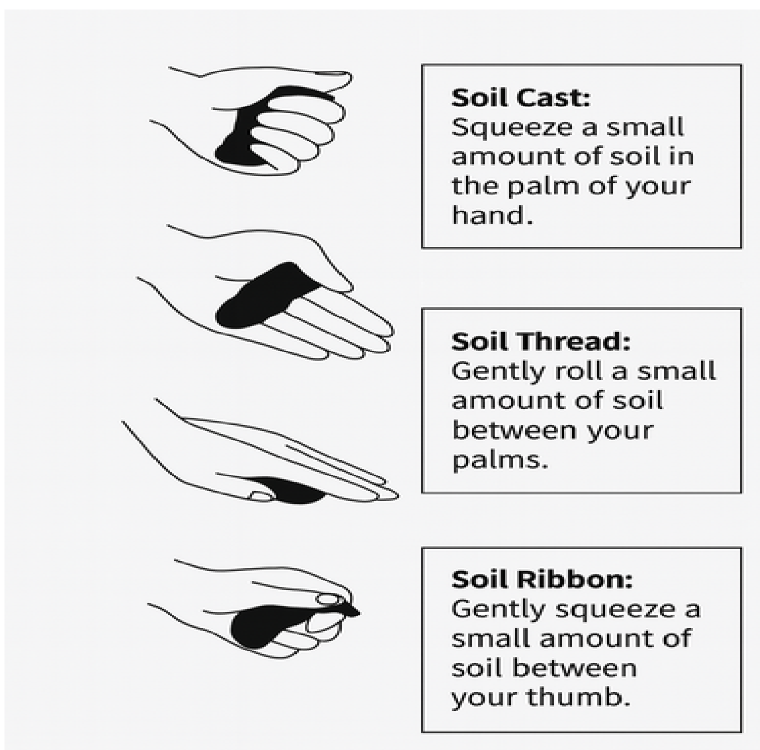


Plate 1: Simple hand tests for determining soil texture *in-situ*.

Table 3. Comparison of soil texture responses to simple hand tests

Soil Texture	Soil Test		
	Soil Cast	**Soil Thread**	**Soil Ribbon**
Sandy (Mchenga)	The cast crumbles easily and falls apart when handled, and in some cases may not form at all.	Threads cannot be formed as the soil quickly disintegrates when rolled.	No ribbon can be formed because the soil breaks apart immediately under pressure.
Clayey (Katondo)	Cast may be moulded into many shapes without breaking.	The thread is strong and elastic and can be rolled to a pinpoint	Soil will form a long, thin ribbon that does not easily break.

Questions & Review:

How do you describe the soil on your farm? (Each farmer takes a turn.)

Why is texture important for your crops? (Drainage, holding nutrients from compost and fertilizer, retaining water during droughts, and providing a suitable environment for crop roots.)

If you can't change the soil texture, what can you do to improve your soil? (Enhance the soil's health, just like we do when eating healthy foods. You can add things needed by crops that help microorganisms in the soil work better to supply crops with natural fertilizer).

Activity 1.2. Understanding soil drainage

Background

Soil drainage is crucial for maintaining soil health, particularly after heavy rainfall. Have you seen crops that sit in water for more than a day? What happens?

Goal: Observing water drainage in two different types of soil.

Note: This activity should be conducted at least a week or more after a rainfall event.

What is Needed:

- Two tins with both ends cut out so they have no top or bottom

- Mallet or hammer

- Marker

Steps:

Find two fields, one with healthy soil and one with poor soil. Have a discussion about how to distinguish between them and how to identify each. Use your observation skills and experiences to share with the class.

Here's what to do:

1. Mark each tin at the halfway point.
2. Drive each tin into the ground until it reaches the halfway mark.
3. Fill each with water to the very top (be careful not to spill water around the tin).
4. Observe which tin drains first (becomes empty).

Questions & Review:

Why did the two soils drain differently (or were they the same)? How does water drainage affect the crops? Can drainage in a field be improved? If so, how?

Activity 1.3. How to measure soil pH

Background

Soil pH is a measure of how acidic, neutral, or alkaline the soil is. If pH is less than 6.5 (measured in water), the soil is acidic; if it falls between 6.5 and 7.5, it's considered neutral; and if it's greater than 7.5, it's alkaline. There are several methods for measuring soil pH. Traditionally, soil pH was tested in the lab using a 1:1 soil-to-water ratio, or sometimes with 1:1.25 or 1:5 ratios. More diluted solutions generally show higher pH values than more concentrated samples. Other methods include using $CaCl_2$ and KCl solutions, which typically yield readings approximately 1 pH unit lower than those obtained from a 1:1 soil-to-water ratio. Recently, quick tests based on mid-infrared and near-infrared spectroscopy have been developed for field measurement, and portable spectroscopic devices are now increasingly used to provide fast, reliable, and non-destructive pH estimates directly in the field.

For farmers, simpler methods are also accessible. These include pH test kits or strips, where soil is mixed with water and compared against a color chart, and portable digital pH meters that give numerical readings after inserting a probe into soil-water mixtures.

While straightforward and affordable, these farmer-friendly methods have limitations: they only provide approximate results, can be inconsistent, and are less precise than laboratory or spectroscopic techniques for detailed pH management. Nonetheless, we include them in this manual for practical reasons.

Goal: To gain practical knowledge and skills to assess soil acidity or alkalinity for guiding informed decisions on soil management, nutrient use, and crop selection, thereby improving productivity and maintaining soil health.

Time: 1 hour
Measuring soil pH using pH test kits

What is Needed:
- Soil sample
- Clean jar
- One cup of distilled water
- pH test kit/strips
- Color chart

Steps:

1. Collect about 10-20 grams of soil from the root zone (~15 cm deep).
2. Mix it with an equal volume of clean or distilled water (around 10–20 ml).
3. Prepare a slurry that is deep enough to dip a test strip or insert a probe.
4. Dip the pH strip into the slurry.
5. Compare the color change with the chart to determine pH.

Questions & Review:
- What does a pH below 6.5 indicate?
- How does soil pH influence nutrient availability?
- Why is using clean water in the test important?

Module 2. Conservation Agriculture

Background

Conservation agriculture (CA) is a farming system that aims to maintain sustainable and profitable agriculture while conserving the environment. The practice includes three main principles, which are:

i. Minimum soil disturbance: this is achieved through no-till or reduced tillage. By minimizing soil disturbance, the structure and organic matter content of the soil are preserved, which helps improve soil health, reduce erosion, and enhance water retention.
ii. Permanent soil cover: This can be achieved by retaining crop residues or planting cover crops. This helps protect soil from erosion, reduces moisture

loss through evaporation, suppresses weed growth, and improves soil fertility. This principle emphasizes the importance of maintaining continuous soil cover throughout the year.

iii. Crop diversification: By rotating cereal crops or intercropping with legume species, farmers can enhance soil health, mitigate pest and disease pressures, and increase overall resilience to environmental stresses. This principle also includes agroforestry practices to enhance biodiversity and ecosystem services.

Conservation agriculture offers numerous benefits, including improved soil health, increased crop yields and resilience, reduced erosion and water pollution, and more biodiversity. Starting CA requires a commitment to long-term sustainability and resilience, as well as a willingness to experiment, learn, and adapt over time.

Activity 2.1. Understanding Conservation agriculture principles and practices

Goal: To build more sustainable and resilient farming systems that benefit the environment and livelihoods.

What is needed:

- Implement for minimum soil disturbance, e.g., dibble stick, ripper, hoe (for creating basins), jab planter, direct seeder.
- Crop residues (these could be imported or produced in situ).
- Seed of different crop species (cereal, legumes, cover crops, etc.).

Steps:

1. Understand local conditions such as climate, soil types, topography, and available resources to tailor CA practices to suit your specific environment and farming context.
2. Seek out educational resources, workshops, and training programs on Conservation Agriculture.
3. Depending on your current farming practices and the CA techniques you plan to adopt, you may need access to specialized equipment such as no-till planters, cover crop seeders, or conservation tillage implements.
4. Consider the availability of inputs like cover crop seeds, organic amendments, and crop residues for mulching.
5. Plan crop rotations and/or intercrops incorporating diverse crop species to improve soil health, reduce pest and disease pressure, and optimize resource use. Choose crops that are well-suited to your local conditions and market demand.

6. Conduct soil tests to assess soil fertility, pH, and nutrient levels. Use this information to develop a nutrient management plan that includes organic amendments, cover cropping, and targeted fertilizer applications to meet crop requirements while minimizing environmental impacts.
7. Prepare your soil by minimizing soil disturbance, opening only where you place seeds and fertilizer.
8. Plant different crops at recommended spacings and follow proper management practices. Remember, crop diversification is essential; therefore, crops should be grown in rotations and/or intercropped. Establish soil cover by maintaining continuous soil cover throughout the year by applying crop residues immediately after planting and leaving them in the field after harvest. Soil cover can also be achieved through planting cover crops during fallow periods or applying mulch.
9. Monitor soil health, crop performance, and environmental indicators regularly to evaluate the effectiveness of CA practices. Be prepared to adapt your management strategies based on observed results and feedback from your farming community.

Questions & Review:

- Does the choice of tool used for minimum tillage matter? *Yes, the choice of tools depends on factors such as socio-economic status, farm size, soil type, soil condition, and the crop diversification strategy employed.*
- Is a transition period necessary when shifting to or starting with conservation agriculture? *Yes, transitioning to CA may require a period of adjustment. You can start by implementing CA practices on a small scale or in experimental plots to test their effectiveness and adapt them to your farm's needs.*

Activity 2.2. How to make planting basins

Background

Planting basins are holes dug in the soil with a hand hoe, where seeds, organic amendments, and/or fertilizer are placed. Typically, these holes measure 15 cm × 15 cm × 15 cm and are spaced according to the crop being grown. The timing of digging planting basins is crucial due to the labor-intensive nature of the process. Usually, basins are prepared during the dry season before the demand for labor on other field activities peaks, and to collect water from the first rains. Preparing basins too early can also lead to livestock destroying them. Basins are more effective in clayey soils, as they are easily disturbed in sandy soils, even by strong winds (Table 1).

Goal: To minimally disturb soil when preparing land for planting under conservation agriculture and to collect rainwater through the prevention of run-off.

What is Needed:

- Hand hoe or basin digger (mechanized option)

- Measuring tape
- Machete
- Two sticks (pegs)
- Marked teren rope

Steps:

1. Control weeds either through manual or chemical methods before digging the basins. The biomass from the weeds can also be used as ground cover.
2. Mark teren ropes at specific spacings depending on the crop and use the rope to maintain a consistent distance between the basins.
3. Prepare the land by digging basins a few weeks before planting to save time for planting once the rains begin
4. Apply compost or manure to each basin soon after digging the basins. Apply fertilizer in the basins just before planting to reduce losses from leaching and volatilization.
5. Cover the fertilizer and or compost/manure with 1-2 cm of soil.
6. Plant the crop seeds in the basins following the recommended spacing for the crop.

Questions & Review:

What are the benefits of planting basins? The depression collects water, prevents runoff, and allows it to percolate into the soil around the plant roots. This helps retain water near the roots, ensuring better hydration and reducing water loss through runoff. By concentrating water directly around the plant's root zone, basins make sure that plants receive sufficient moisture for growth and development, even during dry periods. Basins can also help concentrate nutrients, such as fertilizers or compost, around the roots, promoting better nutrient absorption. Additionally, the depressed shape of basins can help prevent weed growth around the plant by preventing weed seeds from germinating and competing with the plant for water and nutrients.

Activity 2.3. How to prepare land by ripping

Background

Ripping involves land preparation by creating planting furrows across the prevailing slope at a prescribed spacing (usually 0.9 meters for maize) and at a minimum depth of 15 cm. Soil tillage is limited only to the row where the crop will be planted, leaving the rest of the land undisturbed. There are various ripper designs, including popular types like the Magoye ripper, the subsoiler, and the traditional Ethiopian Maresha. The ripper can be drawn by a pair of trained oxen. In this manual, it is assumed that extension staff and other farmer trainers are well-versed in maintenance, harnessing oxen, and operating rippers. For details, readers are highly encouraged to refer to the *Conservation Farming Handbook for Ox Farmers*. Ripping is more suitable for clayey soils than sandy soils (See Table 1).

Goal: To prepare land for planting under conservation agriculture

What is Needed:
- Ripper
- Two trained oxen
- Yoke and harness equipment
- Moldboard plow frame
- Measuring tape
- Machete
- Two sticks
- Hand hoe
- Teren rope

Steps:
1. Clear the vegetation several weeks before ripping, and allow the foliage to dry up.
2. Prepare the land by ripping a few weeks before planting in order to save time for planting once the rains begin
3. Spread compost or manure in the rip lines as soon as ripping is done. Apply fertilizer in the furrows just before planting to reduce losses from leaching and volatilization.
4. Cover the fertilizer and or compost/manure with 1-2 cm of soil.
5. Plant the crop seeds in the furrows following the recommended spacing for the crop
6. Use teren ropes to maintain consistent seed distance within furrows.

Questions & Review:

What are the benefits of ripping? It helps break the pans, captures moisture from early rains in the furrow depressions, improves soil structure, and promotes deeper rooting and larger root volumes. Ripping also enhances the timeliness of land preparation.

What is the right time to do ripping? The ideal time for ripping is in March or April, when the soil is still moist and easier to work with, allowing for a significant portion of land preparation to be completed well before the upcoming rainy season, rather than after the first rains.

Activity 2.4. How to make permanently raised beds

Background

Permanent raised beds are Conservation Agriculture systems characterized by broad ridges that can accommodate at least two maize rows on the bed,

functioning similarly to conventional ridges (see the top panel of the diagram below). However, they are not destroyed annually but are maintained permanently. The system also allows for surface residue mulch to be applied on the bed, just like in standard flat-planted Conservation Agriculture systems. The raised beds are designed to be aligned on a slope with a gradient of 0.4 to 1% to ensure that excess water drains away during excessive rains or when fields start to waterlog (see bottom panel of the diagram below). Graded permanent raised beds should be prepared with a height of about 20 cm and a width of 150 cm.
Goal: To prepare land for planting through the creation of permanent raised beds to reduce the frequency of soil disturbance under conservation agriculture.

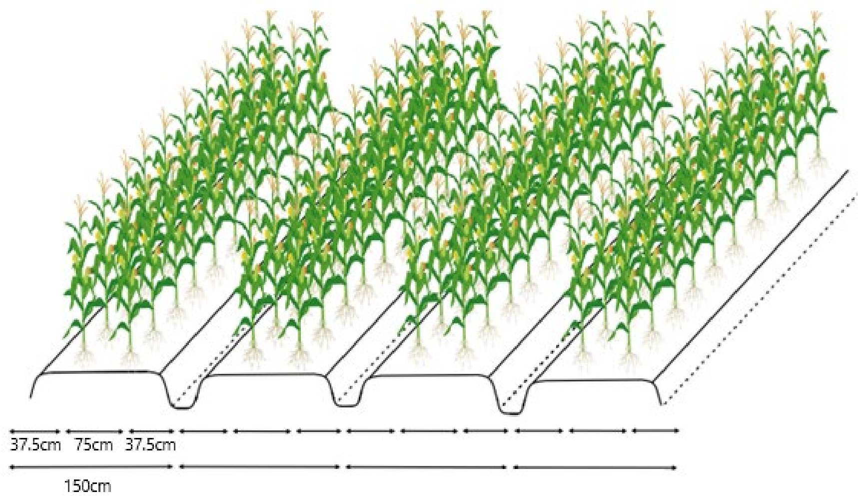


Plate 2a. Illustration of permanent raised beds with recommended row spacing.

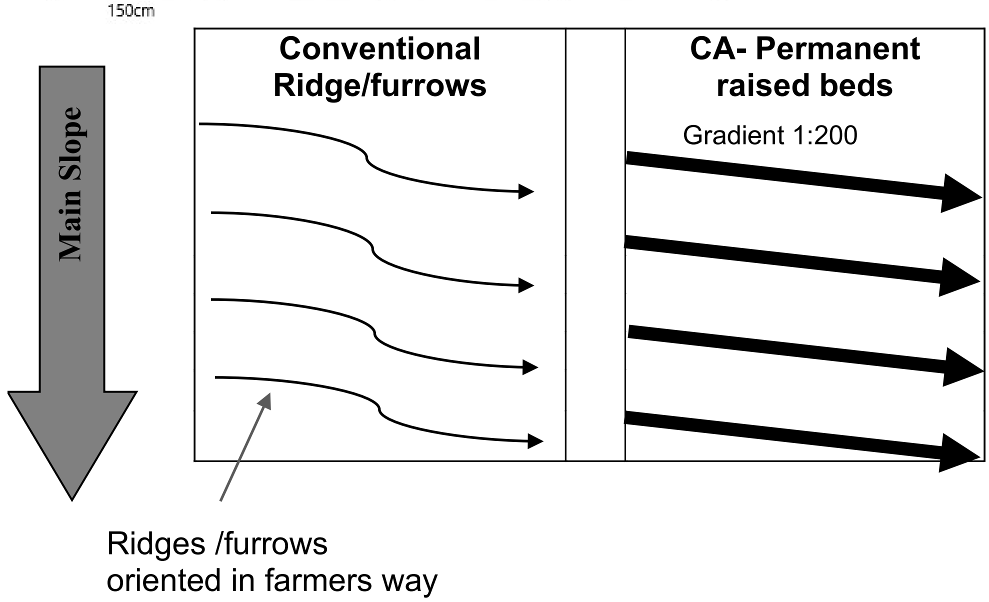


Plate 2b. Illustration of how to align permanent ridges and furrows on sloping land

What is Needed:
- Fertilizer
- Dollop cups or bottle tops
- Weighing scale (for calibrating quantity per stand)

Steps:

1. Plant your crop at the recommended spacing between planting stations.
2. Apply the recommended number of dollop cups per station for your area using the appropriately sized cup. There are three sizes of dollop cups (#2, #5, and #8) appropriate for the basic fertilizer rates.
3. If your chosen nitrogen fertilizer is urea, exercise care when applying.
4. Dig a hole 5 cm deep to apply fertilizer 8 cm away from the seed/plant. Apply corrosive fertilizers like urea only when the soil moisture is moderate to high.
5. Cover the fertilizer with soil to avoid volatilization.

Module 3: Adding organic matter to your soil

Background

Soil organic matter, also known as the soil organic carbon pool, is a vital indicator of soil quality and a key factor in promoting agricultural sustainability. It plays a crucial role in ensuring soil functions properly by regulating critical physical, chemical, and biological processes. Additionally, it enhances soil fertility by helping to retain plant-available water and nutrients, and by supporting the formation of good soil structure, which together ensure the productivity of your soil. A decrease in soil organic matter is a significant sign of soil degradation. Losing soil organic matter is often associated with structural decline, resulting in compaction, surface crusting, and reduced water infiltration. Soils with low organic matter levels are less resilient to drought and flooding; they are also more vulnerable to erosion and runoff during heavy rain. Therefore, taking deliberate actions to prevent the loss of organic matter is essential for maintaining healthy soil on your farm. In the upcoming activities, you will learn about the primary methods for adding soil organic matter to your soil.

Goal: Try different ways to add soil organic matter to improve soil and understand how organic matter helps to improve soil health and increase crop yields

Activity 3.1: Compost making and applying to the field

Background
Note that there are several methods for making compost. They are all acceptable, with only minor differences. Feel free to try different methods and compare how they work and the effort required compared to this one.

Time: 1.5 hours (not including gathering the ingredients)

What is Needed:
- Types of nitrogen-filled (green and wet) ingredients (a mixture of what you have available): Manure, bean or groundnut crop residue, green grass.
- Types of carbon (brown and dry) filled ingredients (a mixture of what you have available) Soil. Dry leaves, dry grasses, torn cardboard, and old thatching.
- Water
- A place where the pile or pit can sit for 2-3 months
- Hoe(s)
- A stick that is longer than the height of the pile
- Long grass (like you use for thatching), enough to cover the pile.

Steps:

1. Collect the inputs and divide them into two piles: one with brown ingredients and the other with green ingredients.
2. The brown pile should be 3 times larger than the green pile.
3. Where the pile will be placed, dig out the soil 10 cm deep in a circle approximately 1 meter wide. This is where you will have the compost pile.
4. Mix the two piles with your hands and hoes.
5. Place the stick in the center where the pile will be, and use a hoe to distribute the compost evenly around the stick. This stick will help hold the thatch that covers the pile at the last step.
6. Add water while mixing. A watering can works well to add water to the pile. The pile should be just moist or damp, NOT DRIPPING.
7. Cover the heap with thatch grass, standing it on end and wrapping it around the pile. This helps to keep the pile moist.
8. After 2 days, remove the thatch and pull the stick out of the center. Check if the stick is warm/hot. The hot stick indicates that the composting process is well underway. If the stick is not hot, then there is a need to rebuild the compost pile by adding more green ingredients and mixing them into the pile to recover.
9. After 1-2 months, this compost is ready to be applied to the soil. Remove thatch and transport to the field before planting maize or other crops. Place some compost along the row where you will plant.

Questions & Review:

What does the application of compost do to the crops in the field? It adds nitrogen and also nourishes the life in the soil to help produce other beneficial elements for your crops. Can you have too much compost? Probably not, especially since it requires a significant amount of time and effort to create. When should I apply the compost to the field? It is recommended to do so when making rip lines, ridges, or rows. Are there correct or incorrect ways to apply compost? You should always add it to the soil. It's better to incorporate it into the field a bit before planting your crop.

Activity 3.2: Applying livestock manure

Background

Livestock manure is one of the most commonly available materials rich in organic matter and soil nutrients. It includes the excreta (dung and urine) of domestic animals and the plant materials used as bedding for animals. Low-quality manure is not suitable for clayey soil in any agroecological zone. On the other hand, the application of livestock manure combined with nitrogen fertilizer is suitable for both clayey and sandy soils across all agroecological zones (see Table 1).

Time: 1-2 hours (not including gathering manure)

What is Needed:

- Manure: You can get manure from cattle, goats, sheep, pigs, and chickens. Manure from cattle is of low quality, while manure from goats and sheep is of medium quality. Chicken and pig manure are of high quality.
- A place where the manure pile can be kept or a pit where it can be composted for 2-3 months.
- Hoe(s) and shovel

Steps:

1. Collect the manure and keep it in a pile, as in farmyard manure.
2. If you decide to store the manure in a pit, dig a pit and cover it.
3. Cover the pile or pit with grass or anything that can protect it from exposure to the sun and wind.
4. After 2-3 months, the farmyard manure or composted manure is ready to apply to the field.
5. Remove the cover, transport to your field, and apply preferably before or at the time of planting seeds.
6. Always incorporate manure into the soil. If you leave it on the soil surface, it will be wasted.
7. Spot apply manure in the planting holes or basins, and apply by banding along the crop rows or in the furrows prepared using rippers.
8. Always use low-quality manure, such as cattle manure, in combination with nitrogen fertilizers like urea, CAN, or AS. Cattle manure alone does not provide enough nitrogen to meet crop needs.
9. Large quantities (more than 5 tons/ha) of high-quality manure, such as poultry and pig manure, can be applied without nitrogen fertilizer.

Questions & Review:

- What does livestock manure do for my land and crops? It adds organic matter that feeds the soil microorganisms, retains moisture, and promotes healthier soil. It also supplies most of the nutrients that the crop needs. Unlike commercial fertilizer, manure does not contain enough nitrogen. Therefore, adding urea, CAN, or AS can improve crop performance.
- How much manure do I need to apply? Depending on availability, 2-3 tons per hectare applied every year is adequate.
- How often should I apply manure? Applying once a year is adequate.
- Is there a right and wrong way to apply manure? Yes, broadcasting and leaving manure on the soil surface is an inefficient method. The correct method is to incorporate it into the soil. Broadcasting is less effective than spot application (in basins or around the planting hole) or banding (placing it along the row where seeds will be planted).
- Is there a right time for manure application? Yes, applying manure 2-3 weeks before planting is advisable because manure needs time to decompose before the nutrients in it become readily available to your crop. Manure

applied at the time of planting or weeks after planting is less efficient. If you apply manure after planting seeds, the current crop will not benefit from it.

Activity 3.3: Crop residues application

Background

Crop residues are the plant parts left on the field after harvest. They include cereal straw, pods and stems of legumes, and tops, stalks, leaves, and shoots of tuber, oil, sugar, and vegetable crops, as well as pruning and litter from fruit and nut trees. These residues are rich in organic matter and soil nutrients. When cereal residues are left on the surface, they can help reduce soil erosion and improve rainwater infiltration into the soil. Returning crop residues to the soil is crucial in preventing nutrient depletion, which occurs when nutrients are lost through the export of edible grains and straw. Avoid burning crop residues in the field, as burning and removing residues can result in nutrient loss, leading to poorer and more acidic soil over time. Since the synthetic fertilizer recommended in Malawi does not contain K, it is also essential to incorporate crop residues to maintain the potassium balance in your field. The quality of the residues affects crop response, with cereal residues providing greater yield increases on clayey soils and reducing erosion on sandy soils, making them suitable across different regions (See Table 1). However, due to their high C: N ratio, cereal residues decompose slowly and can temporarily lock up nitrogen in the soil during the decomposition process.

Time: 1 hour

What is needed:

- Crop residues from beans, soya, pigeon peas, and ground nuts, maize
- Hoes
- Cloth to carry residues to the field

Steps:

1. After harvesting beans, pigeon peas, or groundnuts, save all the stems, leaves, and pod shells to feed your soil.
2. If possible, perform all harvest activities in the fields where the crops were planted.
3. If not, then collect the non-edible plant pieces after shelling and carry them back to the field.
4. Incorporate legume residues, such as leaves, stems, roots, and empty pods and incorporate into the soil.
5. Spread maize residue (stover) as a mulch across the field. Do not incorporate maize stover into the soil, as it will not decompose quickly.
6. Allow them to stay in the soil until the following season.
7. When you prepare the soil for planting next season, the crop residue will be broken down, feeding the soil and helping your new crops.

Questions & Review:

- Why do we incorporate legume residues into the soil but not maize stover? *Legume residues are richer in nutrients, especially N, decompose faster, and add nutrients and organic matter to the soil.*
- Are they better than maize residues? *Yes, they are richer in nitrogen than maize stover and, therefore, help the crop grow well.*
- Can adding maize stover help feed your soil? *Yes, maize stover also contains more carbon, which serves as the primary source of energy for life in the soil.*
- Why can't I incorporate maize stover into the soil? *Because maize stover immobilizes (holds) the nutrients, therefore, crops do not grow well. Instead, applying it as a mulch helps reduce soil erosion and improve infiltration.*
- Can I apply crop residues together with manure or fertilizer to the soil? How does that help the soil? *Yes, that is the best way to ensure better use of both inputs. If you incorporate manure and legume residues into your soil, they will increase the fertility of your soil, protect your soil, and crops will grow better. If you incorporate manure into the soil and maize stover as mulch, your crops will have better access to nutrients, and at the same time, your soil will be protected from erosion.*

Module 4. Doubled-up legume rotation

Background

The doubled-up legume system refers to a farming practice where two different legume crops are grown together on the same land during the legume phase of the cereal-legume rotation system. Instead of alternating cereals with a single legume, rotation involves growing two legumes simultaneously in the same area. Legumes are known for their ability to fix atmospheric nitrogen (N) through symbiotic relationships with nitrogen-fixing bacteria in their root nodules. This nitrogen-fixing ability makes them valuable components of sustainable soil health strategies, as they can reduce the need for synthetic nitrogen fertilizers. In the doubled-up legume system, combining two legume crops offers several potential benefits.

> **Nitrogen fixation:** Both legume species contribute to nitrogen fixation, enriching the soil with this essential nutrient. This can benefit subsequent cereal crops that cannot fix nitrogen.
> **Diverse crop rotation:** Growing two different legume crops together or in succession can enhance crop rotation strategies. This helps break pest and disease cycles, improve soil health, and lower the risk of nutrient depletion.
> **Improved soil health:** Legumes, with their ability to fix nitrogen, can boost soil fertility and structure. Growing two legume species together may increase these benefits, supporting overall soil health and lessening reliance on external inputs.
> **Weed suppression:** When densely planted, legumes can smother weeds, reducing the need for herbicides and manual weed control efforts.
> **Increased yield stability:** Diversifying crop combinations can lead to more stable yields, as different legume species may have varying responses to environmental stressors such as drought or disease.

Overall, the doubled-up legume system is one of the many strategies employed in sustainable agriculture to promote resilience, productivity, and environmental stewardship.

Goal: To increase the effectiveness of integrating legumes in cereal-based systems by combining characteristics of two different legumes.

What is needed:

- Identification of two commonly cultivated legumes with more complementary than competitive characteristics, e.g., pigeon pea and groundnut.
- Secure viable seeds of the selected legumes.

- Select a land where you will practice the doubled-up legume system and assess the soil type.
- Design a crop rotation calendar.

Steps:

1. Understand the local climate and soil type of the farmer, as defined in Table 1.
2. Identify legumes that are well adapted to your local climate and soil conditions.
3. Identify two legume species that complement each other regarding growth habits, root characteristics, and nitrogen-fixing abilities. Consider factors such as growth rate, root structure, and compatibility with other crops. For example, pigeon pea and groundnut can be suitable for Malawi conditions, as groundnut grows faster than pigeon pea and has a different rooting depth, which reduces competition. Decide whether you will implement a crop rotation, an intercropping system, or both. When you implement both, as we recommend for Malawi, you grow both legume species in the same field simultaneously and then rotate this with a maize crop.
4. Prepare the soil by testing its fertility levels and making any necessary amendments to ensure optimal growing conditions for the legumes. Legumes generally prefer well-drained soil with good organic matter content.
5. Plant the seeds or transplants of the selected legume species following the planned rotation or intercropping schedule. Adhere to recommended spacing and planting depth guidelines for each species. For a pigeon pea-groundnut double-legume system, plant groundnut at 45 cm between rows and 20 cm between plants. Position pigeon pea rows within the groundnut row at 90 cm apart, meaning skip one row of groundnut. Implement weed control measures to minimize competition with the legume crops. This may include mechanical cultivation, mulching, or the use of herbicides if necessary.
6. Monitor pests and diseases by closely inspecting the legume crops for signs of pest infestations or diseases. Practice integrated pest management strategies to control pests and diseases while minimizing environmental impact.
7. Ensure that the legume crops receive sufficient water, especially during critical growth stages. Legumes generally require moderate water levels, but specific requirements may vary depending on the species and environmental conditions.
8. After each growing season, evaluate the performance of the doubled-up legume system. Note any successes, challenges, or areas for improvement, and adjust your strategy accordingly for future seasons.

Questions & Review:

- Does the legume combination matter for the doubled-up system? *Yes, the specific combination determines the benefits of the doubled-up legume system. Success depends on legume traits, local climate, soil conditions, cropping systems, and market demand.*
- Is strategic planning essential when developing a doubled-up legume system? *Yes, creating such a system requires careful planning to maximize the advantages of growing two different legume crops in rotation or intercropping.*

Module 5. Green manure legumes

Background

Green manure legumes are herbaceous, non-edible plants grown to be incorporated into the soil as a fertilizer and nutrient source for the following crops. They are very easy to establish through direct seeding and do not need any extra land preparation or inputs. Mucuna, Tephrosia, and Sesbania are suitable for maize-growing regions in Malawi.
Goal: To improve your soil health and increase crop productivity

What is needed:
Mucuna, Tephrosia, or Sesbania seeds.

You can establish green manure legumes either in rotation or through relay intercropping with annual crops such as maize. In the rotational method, legume seeds are planted as a monoculture and left to grow for one season. Then the biomass is incorporated into the soil during land preparation the following season. A maize crop is then planted. This technique is often referred to as an improved fallow and can be repeated every other year.

Relay intercropping involves planting the green manure legume, especially Tephrosia or Sesbania, within 1-4 weeks after planting maize and allowing it to grow alongside the maize crop. After harvesting the maize, the legume is left to grow until land preparation for the subsequent maize crop is completed. The biomass must be incorporated into the soil during the land preparation process. This cycle can be repeated annually.

Module 6. Agroforestry

Background

Agroforestry is an umbrella term that encompasses a diverse range of practices involving the deliberate integration of trees, crops, and/or livestock. Agroforestry practices may vary widely in terms of plant species composition, tree density, and management, depending on farmers' needs and preferences. Typical examples of agroforestry in Malawi include Gliricidia-maize intercropping, relay cropping, and rotations, alley cropping, disbursed shading, boundary planting, and home gardens with green manure and fertilizer trees such as Tephrosia and Sesbania.

Activity 6.1. Gliricidia-maize intercropping

The Gliricidia-maize intercrop is a form of agroforestry where maize is cultivated alongside *Gliricidia sepium*, a nitrogen-fixing tree species. This intercropping system is practiced in various parts of the world, including Malawi, due to its numerous benefits. Gliricidia-maize intercropping is suited for farmers with small landholdings, as it allows the integration of Gliricidia within the same piece of land. By intercropping maize with Gliricidia, farmers can harness the nitrogen-fixing ability of this species to improve soil fertility and provide a natural nitrogen source for the maize crop. The presence of Gliricidia in the intercrop system contributes organic matter to the soil through leaf litter and root turnover, enhancing soil structure, moisture retention, and nutrient cycling. This improves soil health over time, leading to increased productivity and sustainability of the farm. Gliricidia-maize intercropping is suitable for both clayey and sandy soils in the lakeshore plains and mid-altitudes, but less suitable for these soil textures in high-altitude areas (See Table 1).

Goal: To improve your soil health and increase crop productivity

How to raise Gliricidia seedlings

There are two ways to raise Gliricidia seedlings: in containers (sleeves, plastic) or on a seedbed (called Swazi bed).

What is needed:

- Suitable site close to a source of water
- Gliricidia seeds
- Hoe
- Panga knife
- Watering Can
- Wooden planks, branches, and grass
- A well-mixed potting mixture constituted from 3 parts of agricultural soil, 1 part of humus-rich soil (e.g., compost or forest soil), and 1 part of sand, as in the illustration below (Plate 3).

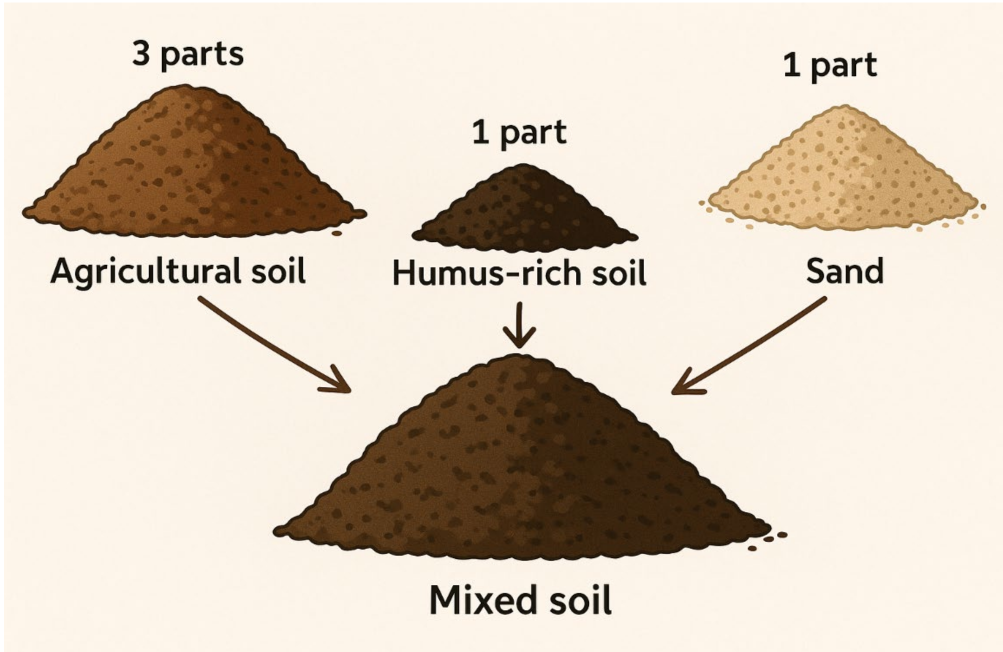


Plate 3. Recommended soil mixture for Gliricidia seedling production.

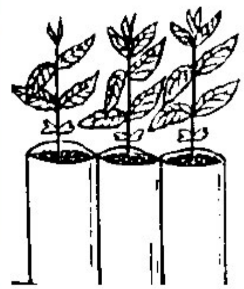
Raising seedlings in containers

Raising seedlings in containers is the standard method, but it can be expensive if plastic sleeves are used. However, if seedlings are raised through a group or community initiative, it is the fastest and safest method. The advantage of containers is that they reduce the risk of injuries to seedlings during transplanting. Containers may include mineral water bottles, Chibuku packets, milk bags, or cans.

Steps

1. Drill a hole in the bottom of the container to allow for drainage of excess water.
2. Fill the containers with the potting mixture until they are full to the top.
3. After filling all the containers, plant the seeds, water them thoroughly, and keep the containers in a shaded area, as shown in the picture below.

A community nursery

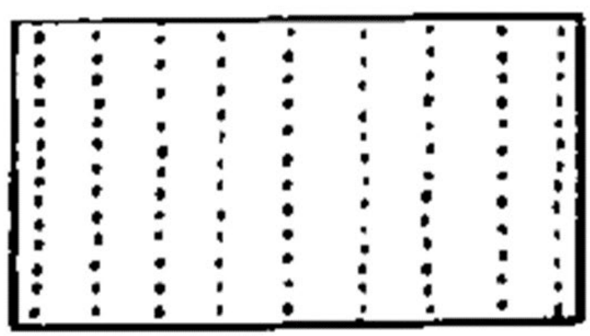


Seedlings raised in plastic sleeves

Plate 4. Community nursery management of Gliricidia seedlings in plastic sleeves

Raising seedlings in a Swazi bed as a nursery
A Swazi bed is a raised bed that resembles the one pictured below. Many smallholder farmers in Malawi prefer this method.

Swazi bed



Correct way of planting Gliricidia seeds in a Swazi bed

Plate 5. Swazi bed nursery management of Gliricidia seedlings.

Steps:

1. Select a suitable site with sufficient sunlight, well-drained soil, and easy access to water.
2. Prepare the land by clearing weeds and debris, and if necessary, conduct soil testing to assess soil fertility and pH levels.
3. Prepare a seedbed that is approximately 1 meter wide and 10 m long. The beds should be 20 cm high, constructed from a perimeter of wooden planks, bricks, or other locally available materials, such as grass. You need to build

as many Swazi beds as necessary to raise seedlings adequate for your crop land.

4. Once you build the perimeter, pour in the fertile soil. The soil should fill the bed up to 1 cm from the top of the perimeter. Water the soil thoroughly and add more soil if needed.
5. In preparation for planting the seeds, drag a stick or a panga knife in a straight line 5 cm from the edge of the bed. Then, make lines 1 cm deep (grooves) and 5 cm apart, continuing until you have created all the rows as shown in the figure on the right side (below). Once grooves are made, place Gliricidia seeds along the lines as shown below. Then, push each seed into the soil about 1 cm deep.
6. Place dried grass mulch on top of the raised beds to prevent water loss and damage from watering.
7. Water the bed thoroughly after planting and mulching.
8. Afterwards, water the bed twice a day, in the morning and evening, every day until germination occurs.
9. When the seeds begin to germinate, build a shade structure (or roof) to protect the seedlings for a few weeks. The roof should be approximately 70 cm high. Now, you can water the seedlings once a day, depending on local weather and soil conditions. The roof should be removed to expose the seedlings to full sun in the weeks before transplanting.
10. In the two weeks prior to transplant, decrease watering frequency to help harden the seedlings. But be careful not to let them wilt! The night or morning before lifting the seedlings from the seedbed, water them thoroughly.
11. Lifting the seedlings from the seedbed starts with cutting the seedbed into grids a few days before transplanting. Cut the bed into equal squares, ensuring the same amount of soil around each seedling. The panga (cutlass) should reach the bottom of the seedbed, cutting all roots in between. The seedlings should be planted immediately after being lifted from the seedbed.

Questions & Review:

- When is the right time to raise Gliricidia seedlings in the nursery?

In Malawi, September is the ideal time. This allows seedlings to grow for 6-8 weeks before transplanting in mid-November to December, when the rains begin. Keeping seedlings in the nursery for more than eight weeks can lead to overgrowth, reducing their chances of survival in the field. Conversely, growing them for less than 6 weeks may prevent proper establishment.

Field establishment and management of Gliricidia-maize intercropping

1. Start site preparation and make your ridges for the upcoming growing season two months before transplanting Gliricidia into your field; depending on *the* rainfall pattern, this should be in September or October.
2. Plant maize as usual - according to the recommended practice.
3. Mark the planting stations for Gliricidia seedlings in the furrows between the ridges and spaced 90 cm apart, starting from the beginning of the furrow.
4. Once you mark the stations in the first furrow, skip two ridges and begin measuring and marking every 90 cm again, starting at the beginning of the furrow.
5. Continue this process until you have marked the entire maize field.
6. Then dig holes measuring 20 cm deep and 10 cm wide at each planting station that you marked before. Do this a week or so before transplanting to ensure that the transplanted seedlings are planted quickly.
7. Transplant Gliricidia seedlings four weeks after you plant maize.
8. Transport seedlings to the field in containers such as trays, boxes, or cloth that will protect them from the sun and physical damage.
9. Transplant Gliricidia seedlings as shown in the picture below, 90 cm apart in the furrows, and skipping two ridges. This spacing optimizes sunlight penetration and avoids excessive shading of maize plants.
10. Once you transplant seedlings, allow them to grow in the maize field until next February.
11. In the next maize cropping season, plant maize as usual. If the Gliricidia plants are growing well, prune them in February to prevent them from shading the maize crop when they become overgrown and competing with it. If the Gliricidia plants are slow-growing, do not prune them in the first two seasons.
12. When pruning, cut the stem above 30 cm and leave the stump to regrow new branches.
13. Once the Gliricidia is well-established, it should be pruned at least three times every year. The first pruning should be in late October or early November, or in the weeks before planting. The second and third pruning should be done during the growing season, preferably at the time of the first and second weeding times. This will encourage re-growth and reduce shading of maize plants.
14. Every time you prune the branches, incorporate the leaves and twigs into the soil. Do not incorporate woody materials into the soil; they will not decompose fast enough to provide nutrients to the growing crop.

To incorporate Gliricidia pruning into the soil, follow the following steps.

- Split the ridges on either side of the row of Gliricidia trees. The split should be large enough to hold the leaves and young, tender stems that are pruned.

- As shown in the bottom panel of the picture below, evenly distribute the leaves and young, tender branches in the split ridges. Also, make sure to distribute the biomass evenly throughout both rows.
- Cover the leaves and young branches by building the ridges over them. The ridges should be in the same place, with all of the biomass within the ridges.

Plate 6. Gliricidia seedlings should be planted in the furrow. Skip two ridges

Plate 7. Incorporation of Gliricidia

Questions & Review:

- What is the right time to transplant? *On a day when* the *rains have completely soaked the soil, four weeks after planting maize*.
- What is the right time to lift and transport my seedlings? To avoid heat, it is best to do so in the early morning or late afternoon.
- Why do I have to incorporate the pruned biomass into the soil? *To add organic matter and nutrients and improve soil health*.

Activity 6.2. Biomass transfer

Background

Biomass transfer involves cutting and carrying (transferring) leafy and tender twigs from a field where fertilizer trees are grown to a garden or field for incorporation to improve soil fertility. Biomass transfer can be applied to any crop. However, harvesting and transporting biomass require labor, so it is recommended for high-value crops, such as vegetables. Once biomass is incorporated, there is no need for additional fertilizer because the crop will grow well with the steady release of nutrients from the biomass. Nonetheless, farmers can supplement with a quarter or half of the recommended top-dressing fertilizer to boost yields.

Biomass transfer can be applied in both upland areas and seasonally waterlogged regions, commonly referred to as dambo. The dambo is mainly used during the dry season and rarely in the rainy season, as it becomes flooded. Species suitable for biomass transfer are those that decompose and release nutrients quickly during the early stages of plant growth, thus contributing more to the initial supply of nutrients. Suitable species include fertilizer trees such as Gliricidia, Leucaena, Tithonia, Sesbania, and Tephrosia. Among these, Gliricidia and Leucaena are preferred because they resprout each time they are cut back. Biomass transfer is most effective on clayey soils but less effective on sandy soils.
Goal: To improve your soil and increase the productivity of high-value crops such as vegetables

What is needed:

- A well-established field of fertilizer trees
- Implement pruning of the trees
- Containers to store the biomass

Steps:

1. Establish fertilizer trees on fallow land, field boundaries, or on crop land as in the Gliricidia-maize intercropping described above.
2. Harvest tree biomass (only fresh leafy material and tender green twigs), which can easily decompose.
3. Strip the leaves from the twigs, pluck them off, or remove them using pruning scissors.

4. You can store the biomass in ventilated bags for a maximum of 10 days or dry it in the shade and keep it for as long as needed.
5. Prepare the land according to the usual practice for growing vegetables or field crops, such as maize.
6. Incorporate dry biomass into the soil within 7-14 days before transplanting vegetable seedlings or crop seeds. If it is fresh leaf material, incorporate it within three days of harvesting or as soon as possible.

Module 7. Saving your soil from erosion and degradation

Background

Soil erosion and degradation pose significant threats to sustainable farming, as they lower soil fertility, reduce crop yields, and harm long-term productivity. In Malawi and much of sub-Saharan Africa, heavy rains, steep slopes, deforestation, and continuous cultivation without adequate soil cover accelerate the loss of topsoil. Soil degradation also occurs through nutrient mining, loss of organic matter, and compaction, which weaken the soil's capacity to support crops. Saving your soil involves adopting practices that conserve topsoil, improve soil structure, and restore fertility. Standard methods include contour ridging, tied ridges, permanent raised beds, mulching, cover crops, crop rotations, agroforestry, and the use of organic and inorganic soil amendments. These practices not only prevent erosion but also help build resilient soils that retain water and nutrients, enabling farmers to adapt to climate variability.

Activity 7.1. Soil and water conservation practices

Goal: Learn how to identify and manage erosion in your farm/garden

Time: 1 hour

What is needed:

- A-frame
- Hoes
- Tree seedlings, vetiver grass, pigeon pea seeds.
- A few sloped fields

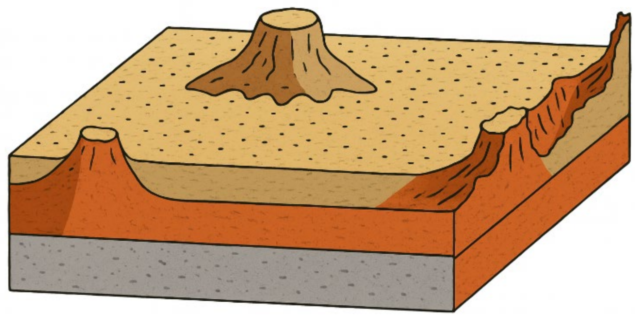
1. Take a walk along the slopes of fields. Find fields that have nothing planted and other fields with a mixture of plant types (crops, trees, and perennials).

Note: Look for areas where there are:

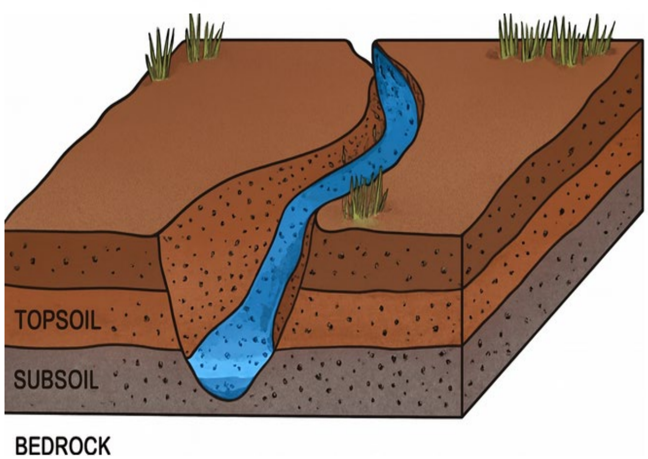
- Holes in the soil
- Uneven areas of soil
- Ridges of soil
- Different colors of soil in the same area (1 meter area)
- Puddles with a slit located at the bottom of the slopes

All types of erosion cause soil loss. All erosion can be stopped or reduced by keeping the soil covered with plant materials. Plants can be grown across slopes to reduce the erosive potential of water running downhill. The steeper the slope, the faster the water flows and the more soil it can carry. Even if you cannot see soil in the rainwater, it is there and needs to be controlled. Soil is a valuable resource that takes thousands of years to form; therefore, it is essential to conserve it.

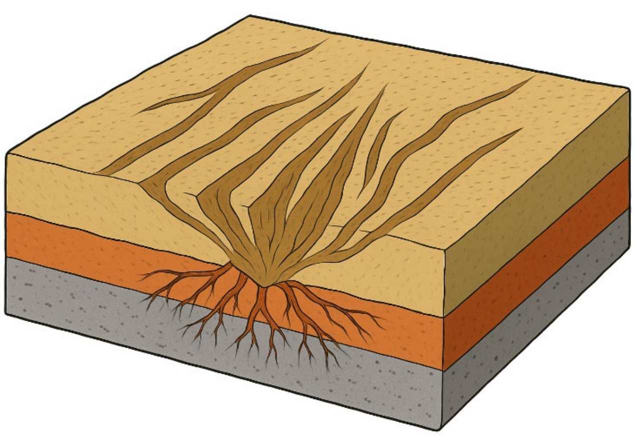
All types of erosion are essential to control. Some are easier to see in a field. Here are the types that may occur in your garden/field.



Sheet erosion: This type is slow and less obvious that soil is being lost.



Gully erosion (dongas): This type usually occurs near the bottom of slopes and forms a deep channel or gully. This is often a problem on steep land.



Rill erosion (channel erosion)**:** Channel erosion can be found on steep land or on land that slopes more gently. So, all land can have erosion problems.

Questions to consider

1. What is erosion? Removal of topsoil from the surface of the field by wind or water.
2. When does erosion occur? After heavy rains, or during strong winds, and on hillsides.
3. Why should you care about erosion? To conserve the soil. Severely eroded soils cannot support the growth of crops.
4. Does slope matter in erosion control? Yes, the steeper the slope, the more protection is needed to protect the soil surface from erosion.
5. How do you now (if at all) manage erosion in your farm? Plant trees, perennials like pigeon pea, Msungu trees (*Faidherbia albida*), tide ridges, bunds, box ridges, vetiver grass on crest.

Wind erosion

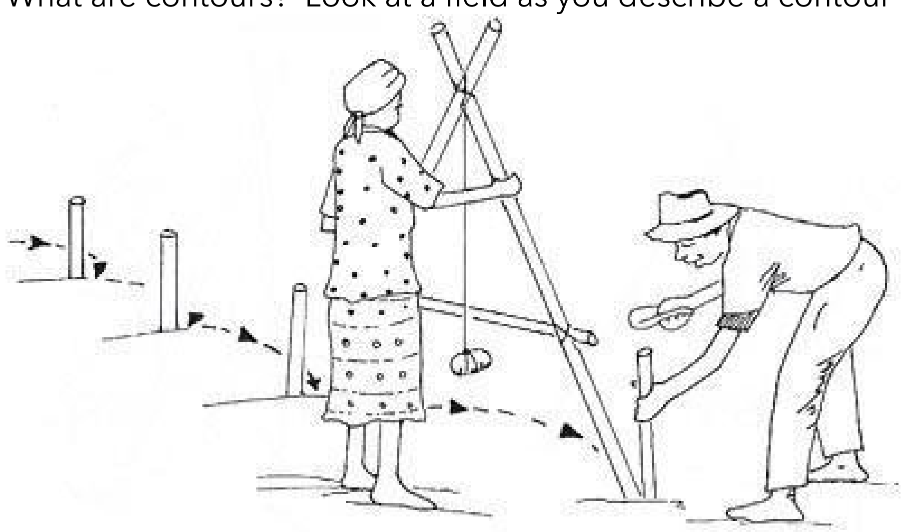
Wind erosion occurs when the land surface becomes exposed and the soil is dry, allowing wind to carry away the soil particles. This is a problem when land is left bare due to deforestation, overgrazing, or bare crop fields.

Activity 7.2. Making ridges in the field to slow the movement of soil downhill - Making and using an A-frame

Time: 3 hours

The A-frame is an accurate and extremely simple tool for measuring and marking level contours on a hillside field.

What are contours? Look at a field as you describe a contour



What is needed:

- Two straight and sturdy stakes or boards ~ 2 meters long
- Stake or board about 1 meter long
- Nails
- A string
- Either a rock or a bottle filled with rocks

Steps:

1. Nail the two long boards together at one end with a single nail. Leave the nail sticking out about half a centimeter so the string can be tied to it.
2. Next, nail the shorter board to the other two to make an "A", as shown in the drawing.
3. Tie the string onto the nail and hang the plumb at the other end of the string so that it will swing freely, but below the horizontal board.
4. Next, find where the string will touch the horizontal board when both ends are on level ground. If you are certain that you have a level spot, mark where the string is resting. Rotate (turn) the A-frame 180 degrees (half a circle) and set it back on exactly the same spot.
5. If the string is not on the same mark, the location is not level. A method for any terrain is to drive two stakes, about 10 centimeters wide, into the ground, spaced so that you can hold the A-frame with one leg on each stake.
6. Mark where the **plumb line** touches the cross member, then rotate the frame 180 degrees and repeat.
7. Place a large mark exactly halfway between the two marks. This should be where the plumb line will touch the cross member when it is on level ground.
8. To double-check, drive the higher stake until the plumb line touches the mark, showing that the frame is level. Then, you can rotate the frame 180 degrees (half circle), and the plumb line will still touch the same mark.
8. To mark out a contour, place a stake into the ground at the starting point and put one leg of the A-frame next to the stake, on the uphill side. Locate the other leg of the A-frame where the plumb line crosses the level mark, then drive a stake by the leg, on the downhill side. This becomes the new starting stake. Continue in this way across the hillside.

Questions & Review

- Do you need to use an A-frame on all fields? Explain
- What does an A-frame help you mark?
- What can you do if you do not have an A-Frame? (Plant across the slope. Plant perennials with your crops. Even if the slope is not perfect, it will help reduce erosion).

Activity 7.3. Building ridges along the marked slope line

Time: 3 hours

Goal: Learn different ways to manage erosion on hilly fields. Find ways that work best for you and your garden.

What is needed:

- Hoes
- Choose which type you will try. Each group of farmers could try a different way and share their experiences with the class at the end of the activity.

Choices to keep the soil from slipping downhill (erosion).

- Vetiver grass plants
- Agroforestry tree seedlings
- Ridging
- Box Ridges

1. TIED RIDGING

Tied ridging involves creating ridges along the contour line. These ridges help reduce soil erosion, allow water to infiltrate the ground, and trap silt. Furrows can be blocked at regular intervals with smaller ridges of soil. This system is only suitable for areas with light rainfall.

What is needed:

- Hoes
- labor

2. GRASSED CHANNELS

- Grassed channels are rows of crops that move excess water from the fields, reducing erosion.
- The channels sh5ould be planted with grass or other perennial crops. They slow down rain runoff and hold soil together.
- Vetiver grass, *Crotalaria,* and *Cynodium* species are commonly grown on the channels. Any plant that grows throughout the year will work. These plants can be grown from seed or found as seedlings at the AEDO's office or a local community tree nursery.
- Bunding along the contour line: Soil is moved to form boxes between the contours. These boxes hold water and allow it to drain into the ground. Vertical channels can be created to help excess rainwater drain away. This method requires a lot of labor but does not need plants, making it less costly. Where possible, keep soil moist and maintain plant cover. This will reduce the chances of losing topsoil while feeding the soil microbes.

Questions & Review:

1. Why is it essential to control erosion?
2. How do you know if you have a problem with erosion? Use observation skills and describe.
3. Which approach to control erosion did you try?
    a. What do you think of that method?
    b. Have you done it before?
    c. Describe what you have learned from doing the different approaches to control erosion.
    d. Please describe how you did it and provide tips to the other farmers.