SOIL AND WATER MANAGEMENT

A TRAINER'S GUIDE

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FOREWORD

This training guide was developed as one of the products from the ASARECA- supported project "Promoting Sustainable Natural Resource Management through Effective Governance and Farmer-Market Linkages". The project was implemented in Uganda, Kenya and Tanzania **between 2009 and 2011**. The project aimed at enhancing the capacity of resource users (farmers) to manage their natural resources by engaging in production of readily marketable enterprises.

As part of capacity building, the project produced two training guides on soil and water conservation: Soil and Water conservation: A Necessity for Farm Productivity (intended for farmers), and the current Soil and Water management: A Trainer's Guide (targeting farmer trainers, extension workers, NGOs and other agricultural service providers). This Trainer's Guide gives additional technical information to supplement the farmers' guide.

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ACRONYMS

DDSA	Diagnostic and Decision Support Aid
NARO	National Agricultural Research Organization

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ABOUT THIS GUIDE

Purpose

This guide has been developed as a training tool to help farmer trainers to know some of the soil and water conservation practices and train farmers in putting them into practice on their farms. This hands-on guide attempts to bridge the gap between technology availability from researchers and its application by the farmers. By using this guide, the farmer trainer should be in a better position to train farmers into practical skills that will help them manage their soil resources better and more sustainably.

Target Users

The information provided in this manual will be of value to farmer trainers, extension workers, NGOs, and students in tertiary institutions offering agriculture, environment, natural resource management and other related courses. The simple illustrations make the guide easy to understand and the message easy to follow.

How to use this guide

This practical guide gives simple step by step instructions for an agricultural service provider (farmer trainer, field extension worker) involved in teaching farmers how to implement soil and water conservation activities.

Information in this manual has been simplified to suit trainers of various backgrounds. The trainer should endeavour to articulate the technical information in this manual, into the local languages using relevant local examples plus pictures and illustrations in the guide, to facilitate the learning process.

The guide is divided into eight modules.

Module one gives a general introduction to soil and water management and its relevance to sustainable crop production.

Module two gives some important aspects about how a farmer can know his/her soil resource. This is important because it is key before one takes a decision as to which soil management technology he/she is to take on.

Module three defines soil fertility concepts and presents a brief on nutrient management options.

Module four deals with different processes through which soils lose their fertility, the signs that a farmer can visualise in the field, and the coping methods available to a farmer so as to minimise soil fertility loss.

Module five presents simple practical/ demonstrations a trainer could carry out in a field or classroom, followed by examples of the different structural options for soil and water conservation. These are possible options that a farmer can put in place to control soil erosion and conserve water for crop use.

Module six outlines some of the equipment used to construct soil and water conservation structures. It gives a detailed account of the practical step by step procedures in the use of the line level for citing contours, determining the vertical interval and contour spacing.

Module seven gives some of the agronomic/ cultural/conservation farming measures that a farmer can use to manage his/her soil better.

Module eight gives some examples of how soil conservation practices can be integrated in the farming system, citing agro-forestry, zero grazing and pasture management, among others.

Within each module there are small colored boxes that contain key notes which the trainer should emphasize during the training. There are also text boxes with key points for the trainer to note and act on during the course of the training. Overall, this book is meant to serve as an interactive guide between the trainer and the trainees on how to identify and address common challenges to soil management.

At the end of the book there are general facilitation/training guidelines for the trainer/facilitator that he / she could use.

MODULE ONE: INTRODUCTION TO SOIL AND WATER MANAGEMENT

Note:

Give brief background to soil and water management, principles, its importance to crop productivity and challenges

1.1 BACKGROUND TO SOIL AND WATER CONSERVATION

In East Africa, the majority of the population particularly in rural areas, derive their livelihoods from agriculture. Indeed the economies of most developing nations largely hinge on agriculture. However, many farmers rarely get close to the expected crop variety potential yields.

While many factors are responsible for this gap such as pests and diseases, weather- related problems, soil related factors are rarely appreciated. Among the soil-related factors are: (i) inadequate use of appropriate soil management practices leading to extensive soil erosion, nutrient mining and declining soil fertility; (ii) limited soil moisture conservation which affects crop growth and development.

It is therefore imperative that farmers integrate SWC practices into farming. Integration of SWC into farming hinges largely on farmers' knowledge and ability to invest into the practices. To encourage and guide the farmers to adopt and sustain the soil and water management practices, the agricultural service providers need to be equipped with a wealth of knowledge and skills.

1.2 IMPORTANCE OF SOIL AND WATER MANAGEMENT TO CROP PRODUCTION

Soil is a medium for plant growth. It stores nutrients which are required for proper plant growth. Soil also offers a medium where plant roots can anchor and be able to trap sunshine and carbondioxide from the atmosphere, and as a result, grow. Plants take up nutrients from the soil in solution form. The nutrients taken up are utilized with carbondioxide in presence of water and sunshine to manufacture food both for man and the plant's own use. For tropical soils most nutrients required by plants are derived from the black organic matter layer found in the top part of the soil, and varies from about 10 to 30cm thick.

Since crop nutrients are associated with soil organic matter found mainly in the surface layers of the soil, they are susceptible to losses through erosion by water and wind, once vegetation cover is removed. The nutrients are also prone to leaching in high rainfall areas. When these nutrient losses are coupled with deterioration of soil physical properties, crop yields gradually fall especially where intensive cropping is practiced.

Sustainable soil productivity implies that a soil resource can give the desired crop/ animal yield and maintain it through a long time for the benefit of the present and future generations. To achieve this, proper management of the soil and the land in general, is essential. Proper soil and water management is a component of Integrated Soil Fertility Management (ISFM) which entails a number of inter-related practices. Briefly, they include soil erosion prevention, water conservation / management, managing soil physical, chemical and biological properties, organic matter management, soil fertility management and nutrient recycling/ replenishment.

Managing soil physical, chemical and biological properties:

Soil physical characteristics (e.g. structure, texture, porosity, permeability) affect soil water relations (percolation, infiltration, availability), aeration and root development, among other things. Soil physical properties are normally managed through proper tillage practices and organic matter management. Soil also serves as a habitat for many living organisms (macro and micro). These perform essential functions such as improving soil aeration and permeability (hence better root development), decomposition of plant residues, recycling of plant nutrients, etc. Proper organic matter management promotes soil biological life leading to a better soil medium. Soil chemical properties reflect its ability to supply plant nutrients, among other things.

Organic matter management:

Organic matter is an important component of the soil medium in improving soil physical, and biological properties. Organic matter also serves as a nutrient reserve; many nutrients are replenished through organic matter decomposition. Organic matter management implies recycling of crop residues, mulching, use of compost, farmyard manure, animal manure, green manures, etc. It also implies prevention of soil erosion since organic matter is mainly found in the topsoil. Fallow and minimum tillage practices reduce organic matter depletion and are therefore good components of organic matter management.

Soil fertility management and nutrient recycling/replenishment:

Soil nutrients are lost through crop harvesting, erosion and leaching. To maintain soil fertility, the nutrients lost must be replaced. This can be achieved through addition of external inputs e.g. fertilizers (organic and inorganic), BNF, recycling plant residues, among others. Sound crop management e.g. crop rotation and fallow (natural or improved) also help to reduce soil fertility decline and improve soil fertility. Crop rotations involving shallow and deep rooted crops help to recycle nutrients back into the root zone. While nutrients are removed from the entire farm (through crop harvesting), farmers often tend to recycle residues around the homestead, leaving other areas of the farm impoverished of nutrients. Farmers need to replace/recycle nutrients in the entire field.

1.3 CHOICE OF SOIL AND WATER MANAGEMENT MEASURES

The choice of soil and water conservation/ management measure to use will normally depend on characteristics of the land (e.g. slope), resources available to the farmer (hence affordability in terms of labour and capital). Among, other things, aspects like government policy (e.g. land tenure) also affects the level of investment (hence soil conservation measure) a farmer is likely to put in place. Soil erosion control also involves using appropriate land preparation and crop management practices e.g. cultivating and planting along the contour (across the slope), not up and down the slope.

1.4 CHALLENGES OF SOIL AND WATER MANAGEMENT

Soil and Water Conservation/Management is a key component of sustainable crop production. However, many practices are labour intensive, expensive and take long to yield results. As a result many farmers are reluctant to invest into soil and water conservation practices. In addition where a farmer does not have security of tenure over the land, s/he may not be motivated to invest in soil and water conservation. Nevertheless, for sustainable crop productivity and production, soil and water conservation needs to be implemented as part of good soil and crop husbandry practices.

MODULE TWO: KNOWING YOUR SOIL

2.1 KEY DEFINITIONS

Note:

Define soil, soil texture, soil structure, organic matter, soil fertility, soil productivity.

Soil is a medium for plant growth. It provides space for rooting, supplies nutrients, water and air, and support plants (anchorage). Soil is derived out of decomposing rocks and organic materials. Soil contains rock mineral particles, air, moisture, living organisms and dead/decaying organic matter. The mineral part of a soil is made of sand, silt and clay.

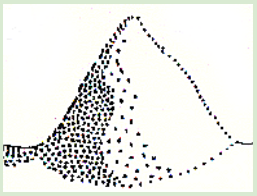
Soil texture refers to the relative percentages of sand, silt and clay. Owing to the different proportions of sand, silt and clay, soils can differ in textures. Soil texture can be determined in the field or laboratory. Below is a simple method for determining soil texture in the field.

Box1 Determining soil texture in the field

Simple method to determine soil texture

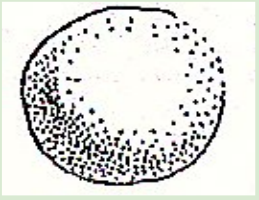
Take a small handful of soil from the field, drip water slowly onto the sample until it reaches the "sticky point", the point at which the soil adheres to itself but not to the hand. Using the moist soil sample form different shapes as shown below. The shape you can make roughly indicates the texture of soil.

1



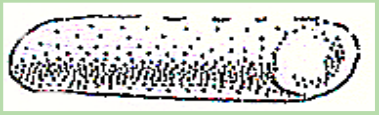
Sand
Soil remains loose and single grained and can only be heaped into a pyramid

2



Loamy Sand
Soil can be shaped into a ball

3



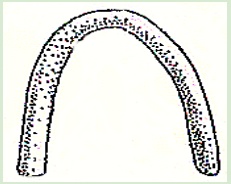
Silt loam
Soil remains loose and single grained and can only be heaped into a pyramid

4



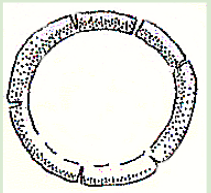
Loam
Soil can be rolled into a cylinder, about 15 cm long

5



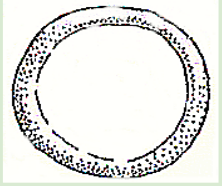
Clay loam
Soil can be bent into a U shape

6



Light clay
Soil can be bent into a circle with cracks

7



Light clay
Soil can be bent into a circle without cracks

Soil structure:

Refers to the physical arrangement of soil particles. Soil particles can be unattached as in sandy soils or they can be closely packed together as in clay soils. Usually the particles are held together in aggregates (crumbs) with the formation of stable aggregates, an important feature of a productive soil. Higher organic matter content improves stability of soil aggregates. Soils with good structure allow seedlings to emerge easily and provide a ready supply of water and air to plant roots.

Organic matter:

Refers to the remains of living plants and animals after death. It decomposes to form dark small particles called humus, which normally imparts a dark colour to soil. Humus contributes to soil structure and water holding capacity. Humus also acts as a source of food to important soil micro organisms. During decomposition of organic materials, soil nutrients are released which serve as food for plants.

Organic matter contributes to soil fertility in the following ways:

- Provides nutrients during decomposition
- Increases the soil's capacity to hold nutrients
- Builds soil structure which increases water infiltration and crop water use
- Protects the soil against rapid changes in acidity or alkalinity (soil pH).

Note:
Show physical differences between a soil with and without organic matter.

Soil organic matter content:

The amount of organic matter in a soil depends on:

(i) Soil type – sandy soils usually have low organic matter than clayey ones
(ii) Temperature – influences the rate at which organic materials are decomposed by soil organisms.
(iii) Amount and type of organic material added as manure or in crop residues
(iv) Management practices

- method and frequency of tillage - tilling soil increases organic matter breakdown
- burning destroys organic materials in the soil (e.g. living and dead organisms),

Soil organic matter can be increased through reduced tillage, planting cover crops, addition of crop and animal residues, composts, farm yard manure, mulching, etc.

Soil fertility:

Refers to the ability of a soil to supply nutrients in the form and quantity required by a plant. Most tropical soils derive their fertility from organic matter.

Soil productivity:

Is the ability of a soil to provide a favourable rooting medium for plant growth [ability to supply nutrients and provide a good physical environment for the roots (good aeration, structure, rooting depth, favourable temperature)].

Soil rooting depth is an important indicator of soil's ability to support crop growth by providing moisture, nutrients, and physical support. Soil rooting depth depends on the presence of rocks, layers in soil or cultivation pans, which restrict downward root penetration. Shallow soils are poor for crops because of lower nutrient and water availability (smaller root volume) for plant growth. Soil erosion is one of the main causes of reduced rooting depth.

2.2 CHARACTERISTICS OF DIFFERENT SOIL TYPES

Note: Give characteristics of each soil type and show the different soil types

Sand

- Large soil particles (2mm diameter or greater)
- Coarse texture
- Large air spaces
- High aeration
- High infiltration rate-less runoff
- Low water storage capacity
- Easy to plough through
- Low nutrient retention

Clay loam

- Tiny soil particles
- Fine texture
- Very small air spaces
- Low aeration
- Low infiltration rate
- High water storage capacity
- Difficult to plough through High
- nutrient retention

Loam

- The characteristics for loam soil are intermediate between those of sand and clay soils.

MODULE THREE: SOIL FERTILITY CONCEPT, EXPERIENCES, PROBLEMS AND MANAGEMENT

Soil fertility refers to the capacity of soil to supply essential plant nutrients in the amount and form that a plant can take them up easily. For this to be achieved, soil must have good physical, chemical and biological properties. Thus, a fertile soil must:

- Be deep enough to enable roots explore a sufficient soil volume without any obstructing layer
- Contain sufficient organic matter.
- Have good structure (based on the distribution and aggregation of particles) to ensure proper aeration, hence growth and development of roots
- Have a favourable soil reaction (pH range 5.5 to 6.5 for most crops)
- Have a good supply of both available and reserve plant nutrients
- Be able to store soluble nutrients e.g. from fertilizers

3.1 ESSENTIAL PLANT ELEMENTS

An essential plant element is one which:

- A plant cannot complete its life cycle without it
- Cannot be substituted by any other element
- Is involved in plant nutrition, e.g. forms a structural constituent or an essential metabolite.

There are 16 essential plant elements. They include: **carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, molybdenum, boron, zinc, copper, iron, manganese and chlorine.**

Carbon is taken up as carbondioxide from the air; hydrogen and oxygen are derived from water. Carbon, hydrogen and oxygen form the basic building blocks of all plants. They are involved in the formation of all organic plant constituents, such as carbohydrates, proteins, nucleic acids and others. Other elements are derived from the soil solution, having been released from the mineral constituents of the parent material through weathering processes. Essential plant nutrients can also be supplied to the soil through addition of fertilizers (organic or inorganic), or through the decomposition of plant and animal residues. Nitrogen can also be derived from the atmosphere through nitrogen fixation (BNF) by legumes. Shortage or lack of essential element in a plant results in improper signs/appearance and growth of a plant, known as deficiency symptoms. Excess of an essential element may lead to toxicity in the plant. Box 2 presents functions and deficiency symptoms of essential elements in plants. A DDSA chart for quick identification of plant disorders is given in in Fig. 1.

3.2 NUTRIENT LOSSES

Soil nutrient losses occur through crop harvesting, leaching, immobilization, fixation, denitrification and volatilization. Due to these losses, soil fertility declines continuously and there is need to replenish the nutrients lost. Most soils in Uganda are old and their nutrient reserves are very poor. The most limiting nutrients in Uganda soils include nitrogen, phosphorus and especially for bananas, potassium. The best way to manage our soils is by managing organic matter (see module 1 of this book).

Box 2: Functions and deficiency symptoms of essential mineral elements

A. Macro nutrients are absorbed in large amounts and comprise of the primary and secondary elements

Element & Form Absorbed	Proportion of plant, (%)	Functions	Deficiency symptoms
Carbon (Carbondioxide, CO_2)	41.2	Involved in the formation of all organic plant constituents e.g. carbohydrates proteins, nucleic acids, etc.	
Oxygen (Carbondioxide, CO_2)	46.3	Involved in the formation of all organic plant constituents e.g. carbohydrates proteins, nucleic acids, etc.	
Hydrogen (Water, H_2O)	5.4	Involved in the formation of all organic plant constituents e.g. carbohydrates proteins, nucleic acids, etc.	
(i) Primary elements (required in large quantities)			
Nitrogen (Nitrate, NO_3^-, Ammonium, NH_4^+)	3.3	Constituent of chlorophyll, protein and nucleic acids (DNA & RNA) in the cell nuclei.	Yellowing (chlorosis) of lower leaves starting from tips; stunted growth.
Phosphorus (Phosphates: H_2PO_4, HPO_4^{2-})	0.3	Essential for root growth, cell division and growth, respiration; fruiting and seed formation; constituent of nucleic acids.	Purplish leaves especially on margins; stunted growth. Deficiencies common in early growth stages.
Potassium (Potassium ion, K^+)	0.8	Cell division, carbohydrate formation & translocation, enzyme action; plant resistance to certain diseases, cell permeability	Marginal burning (necrosis), weak plants
(ii) Secondary elements (generally required in less amounts than the primary elements)			
Calcium (Calcium ion, Ca^{2+})	2.1	Constituent of the middle lamella and hence the cell wall; required for selective absorption of nutrients by cells; essential for cell division	Deformation of the terminal bud; dead spots in the midrib of some plants.
Magnesium (Magnesium ion, Mg^{2+})	0.42	Chlorophyll constituent, acts as a Phosphorus carrier in plants; helps in starch translocation; aids in formation of oils and fats	Chlorosis between veins (veins remain green)
Sulfur (Sulphate, SO_4^{2-})	0.085	Constituent of amino acids hence an essential part of protein, vitamin and oils.	Mottled yellowish-green leaves and veins.

B. Micro (trace) elements (required in very small amounts; may be toxic if in excess			
Element & Form Absorbed	**Proportion of plant, (%)**	**Functions**	**Deficiency symptoms**
Iron (Ferrous ion, Fe^{2+})	0.0066	Enzyme activator	Interveinal chlorosis (light coloured areas between dark veins)
Boron (boric acid, H_3BO_3, borate, H_2BO_3)	0.0045	Enzyme activator; essential for cell metabolism & cell division; germination & fertilization	Terminal buds die; flower or fruit shedding.
Manganese (Manganese II ion, Mn^{2+})	0.0036	Enzyme activator	Brownish, greyish, whitish spots (cereals); (brownish black spots (legumes & potatoes).
Zinc (Zinc ion, Zn^{2+})	0.0009	Enzyme activator; formation of auxins.	Pale to white colouration of young leaves, stunted growth; common in maize, beans, citrus.
Copper (Copper II ion, Cu^{2+})	0.0007	Enzyme activator; constituent of chlorophyll	White tip on youngest leaf, leaves are narrowed & twisted; stunted growth; terminal buds die
Molybdenum (Molybdate ion, MoO_4^{2})	0.000005	Required by legumes for N fixation.	Resemble N deficiency symptoms.
Chlorine (Chloride, Cl)	0.011	Root growth; cell respiration.	Chloritic leaves; some leaf necrosis.

PS: Symptoms for N, K, Mg and P appear first on older leaves; symptoms for S, Fe, Cu and B appear first on younger leaves. For cereals, Mn deficiency symptoms appear first on older leaves, while for legumes and Irish potatoes, they appear first on younger leaves.

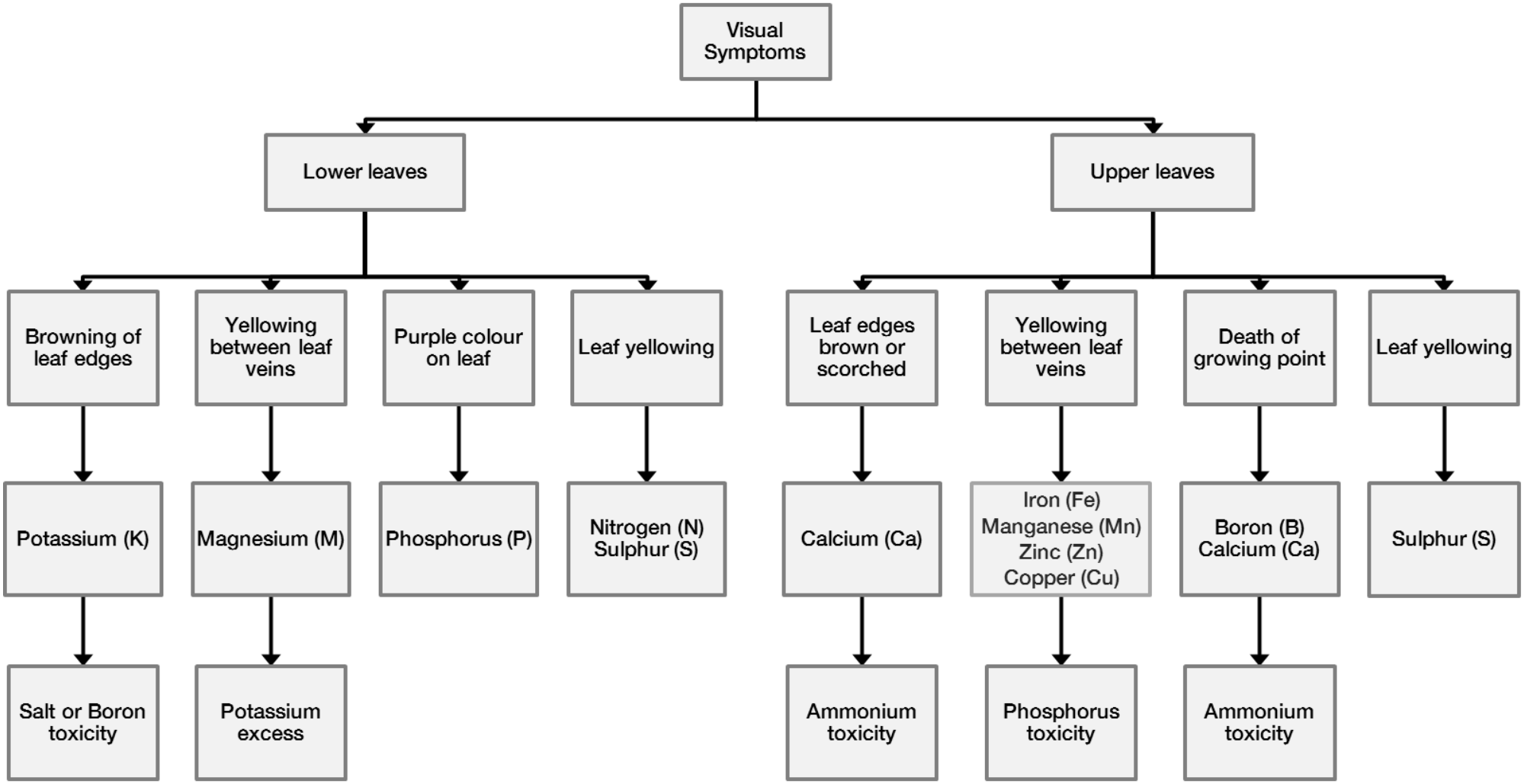


Figure 1: Visual symptoms of nutrient deficiencies and disorders (Source, Fairhurt, 2012)

3.3. SOIL FERTILITY AND NUTRIENT MANAGEMENT

Soil fertility management involves knowledge of the nutrient transformations (changes, gains and losses) that essential plant nutrients undergo in nature. Nitrogen is the most limiting of all nutrients due to the many transformations it undergoes.

3.4 SOIL NITROGEN

3.4.1 Nitrogen transformations

Nitrogen fixation

Nitrogen occurs naturally abundantly in the atmosphere, although this form is not directly available to plants. Through BNF a small proportion of the atmospheric nitrogen can be fixed into plants and consequently, ends up into the soil. Nitrogen can also be added to soil through addition of fertilisers (organic or inorganic) and through atmospheric fixation via lightening.

Ammonium fixation

Some types of soil colloids are able to fix NH_4^+ tightly into their structure, thus preventing its loss from the soil. This can slowly be released into the soil solution from where it may be taken up by plant roots.

Mineralisation

This refers to the conversion of organic N into inorganic N forms (e.g. ammonium):

$$\text{Organic-}NH_2 \longrightarrow NH_4^+$$

Nitrification

Refers to the conversion of NH_4^+ into nitrate

$$NH_4^+ + O_2 \xrightarrow{\text{nitrosomonas}} NO_2^- + 2H^+ + \text{Energy}$$

$$2NO_2^- + O_2 \xrightarrow{\text{nitrobacter}} 2NO_3^- + \text{Energy}$$

Nitrification leads to formation of nitrate form of nitrogen (NO_3^-), a more readily leached form of nitrogen.

3.4.2 Nitrogen losses

Leaching – refers to the process whereby NO_3 is dissolved and transported along with the water, to lower soil depths from where plant roots can no longer extract it.

Crop harvest – for every product harvested from the soil, nutrients are lost from the soil. There is need to replace the lost nutrients.

Ammonia volatilisation – loss of N as NH_3, especially at soil pH above 7.

Immobilisation – some of the nitrogen applied to soil may be taken up by micro organisms and thus becomes unavailable to plants. This deprives the growing plant of the essential N (until after the micro organisms die, decay and release the N).

Denitrification – loss of N in gaseous forms such as NO, N_2O or N_2

Soil erosion – by washing away the topsoil, erosion deprives soil of organic matter and any plant nutrients contained therein.

3.4.3 Managing soil nitrogen

- Control soil erosion
- Recycle crop and animal residues Use less easily
- leached N forms, e.g. ammonium forms as opposed to nitrate fertilisers.
  Split-apply N fertilisers instead of a single application
- Use leguminous crop/plant species in the
- cropping cycle.

3.5 SOIL PHOSPHORUS

Phosphorus (P) naturally occurs as very sparingly soluble rock phosphate (apatite).
A large proportion of P in apatite is unavailable to plants. Treatment with very strong acids partially solubilises this material making the P more available to plants.

3.5.1 The Phosphorus status of tropical soils

Being highly weathered, the reserve P status of most tropical soils is very low. In addition, weathered soils tend to fix Phosphorus, making it less available to plants. Because of this, Phosphorus in most tropical soils is supplied through organic matter decomposition.

3.5.2 Soil Phosphorus losses in nature

1. Soil erosion
2. Crop harvesting
3. Fixation by soil constituents.

3.5.3 Managing soil P

1. Reduce soil erosion
2. Recycle crop and animal residues
3. Add P fertilisers
4. Avoid practices that lead to soil acidification e.g. monocropping continuous cropping, use of acidifying fertilisers
5. Apply liming materials, e.g. agricultural lime, kitchen ash, compost.

3.6 SOIL K, Ca and Mg

These nutrients mainly occur naturally in soils, but can be added through application of fertilisers, ash, compost and organic (plant and animal) residues. They are lost through soil erosion, crop harvesting and fixation (for K). Soil acidification also affects the availability of these nutrients.

3.6.1 Managing soil K, Ca and Mg

1. Control soil erosion
2. Avoid practices leading to soil acidification
3. Apply fertiliser materials that can supply these nutrients, e.g. muriate of potash for K, CAN for Ca and N, dolomitic limestone for Ca & Mg.
4. Recycle organic (crop and animal) residues.

3.7 MICRO-NUTRIENTS

Soil micro-nutrients are commonly managed by maintaining soil pH in the range of 5.5 to 6.5. Thus, practices such as crop rotation, liming of acid soils and recycling of organic residues help to ensure a good supply of soil micro nutrients.

Note:

1. Most essential plant nutrients can be managed by controlling soil errosion, hence the need to emphasise soil conservation practices.

2. continuous use of organic (plant and animal) residues promotes survival of soil microorganisms, which are the driving engine for a biologically, chemically and physically healthy soil medium.

MODULE FOUR: SOIL FERTILITY LOSS AND COPING METHODS

Note : Describe soil fertility loss and effect on crop production

4.1 SOIL FERTILITY LOSS

Soil fertility loss refers to the progressive loss of nutrients, leading to reduced crop growth and development. Soil fertility loss can occur in 3 main ways. These include:

1. **Soil erosion:** This mainly affects the top soil layers
2. **Crop cultivation and harvesting**
   This leads to loss of soil nutrients
3. **De-vegetation**: This is loss of vegetation from an area through deforestation, burning, ploughing, over grazing leading to soil fertility loss

Soil fertility loss reduces crop yields and animal output, increases problems with crop diseases and results in lower quality of crop produce.

4.2 SOIL EROSION

4.2.1 Types, causes and coping methods for water-induced soil erosion

Soil erosion is the process of losing topsoil by action of water and/or wind. It results in a progressive decline in soil productivity leading to reduced crop yields and animal outputs. Water-induced erosion can be sheet, rill or gully erosion, depending on the severity.

Note:

Describe and illustrate sheet, rill and gully erosion

Indicate the likely causes of soil erosion and options for interventions

SHEET EROSION





Figure 2: Sheet erosion in Namayingo district, Uganda

Description

- Sheet erosion is soil movement caused by raindrop splash resulting in the breakdown of the soil surface structure and surface runoff (Figure 2).
- It occurs uniformly over the slope and may go unnoticed for some time.
- Sheet erosion can be recognized by soil deposition at hedgerows or the bottom of a slope, exposure of roots or stones, build-up of coarse (big) soil • particles on the surface or the exposure • of light-coloured subsoil.

Likely causes

- Continuous cultivation
- Soils that are bare through overgrazing are particularly susceptible
- Soil compaction through over-stocking, use of heavy machinery

Coping methods

- Crop rotation, contour cultivation, agro-forestry, intercropping, relay cropping
  Control (reduce) grazing pressures Maintain soil cover (minimum tillage, mulching, cover cropping)
  Avoid bush burning
-

RILL EROSION



Figure 3: Small rills
Small rills can be formed after a single storm, when the soil surface is bare or poorly covered



Figure 4: Deep rills
Deep rills can be found at slope bottoms where runoff concentrates

Description

- Rill erosion results when surface runoff concentrates forming shallow linear depressions or small well-defined channels, normally less than 30 cm in depth (Figures 3 and 4).
- The small channels can be smoothed out (filled in by soil from the surrounding) by cultivation
- Rills up to 30 cm deep are often easily visible in recently cultivated soils or areas cleared of vegetation. In tilled soils, rills often extend to the depth of the tilled layer
- Rills are usually aligned along the slope (cut across the contour) and occur in a series of nearly parallel rill lines down the slope.

Likely causes

- Rill erosion is common on agricultural land devoid of vegetation and so is often seen in cropped areas after tillage
- Following intense rainfall, cultivated top- soils overlying denser cohesive sub-soils often show rill erosion

Coping methods

- Planting grass around waterways
- Diversion structures (channels that are constructed across slopes which cause water to flow to a desired outlet)
- Plant vegetation in the land around the gully to reduce runoff and consequently, the amount of water reaching the gully
- Construct diversion banks, drop structures and retention dams, depending on the severity of the gully, in association with earthworks
- Replace vegetation to stabilise banks and exclude grazing animals.

GULLY EROSION



Figure 5: Gully in Mubende District, Uganda



Figure 6: Gully in Masaka District, Uganda

Description

- Gully erosion is an advanced stage of rill erosion where surface channels have been eroded to the point where they cannot be smoothed over by normal tillage operations (Figures 5 and 6).
- The depth of the channels is over 30 cm

Likely causes

- Gully erosion often occurs on lower slopes, but can form in the upper slope of the landscape in erosion susceptible areas.
- Areas commonly affected have easily erodable subsoils when exposed.

Coping methods

- Retain vegetative cover onto the soil surface to avoid leaving soil bare, especially during periods of high intensity rainfall.
  Keep land vegetated throughout the year (perennials are good).
- Improve fallow by growing leguminous
- cover crops and rotation of cropland.
- Reduce grazing pressure
- Improve vegetation management (relay cropping, intercropping, agro-forestry) integrated with soil management (soil bunds, cut off drains, water basins) to maximize rainfall infiltration and use by vegetation.

4.2.2 SOIL EROSION INDICATORS

Note: Discuss with participants, the visual indicators of soil erosion

Box 3: Selected visial indicators of soil erosion

Armour layer



Armour layer, Rakai, Uganda

Fine soil particles have been selectively removed by erosion, leaving an armour layer of coarser soil particles concentrated on the soil surface. The thickness of the layer may

indicate the severity of erosion

Rills



Rills on bare slope soil, Rakai, Uganda

A rill is a shallow linear depression or channel in soil that carries water after a recent rainfall. Rills are usually aligned along the slope (cut across the contour) and occur in a series of nearly parallel rill lines. The small channels can be smoothed out (filled in by soil from the surrounding) by cultivation. In a particular area the total length, depth and width of the rills indicate the seriousness of erosion.

Gully



A gully in a banana field, Mpigi, Uganda

A gully is a deep depression, channel or rift which is deep and wide enough and cannot be smoothed over by normal tillage operations. The length, width and depth of a gully can indicate the extent of accumulated erosion over time.

Crop/tree root exposure



Banana roots exposed by erosion, Mpigi

Plant roots may be exposed when soil around the base of a plant/tree is washed away.

4.2.2 SOIL EROSION INDICATORS CONTINUED

Rock exposure



Rocks exposed by erosion, Rakai, Uganda

The underlying rock has been exposed at the ground surface because of soil erosion. When soil is washed away, marks/ stains may be left on the rock. The extent of soil erosion can then be estimated by the depth of the soil lost.

Soil colour



Change in soil colour after using mucuna green manure, Mpigi, Uganda

Soil colour is a simple but useful indicator of fertility. The colour of a particular soil is largely controlled by the amount of organic matter in the soil. Soils rich in organic matter are dark. Topsoil normally contains more organic matter and is darker than sub-soil. Severely eroded soils tend to be more red than the less eroded ones.

4.2.3 EFFECTS OF SOIL EROSION

Note: Discuss with participants, the effects of soil erosion

- Soil erosion removes the most productive topsoil layer which has the highest amount of organic matter, biological activity, and nutrients.
- Erosion decreases rooting depth and therefore reduces the amount of water, air and nutrients available to crops.
- Erosion breaks down soil structure by selectively removing fine soil particles e.g. clays, small organic particles. Structure breakdown reduces water infiltration and further accelerates erosion
- Erosion makes tillage more difficult by forming gullies, exposing subsoil and rocks.
- Loss of topsoil reduces the capacity of the soil to function and affects its ability to sustain future production.

4.3 CROP CULTIVATION

Note:
Discuss with participants, how crop cultivation can lead to soil fertility loss

- Growing crops extract nutrients from the soil and when harvested, the nutrients are lost unless crop residues are recycled back to the farm.
- Continuous cultivation with little or no use of fertilizers (organic or inorganic) leads to a progressive loss of nutrients, a process known as nutrient mining
- Where land shortage is a problem, continuous cultivation with none or reduced fallow period reduces the time available for natural fertility regeneration
- Different crops have different nutrient demands and mono-cropping can lead to mining of particular nutrients from the soil.

Coping methods

- Return crop residues including ash to the soil
- Add mineral fertilisers to the soil, after soil testing
- Plant legumes such as beans, groundnuts, soybeans
- Carry out crop rotation

Note:
Discuss with participants, possible crop rotation sequence suitable to their areas

4.4 DE-VEGETATION

This is the process by which vegetation cover is lost from an area through deforestation, burning, ploughing, brick making and over grazing leading to soil fertility loss.

Note:
Discuss with participants, how deforestation, burning, ploughing, brick making and over grazing can lead to soil fertility loss

- **Deforestation** in this context refers to loss of forest cover through land clearing cultivation and tree felling for timber, charcoal, firewood, poles, fodder, medicine, food, etc. Deforestation can also be in form of shrub cutting and bush fires. Loss of forest/shrub cover exposes the soil to agents of erosion, leading to soil fertility loss. It also accelerates liter decomposition, further contributing to soil fertility loss.
- **Burning** destroys biomass, soil organisms, and exposes soil to agents of erosion, leading to soil fertility loss.
- **Ploughing** removes biomass and exposes soil to agents of erosion. Poor cultivation methods (e.g. up and down the slope) contribute to soil fertility decline particularly in the upper part of the slope. Continuous use of heavy machinery for ploughing leads to soil compaction, which reduces water infiltration and increases runoff.
- During **brick making**, topsoil which is usually the most productive is removed and subsoil is exposed. In addition, fuel-wood is needed to burn the bricks. These processes impact directly on soil fertility.
- **Grazing** extracts mineral nutrients (fertility) from the soil. Overstocking leads to **overgrazing** which exposes soil to agents of erosion.

Box 4: Possible coping methods for de-vegetation

De-vegetation process	Coping method
Deforestation	Incorporate soil & water conservation practices in the farming system Plant trees (woodlots, agro-forestry), Use energy saving stoves, Use alternative fuel sources (e.g. biogas, saw dust, charcoal bricks, solar) Stop bush burning
Ploughing	Practice minimum tillage; Adopt improved tillage methods (e.g. along the contour not up and down the slope, use of herbicides). Alternate heavy machinery with light technologies (e.g. animal draft)
Brick making	Remove topsoil from the target area prior to brick making, and return it afterwards Use alternative construction materials (e.g. stones, sand bricks)
Over grazing	Optimize stocking rates Zero grazing, Improve local breeds; Plant improved pastures Rotational grazing

MODULE FIVE: SOIL AND WATER CONSERVATION STRUCTURES

5.1 RELATIONSHIP BETWEEN PRECIPITATION, INFILTRATION AND RUNOFF

Note:
Demonstrate the relationship between precipitation, infiltration and runoff

Procedure

1. Fill 2 basins to ¾ full with soil and level.
2. Tilt the basins to create a slope that represents the landscape commonly cultivated in the area
3. Fill two watering cans with water to half full
4. Fit one watering can with a horse having small holes and the other with large holes.
5. Using a watering can with small holes, water one basin
6. Ask to observe the relationship between precipitation intensity, infiltration and runoff
7. Using a watering can with a horse having large holes, water the second basin
8. Ask participants to observe the relationship between precipitation intensity, infiltration and runoff

Key Message

In the humid tropics, precipitation from heavy rains often exceeds the infiltration rate of soils leading to runoff, especially on steep slopes. Runoff causes soil erosion, leading to declining soil fertility and nutrient mining, contributing to reduced productivity. Thus, soil conservation practices or structures should be put in place to divert, intercept, slowdown, store temporarily, or safely dispose off the runoff.

5.2 EFFECT OF SOIL MANAGEMENT PRACTICES ON RUNOFF AND SOIL EROSION

Note:
Demonstrate the effect of soil manage- ment practices on runoff and soil erosion

Procedure

i. Identify 4 small plots (½ m x 1m) in a nearby location having different management practices: bare ground, mulched field, grass and crop (beans) covered field
ii. Using a watering can, water the first plot until runoff is observed
iii. Note the amount (volume) of water used iv. Repeat steps ii and iii for the other remaining plots
v. Compare the amounts of water used in the four plots and discuss the findings

Key Message

On a bare ground, erosion occurs faster than on ground covered with mulch, crops or natural vegetation. A dense cover will minimise erosion much better than a light one.

5.3 TYPES OF SOIL CONSERVATION STRUCTURES

Note: Identify with participants, the different soil conservation structures

There are two types of structures:

1. Structures that temporarily hold water as it infiltrates into the soil
   (a) Those that change steep slope into a series of flat strips along contours across a slope for example terraces, ditches, contour bunds/dykes, built along contours
   (b) Those that change a long (gradual) slope into a series of shorter slopes for example bunds or ditches.
2. Structures that drain runoff from the slope from where it has been concentrated, e.g. cut off drains, man-made waterways, gully control structures, etc.

Note:

Discuss the different soil and water conservation structures/practices and their purpose.

Give description of soil conservation structures and illustrations/diagrams

Give limitations of soil conservation structures/practices

5.4 TYPES OF WATER CONSERVATION STRUCTURES

It is vital to conserve the moisture already in the soil to minimize evaporation and leaching. Using mulch, organic matter and relevant structures e.g. terracing or their combinations, will help farmers to conserve the moisture.

Note:

Identify with participants, the different types of water conservation structures/ practices

Retention ditches

These are small rectangular ditches dug in the ground across the slope with a level bottom and closed ends. These trap runoff and retain it for infiltration into the soil profile. They are most suitable in high rainfall areas.

Basins

These are rectangular or square fields well leveled and surrounded with soil embankments. The embankments retain water that falls in the basins. Sometimes road runoff is directed into a series of basins constructed along a contour. These structures are suitable for crops like rice. They are suitable in high rainfall areas.

Roadside runoff canals

These are road runoff diversions constructed in a canal network along a contour. Pits are dug within the canal to trap sediment and allow water to infiltrate slowly in the soil (Figure 7). Excess water flows into the next pit, connected by a tie ridge. The farmer scoops out soil after a storm and preferably puts it upslope. This is suitable in high rainfall areas.



Figure 7: Roadside runoff water pits

V-shaped bunds (Negarims)

These are small v-shaped earth embankments with the tip at the lower point of the slope (Figure 8). Water is collected within the v-shaped basins and stored in the soil profile at the tip of the structure where the trees are planted. This method is best suited for trees/shrubs in low rainfall areas.

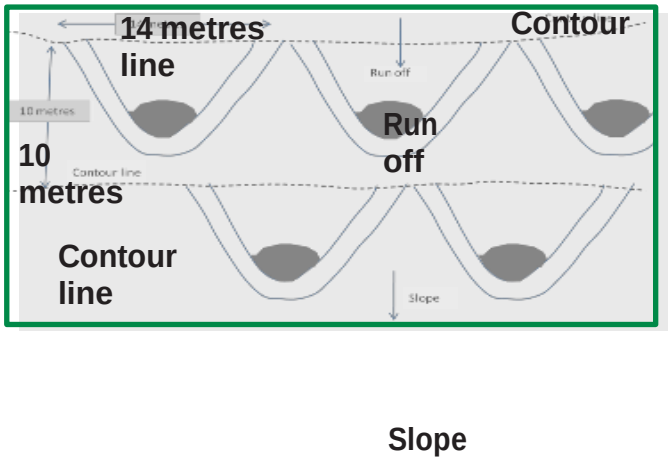


Figure 8: V-shaped bunds (Negarims)

Semi-circular bunds

These are earth embankments having a semi-circular or half moon shape with bottom of the bunds on the contour (Figure 8). Water is collected within the semi-circular basin from the area above it and stored in the basin. Excess water is discharged around the basin. The field layout provides for staggered basins so that runoff from the first row is intercepted by the second row and so on. These are suitable in low rainfall areas.

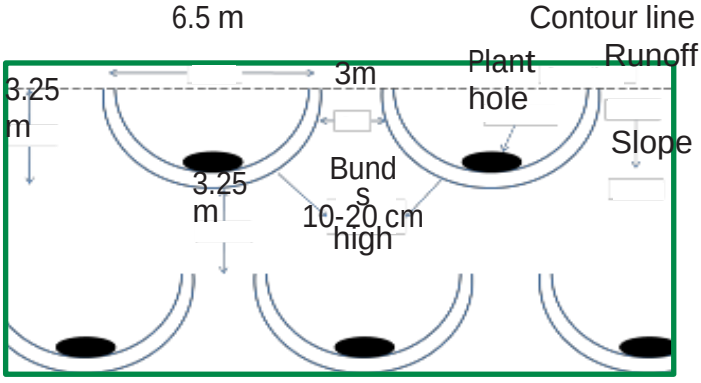


Figure 8: Semi-circular bunds (micro-catchments)

Trapezoidal bund

These bunds are earth filled embankment, which are trapezoidal in shape (Figure 9). Tips of the embankments are placed on contour line and the base along the lower contour. They are used for enclosing large areas and impounding large amounts of water. This method is only suitable for driest areas (less than 400mm rainfall) with non cracking, deep soil and very gentle slopes of 2%.

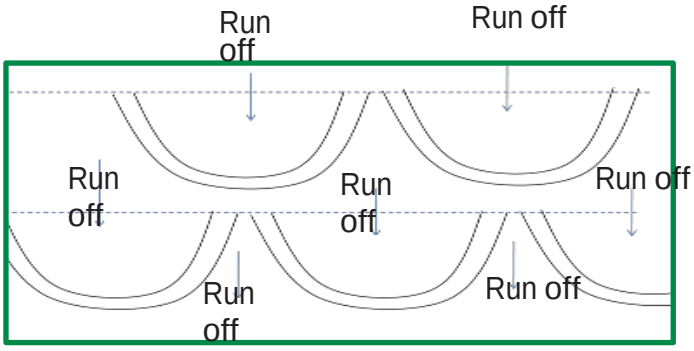


Figure 9: Trapezoidal bunds

Planting pits (water pockets)

These capture rainfall, runoff and litter (Figure 10). Presence of litter attracts termites and other macro organisms which create channels in the soil. The channels facilitate water movement in the soil (infiltration/seepage). The planting pits improve soil fertility and water availability during dry weather.



Figure 10: Planting pit (water pocket)

Micro-basins (Like Negarims) OR 'Ngoro' (Tanzania)

These are small earth ridges in square or honeycomb pattern each side 0.5 – 2.0 m long (Figure 11). Sometimes topsoil is put on the plant material forming these patterns with holes at center. They capture rain falling within field and collect around plants, improves soil fertility, improve infiltration capacity and reduce soil erosion.



Figure 11: Micro - basin

Sunken beds

Beds measuring 1.2m x 10metre with paths 60cm wide between beds (Figure 12). They trap and conserve runoff.



Figure 12: Sunken beds

Runoff water harvesting pits

Runoff from roads, waterways and gullies can be harnessed and stored in pits lined with polyethylene sheets, tanks or ponds to be used for supplementary irrigation. The pits vary in capacity depending on the sizes of enterprises, labour, and duration of the rainy season or dry spell.

Compound water harvesting

Water from the roof catchments can be harnessed and stored in tanks, cemented pits or pits lined with polyethylene sheets and used for domestic use, livestock watering or backyard garden irrigation (Figures 13 a&b).



Figure 13a. Roof water harvesting



Figure 13b. Compound runoff water harvesting for crop use

MODULE SIX: SOIL AND WATER CONSERVATION EQUIPMENT AND STRUCTURES

6.1 TYPES OF FIELD SURVEY EQUIPMENT

Simple survey equipment is used in the construction of soil and water conservation structures. The equipment include: A-frame, Elgon level, Water Ring, Water Tube Level, Quick Set Level, Clinometers and Line Level. However, the quickest, simplest and commonly used is the Line Level. Thus in this manual, emphasis will be put on the line level.

6.2 THE LINE LEVEL

6.2.1 COMPONENTS OF THE LINE LEVEL

A line level is a simple instrument which is used for laying out contours and other simple soil surveying tasks. It is quick to operate, accurate and easy to transport. A line level consists of two boards, a cotton string, a spirit level and 2 anchors (triangular pieces of wood) (Figure 14).

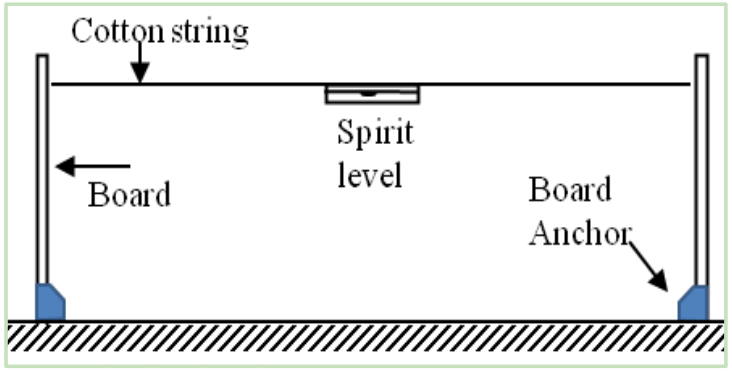


Figure 14: Components of a line level

Boards

The boards are of hard wood each of 2.5cm x 4cm x 150cm. The boards are graduated starting with the zero mark about 5cm down from the top. Graduations are marked starting at 0 on top with intervals of 5cm, with a larger mark at each 10cm, down to the bottom of the board (Figure 15).

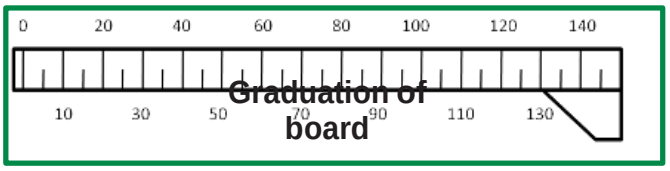


Figure 15: Graduation board

Cotton string

A cotton string of 11 metres long is tied at 1 metre long at the board. Unlike nylon, a cotton string does not stretch hence ensures that the length remains constant.

Spirit level

The spirit level consists of a plastic or metallic tube containing spirit with an air bubble. It has hooks at each end.

6.2.2 SETTING UP THE LINE LEVEL

Note:
Demonstrate how to set up a Line Level (Figure 16)

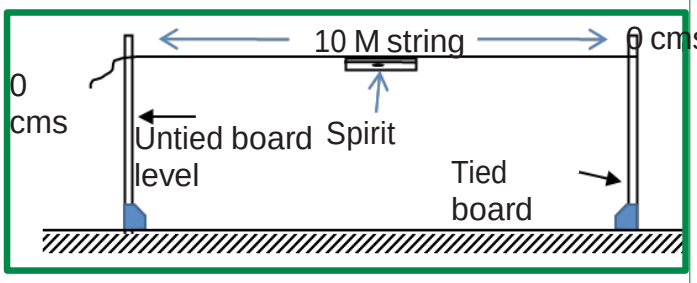


Figure 16: Setting up the line level

Steps

1. Get three people
2. Tie a loop of string at the top (0 graduation mark) of the line level boards
3. Pull the string straight to the other board, leaving a distance of 10m between the two boards
4. Get a second person to hold the second board vertically
5. Get a third person to hook the spirit level exactly onto the centre of the string
6. Align the two boards at the same height by moving the second board with the cotton string fixed at the 0-graduation until the air bubble is exactly in the middle of the spirit level.
7. Check accuracy of spirit level by removing it from the string and turning it upside down (180 degrees) and returning it in its original position and re-hooking it onto the string.
8. Check if the bubble has come to the centre again. If it has not, use another spirit level.

6.2.3 USES OF A LINE LEVEL

A line level can be used to determine:

- Slope gradient (percentage of a slope),
- Vertical interval (V.I)
- Lay out of contours.

CASE 1: Determining the percentage slope (gradient/steepness)

The percentage slope is measured to decide what type of structure and vertical intervals (V.I) should be used.

Steps in determining gradient/steepness

1. Get three people
2. Select a place that is representative of the field
3. Align the line level along the slope
4. Place the tied board down slope with the string tied at zero mark of the board
   Then place the untied board upslope.
5. Hold the string at the zero mark on the untied board
6. Keep the string tight and move it slowly down along the graduation marks until the air bubble is at the centre of the spirit level.
7. Read the figure from the graduation mark on the untied board when the string is leveled
8. Convert the reading into metres
9. Calculate the percent slope using the formula below

Slope % = [(Difference in height reading on the untied board in metres) x 100] divided by (Length of string in metres)

Note:
Determine the percentage of different slopes using strings of different length

In determining the percentage of different slopes, strings of different length are used.

- For gentle slopes 0 to 15% use a string of 10m long
- For steep slopes of 31%-60% use a string of 5m long
- For very steep slopes of more than 60% use a string of 2.5 m long

Determining the percent slopes using strings of different length

Example 1: If 80 cm (0.8 m) was read from the untied board using a 10m string, the percentage slope will be:

Slope % = difference in height on the board (0.8m) / (10 m string) x 100 = 8%

Example 2: If 80 cm (0.8 m) is read from the untied board, using a 5m string, the percentage slope will be:

Slope % = difference in height on the board (0.8m) / (5m string) x 100 = 16%

Example 3: If 80 cm (0.8 m) is read from the untied board, using of 2.5m string, the percentage slope will be:

Slope % = difference in height on the board (0.8m) / (2.5 m string) x 100 = 32%

CASE 2: Determining the Vertical Interval (V.I) and laying out contours for level channels

A vertical Interval (V.I) is the difference in height from one terrace to the next. The V.I will determine the height (riser) of a developed bench terrace. A change in the V.I will affect the distance between terraces, called the horizontal interval (H.I). A larger V.I will increase the distance between terraces (H.I) and the height (riser) of the terrace, and vice versa. It is common to use a constant V.I. It varies from 1.5m to 2.0m. The measurements start from the upper end of the field, going downslope.

A smaller V.I. should be used for more erodible soils, and the maximum H.I. should not exceed 20m. When measuring V.I. the length of the string is not defined and will therefore differ depending on the determined V.I. and slope gradient. If graded terraces are to be constructed, the Vertical Intervals are normally set out from the end nearest the waterway or discharge point. Each V.I. point should be well marked, as the V.I. marks will be the starting point for layout of each contour. Remove the temporary marks to avoid mistakes.

Procedure

1. Decide what V.I you should use. For deep soils with good infiltration, heavily mulched soils or those with a permanent cover crop, the V.I. could be large. A smaller V.I. should be used for shallow soil, easily erodible and on steep land (so that the H.I. is also small).

2. You need three people. Let one person tie the string at the zero mark on the tied board.

3. Let another person lower the string on the untied board from 0 to 100cm mark.

   You have now measured a 100cm (1m) vertical interval. Make a temporary mark on the tied board.

4. Let the person with the tied board move it up and down the slope keeping the string tight until the air bubble in the spirit level is at the centre.

5. Repeat the exercise by placing the person with the untied board at the temporary mark while the person with the tied board moves further down the slope (Figure 17)

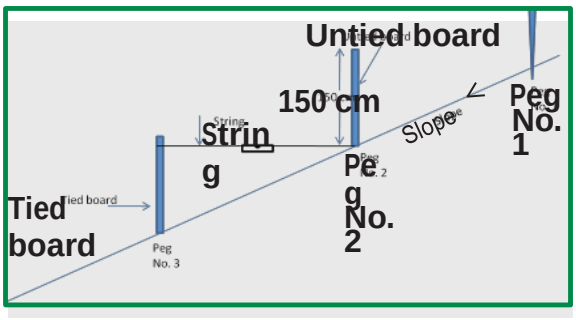


Figure 17: Using the line level to determine the vertical interval

6. Repeat steps 3, 4, and 5.

7. Place the spirit level at the midpoint of the string and let the person with the tied board move down-slope to a new position, keeping the string tight, until the air bubble in the spirit level is at the centre. You have now measured another 100cm (1m) vertical interval. The second measurement of 100cm (1m) will give the intended V.I. of 2m (100cm+100cm).

8. Place a permanent mark at the position of the tied board.

9. Repeat the above process down the slope until you reach the end of the farm

1. Lay out contours as follows:

- Hold the string at zero mark on both boards.
- Tie the string on one board at zero mark.
- Starting from the top of the field at the first Vertical Interval (VI) point pegged out, lay the contour across the slope.
- The person with the tied board positions it (board) at peg 1 (Figure 17)
- The person standing by the spirit level directs the person with the untied board to move up or down hill, while keeping the string tight, until the bubble in the spirit is at the centre and then drives a peg into the ground behind the untied board.
- Move the tied board to the new peg and repeat the process, along the contour up to the end of the field.
- Realign the fixed pegs to smoothen out the curve along the contour
- Dig a shallow trench along the smoothened curve.

Note:
Contours should be laid smoothly across the slope to avoid sharp corners and depressions where water can break through and develop rills and gullies (Figure 18).



Figure 18: Location of contours for conservation structures

CASE 3: Laying out contours for graded channels and drains

Graded channels are used for draining excess runoff from cultivated land to a natural or artificial waterway. The layout of the channels depends on the steepness of the slope. For slopes of 5% and above (erodible/ loose soils) the 10m string is tied at 0 mark on the tied board and placed at 2.5cm on the untied board. For gentle slopes below 5% (stable soils) the 10m string is tied at 0 mark on the tied board and placed at 5cm on the untied board.

Lay out of the channels is carried out the same way as for level contours, but the laying must start from the drainage point to ensure that run-off from channels drains into the intended drainage area.

Layout of a cut off drain (with channel and a Fanya Chini bund)

The purpose of this structure is to harness excess runoff water from the neighbouring land above a farm and prevent erosion. It may be constructed along a level or graded contour line.

Step 1

The farm is surveyed by a trained person to establish the soil structure, slope, spacing of soil conservation structures and determine if a cut off drain is required above the field. Dig a trench (cut off drain) of 1.0 to 1.5m wide at the top and 0.75 to 1.0m wide at the bottom. Depth is approx. 0.6 to 1.0m. Heap the soil down slope/lower side of trench leaving a small step of 20cm between the trench and the bund (heaped soil) so that the soil is not washed back in the trench when it rains (Figure 19).

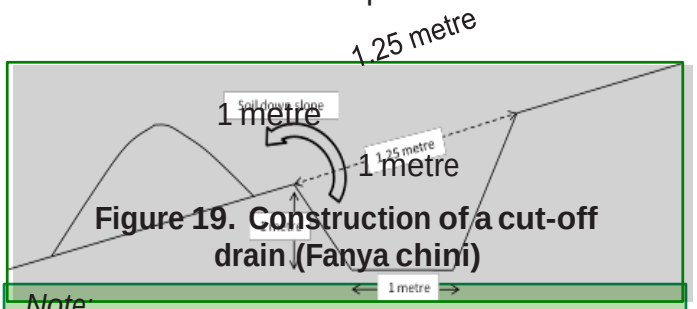


Figure 19. Construction of a cut-off drain (Fanya chini)

Note:
The runoff from outside the farm is held and infiltrates into the soil through the trench. Where runoff water expected is overwhelming, the trench should be connected to an artificial or natural waterway to dispose off excess water.

Layout of fanya-Juu terraces (for farm conservation)

These terraces develop from 'fanya-juu' bunds which are built by throwing soil from the channel up the slope (Figure 20). They reduce runoff and improve water infiltration to the soil. Ploughing, weeding and natural soil movement cause the land between the terrace banks to level off into benches after a few years. These are suitable in marginal/ high rainfall zones (700mm rainfall and above) with deep soils and for slopes from less than 5% to 50%.

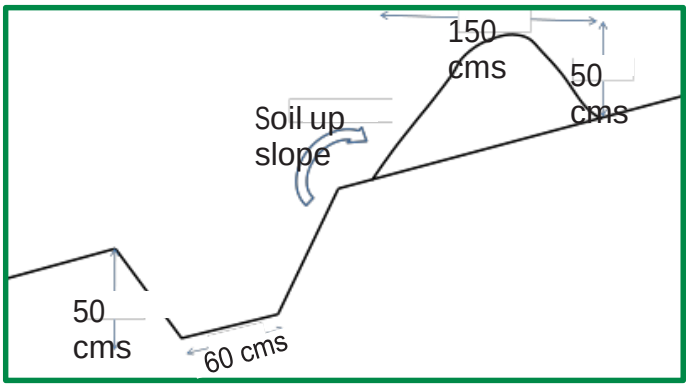


Figure 20. Construction of 'Fannya-Juu' bund

Step 2

(i) Survey contours with a line level. Spacing of the terrace banks is usually between 5 and 20 meters a part, (depends on the slope of the land- the steeper the land the closer the terrace banks).

(ii) Dig soil along a contour and throw it upslope to make a bund (heaped soil or dyke). The trench is 60cm wide and 60cm deep. Leave a small step of 20cm between the trench and the bund so that soil is not washed back in the trench when it rains.

(iii) Each bund is 50cm high and 150cm wide at base with 30-45cm tie bunds every 5 to 10 meters along the trench. A tie bund is an undisturbed strip of soil 30-45cm wide, left along the trench, 10-15cm lower than the soil surface. It checks the speed of runoff and ensures uniform distribution of runoff water along the trench.

(iv) Plant grass on top of the bund to stabilise it.

(v) Ploughing, weeding and natural soil movement cause the land between the terrace banks to level off into benches after a few years.

MODULE SEVEN AGRONOMIC/CULTURAL CONSERVATION FARMING MEASURES

To be effective, soil and water conservation structures have to be used in combination with biological and agronomic/cultural practices and systems. Agronomic practices are in essence, proven techniques of soil management.

7.1 CONSERVATION FARMING PRACTICES Note

Describe and give illustration of the conservation farming practices

Conservation farming means reducing erosion through good crop husbandry. Conservation farming may be carried out through a number of practices including:

(a) Contour ploughing and close planting For erosion control, contour cultivation (across the slope) is better than the up-and- down the slope. However, merely planting crops along the contour will not significantly reduce soil loss and runoff. Close planting (which leads to quick dense ground cover and retards soil loss) along the contour will yield better results whilst planting crops on contour beds on slopes below 12% and on permeable soils controls erosion and runoff even better. Integration of structural measures with close planting gives better results in both yield and soil erosion control.

(b) Correct spacing

This is a farm practice where the crops are given correct horizontal space (within and between rows) so that there is minimum competition for water, nutrients and space for the canopy. This enhances fast plant development and strong growth providing cover and protection to the soil from splash or wind erosion.

(c) Strip cropping

Strip cropping is a conservation practice in which crops are grown in a systematic arrangement of strips or bunds that serve as barriers to water and wind erosion. This practice is more effective under mild rainfall and on gentle slopes of up to 15%. It should be supported with structural measures. There are three major types/designs of strip cropping. These are:

1. Contour Strip Cropping: Two or more crops are planted along contours in alternate strips.
2. Field strip cropping: The alternate strips are of uniform width across the field and do not necessarily conform to the contour. This is used on very irregular topography.
3. Wind strip cropping: Tall, wind- resistant crops and normal crops are planted alternately in narrower strips perpendicular to the direction of prevailing winds.

(d) Timely planting

After land preparation, crop seeds should be sown as early as possible to avoid soil being left bare for a long time. By the time the rains intensify, the crop canopy will have developed to reduce the impact of rain drops to the soil.

(e) Multiple cropping

This is a practice where a farmer plants several crops on the same piece of land at the same or different time period in a cropping season (Figure 21). This is done to ensure maximum use of both horizontal and vertical space hence proper canopy cover and soil protection from sun heat, wind and rain drop splash erosion.



Figure 21. Multiple cropping

(f) Trash lines

These are structures formed by arranging or heaping vegetation materials in a line along the contour to check runoff. After crop harvest the materials on trash line can be distributed and mixed in the soil hence adding more organic matter.

(g) Stone lines

These are structures formed by arranging or heaping stones 25cm-30cm high and 30cm-40cm wide at the base in a line along the contour to check runoff. Stone bunds/lines are spaced 15m-30m apart. Contours are surveyed using a line level starting at the top of the field and working down the slope.

A shallow foundation trench is dug along the contour for each bund. Construction begins with large stones in the rear of the trench (down slope side). Smaller stones are used to build the rest of the bund (Figure 22). The stones must be packed carefully, especially at the bottom. Earth from the trench is piled up in front of the bund and the stone bunds are left for a year to catch sediment. Stone lines slow down runoff, encourage deposition and reduce erosion. Grasses and tree seedlings are planted alongside the bund. Stone lines are used widely, on cultivated land and also barren land which is to be used in future- where the soils are shallow and where stones are available.



Figure 22. Stone bunds

(h) Mulching

Mulching is protecting the soil (on slopes up to 15%) with plant residues, straw, green leaves and stems, and even gravel against splash erosion, wind erosion, capping and extreme temperatures. Mulching provides organic matter which supports micro organisms, soil nutrient supply and minimizes loss of nutrients. The mulch also reduces soil moisture loss and enhances water infiltration. Mulching can be applied over the whole field; between crop rows or along the contours; or around single plants in case of tree crops (Fig. 23a&b). Mulching can be applied in many ways- where plant residue from previous crop harvest is cut and spread over the field as stubble mulching (crop residue chopped and spread over soil surface) then cultivated into the soil. Farmers should be encouraged to grow their own material or practice live mulching and minimum tillage.



Figure 23a. Mulching in a banana field

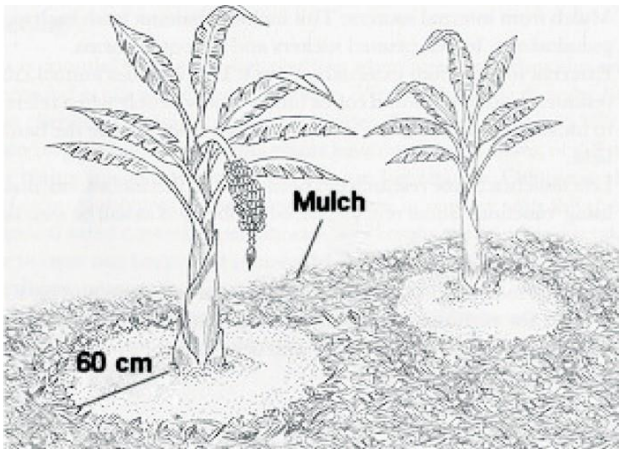


Figure 23b. Sketch of mulching in banana field

(i) Cover cropping

Cover crops are close-growing crops planted mainly to protect soil (on slopes of 15 to 50%) between tree crops or semi- permanent crops or between the seasons for regular crops. Cover crops can be legumes or grasses, depending on the actual needs. With dense cover and roots, cover crops can be very effective in erosion control (Fig. 24). However, cover crops may compete for moisture and nutrients and affect yields of the main crop. Special management such as timely cutting of foliage, circle weeding and probably more fertilizer inputs are needed.



Figure 24. Mucuna used as cover crop

(j) Minimum tillage

Minimum tillage refers to a practice where field operations are carried out with minimum soil manipulation, sometimes referred to as conservation tillage. The practice involves tilling only the crop zones for seed planting, germination and crop establishment with minimal erosion. It may also involve mulching with crop residues, use of special equipment and herbicides etc., depending on various conditions.

(k) Vegetation barriers

These are bushes or hardy grasses planted as a barrier across a gentle slope in order to retard soil from being washed down slope (low rainfall areas). Grass strips and live fences fall in this category. There are two general approaches:

First approach: Install contour drains after every one or two lines of the vegetative barriers. The cutoff drains collect the excess runoff.

Second approach: plant the vegetative barriers closer according to the future bench terrace width. The bench terraces will form after several years of cultivation.

(l) Partial weeding,

Circle weeding around fruit trees, flowers or bananas is usually sufficient especially when trees or plants are planted in individual basins. For plantations of tea or coffee, etc. strip weeding can be applied, leaving the inter space as a grass buffer. Occasionally, the grass should be cut, but there is no need to dig it out.

(m) Deep ploughing,

This is the cultivation of topsoil and subsoil to a depth of 30cm - 60cm depending on soil, crop requirement and the tools to be used, in order to:

- break soil crusts, hard pans, etc.
- provide spaces for air and water in the soil for crop growth,
- increase water infiltration capacity,
- promote earthworm and microbiological activities,
- develop better soil structures, especially with added organic matter.

The crops may be planted on raised beds (Figure 25) in high rainfall areas or sunken beds (see Figure 12) in low rainfall areas.

Integrating mulching, compost manure application and irrigation make this system produce most effectively throughout the year.



Figure 25. Raised bed

(n) Use of compost and farm manure

This is a practice where a farmer makes use of manure from the kraal, zero grazing unit, poultry unit or pig sty mixed with crop residues and kitchen refuse either directly or after composting. This helps to recycle soil nutrient on the farm enhancing sustainability. Addition of compost and farm yard manures to the soil improves soil fertility, aeration, structure and biological life.

Small farmers can make compost in pits or piles in the open air. The site should be near enough to the area of application to reduce future transportation chores. Compost is built by putting down alternate layers of plant material and farm manure (Figure 26). The whole mass should be kept moist in order to reduce the loss of ammonia and to encourage vigorous bacterial action. Sometimes phosphate is also added to balance the mixture and make it more effective. The composting mass should be turned twice after every 3 weeks to maintain aeration and promote microbial activities. Attention should be taken not to let too much rain water soak in; any solution from the compost should be collected and eventually used for fertilizing. Since the whole process needs considerable labour and time to make and collect/use, farmers should use it selectively.

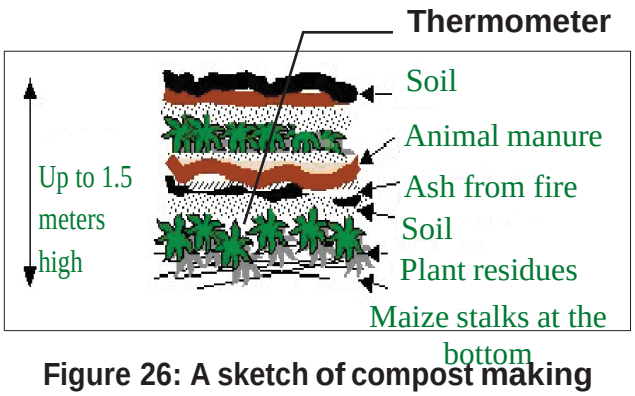


Figure 26: A sketch of compost making

(o) Use of green manures,

This is a practice of ploughing into the soil green plant material when it is in flower to improve the soil structure, replenish plant nutrients, and minimize runoff and erosion. Many leguminous crops are used for this purpose to supplement compost and farm manure.

(p) Use of fertilizers,

Where soils are proved to be deficient in important nutrients (Nitrogen, Phosphorus and Potassium) a farmer is advised to seek technical assistance to apply recommended commercial/mineral or organic fertilizers to correct the deficiency. Proper application of fertilizer will improve soil fertility and promote faster crop cover to protect the ground from splash or wind erosion. This is important especially on degraded and newly reclaimed land or terraces. Because of its high cost, fertilizer should be used selectively by the small farmer. It is best to use fertilizers in conjunction with compost, farm manure, and green manure sometimes referred to as integrated soil fertility management.

(q) Crop rotation

Crop rotation is the growing of different crops in recurring succession on the same piece of land in a planned cycle (Box 5). The best system will depend on the farmer's preference, economic advantages, and physical environment. However the farmer should include legume/grass mixtures to enrich nutrient reserves and improve soil structure. Unlike monocropping which depletes soil nutrients and increases pest and disease hazard, rotations also give small farmers a variety of crops for diverse use as well as flexibility in marketing. This system suits well in the socio-economic needs of the small farm holdings, however not many farmers know how to apply it.

Box 5: Example of a crop rotation sequence

	Year 1	Year 2	Year 3
Season	Virgin land		
Season 1:	Start with a heavy feeder-cereal (maize, rice, sorghum etc.)	Continue with a light feeder from season 2 of year 1 (sweet potatoes)	Plant a light feeder-rootcrop (Cassava, yams)
Season 2:	Plant a light feeder - root crop (sweet potatoes)	Plant a heavy feeder - legume (beans, groundnuts, soy beans, etc)	Continue with light feeder from season 1 (cassava)

MODULE EIGHT: INTEGRATING SOIL CONSERVATION WITH FARMING SYSTEMS

For soil conservation to be successful, it should be well-integrated with the prevailing farming systems and become an indispensable part of the overall package of measures being advocated. Below are some examples:

8.1 HILLSIDE FARMING AND CONSERVATION FARMING SYSTEMS Conservation farming is a system of farming which protects the land from any form of deterioration yet increases or maintains farm production to the benefit of the farmers.



Figure 27 Example of Agro-forestry practice

8.2 AGRO-FORESTRY

This is a system where trees/shrubs, are deliberately grown on the same piece of land with crops, fodders or animal (Nair, 1983). Commonly recommended agro forestry trees and shrubs are: Albizzia, Grevilea, Sesbania, Calliandra, Leuceana among others (Fig. 27).

The main purposes of Agro-forestry are:

a) To use agricultural crops or pasture as a transitional means of utilizing the land until forest plantations are fully established.

b) To bring trees and shrubs, into the farming systems, to the benefit of both crop production and resource protection. If used for land resource conservation, agro-forestry can be more permanent and beneficial to small farmers in many ways- fuelwood, poles, fodder, mulching material, shade, medicine, food, windbreaks to crops, etc.

8.3 PASTURE MANAGEMENT ON SLOPES Small farmers use land mostly for cultivation of food and cash crops. A small portion of a farm may be left to fallow when continuous cropping is found to be unrewarding. Cows, draught animals, or small ruminants are usually grazed on the fallow land. These animals are also turned loose for grazing on roadsides, stream banks or any other public land.

In establishing or rejuvenating pasture on slopes or rolling land, simple conservation structures are sometimes needed to prevent erosion from heavy rains and runoff during the early stages when the land is not well covered. Their spacing, however, may be double or triple of those used for agricultural crops. Diversion ditches are sometimes used to intercept large quantities of runoff coming from the slopes above. Mulching should be practiced for reseeding pasture on steep slopes to prevent the seeds from being washed away and for a better and even germination.

Suitable fertilisation or liming is often needed to help pasture establishment e.g. use of rock phosphates/super phosphates on soils with low pH (acidic). Pasture of mixed grasses and legumes usually provide more diversified and nutritious forage for various animals and maintain better fertility. Once pasture is established, controls on utilisation are necessary.

Three grazing options are discussed:

a) Zero Grazing: Zero grazing is the practice of keeping domestic animals in a confined unit from where it is stall-fed (Figure 28). Figure 29 shows the main components of a zero grazing unit. This practice is especially applicable in densely populated areas, wet seasons and steep slope areas.



Figure 28. A farmer feeding cattle under zero grazing

b) Controlled Grazing: This means controlling the number of animals on a unit piece of land. It is always recommended that the carrying capacity of the land should not be exceeded unless other sources of feeds are available. For community pastures certain public controls are needed.

c) Rotational Grazing: Is a system of pasture utilisation consisting of a short period of heavy or normal stocking followed by periods of rest for plant recovery during the same season. Fertilizers or manures are needed for quick recovery.

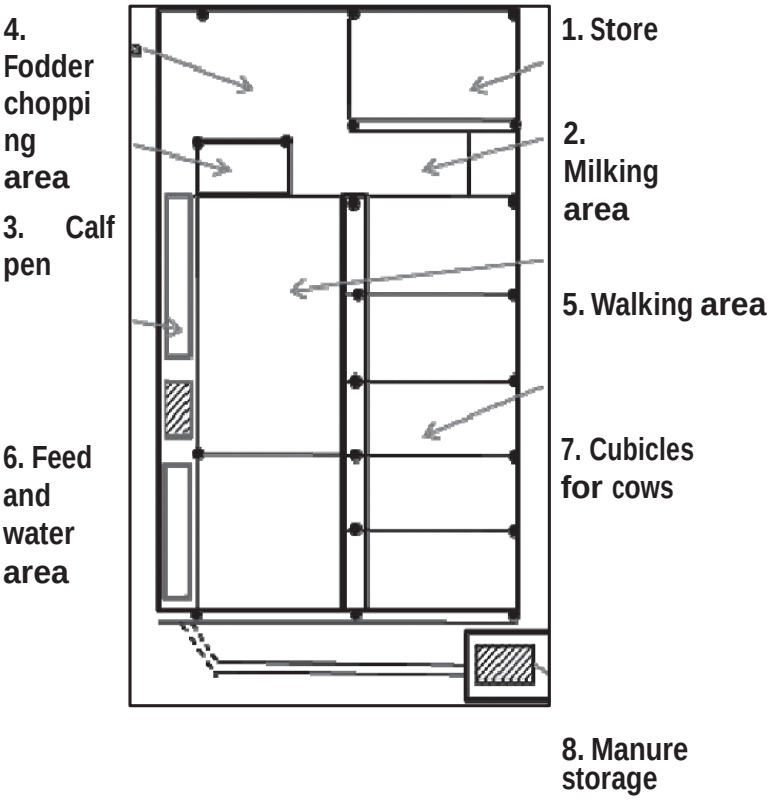


Figure 29: Components of a zero-grazing unit

GENERAL GUIDELINES FOR TRAINERS/FACILITATORS

Facilitation is not teaching or lecturing, rather it is guiding and motivating the learner to enthusiastically acquire, retain and use the needed knowledge, skills, habits/ behaviour and attitudes in a simple, easy and smooth manner. The learning may involve acquisition, modification or adjustment of existing knowledge, skills, behaviour and attitudes to cope with new circumstances. Thus, effective facilitation of adult learning requires the trainer/ facilitator to use different skills and participatory methods that will interest, motivate and re-enforce learning. The facilitator must also enable the learner to retain what she/he has learnt and to transform it into action. Thus the facilitator must be skillful.

Guidelines

1. Prepare, study and get familiar with the culture, traditions, values and socio- economic relationships of the community so that you adjust yourself accordingly in terms of style, clothing and language, and avoid issues that may conflict with norms.

2. It is important to always apply the adult facilitation skills:

- ***Presentation*** – Make the presentation lively and be cheerful throughout the session
- ***Communication*** - Use a combination of oral, written and body language. Listen carefully to understand the audience and give feedback
- ***Inquiry*** - Probe/ask and encourage questions
- ***Interaction*** - Use participatory methods such as:

  group work, discussions, case studies, role plays, story-telling, sharing proverbs, experience sharing, question and answer demonstrations, brain storming, visualization in participatory activities/ exercises/observations.

3. Expose the learner to different ways of learning (seeing, doing, thinking, feeling, hearing, smelling and tasting).

4. Ensure an informal and favourable learning environment.

5. Make Pre-training preparations by securing all necessary training materials, checking on the training venue and preparing the schedule for the training.

6. Warmly welcome the learners.

7. Set the learning climate by creating a warm and friendly environment at the beginning of each session so that the participants are able to talk and express their views freely.

8. At the start of each session introduce the training, brief the learners about the title of the topic/session and the learning objectives.

9. Ask learners to give their experiences about the new topic :

- Encourage active participation throughout the session

- Focus on the important aspects or key areas of the topic/session at hand. Avoid giving irrelevant information

- At the end of each session make a conclusion and where applicable introduce the next topic/session and ask learners to think about it

- Where applicable, review what was learnt in the previous topic/session before starting a new one. Give a chance to each participant to contribute. Compliment their answers by emphasizing the key points of the previous topic. If you get unsatisfactory answers, review your teaching methods and incorporate those that can improve their learning.

- Reinforce learning by:

1. Using language most understood
2. Simplifying the content and reconsidering the sequence or pattern of it
3. Changing the facilitation skills, instructional methods/techniques or combine techniques
4. Giving practical and where possible live examples
5. Conducting method and result demonstrations
6. Encouraging hands-on activities or learner to review what she/he has learnt
7. Giving exercises
8. Encouraging questions and free interactions
9. Encouraging the learner to associate the new information/skill/behaviour with something she/he already knows
10. Relating the subject/topic to something beneficial or critical
11. Giving an example (story) from experience or refer to something currently topical (up to date/modern) and relevant
12. Generating summary
13. Jointly make an agreed implementation and follow-up plans
14. If possible plan for exposure excursions and study tours.

Always consult your local extension officer or Agricultural service provider.

References

Uganda Land Resouces: Aguide for extension workers ,Charles Rusoke et al
Intergrated Soil Fertility management on small scale farms in eastern province of Zambia
Soil Conservation in Arusha Region Tanzania.