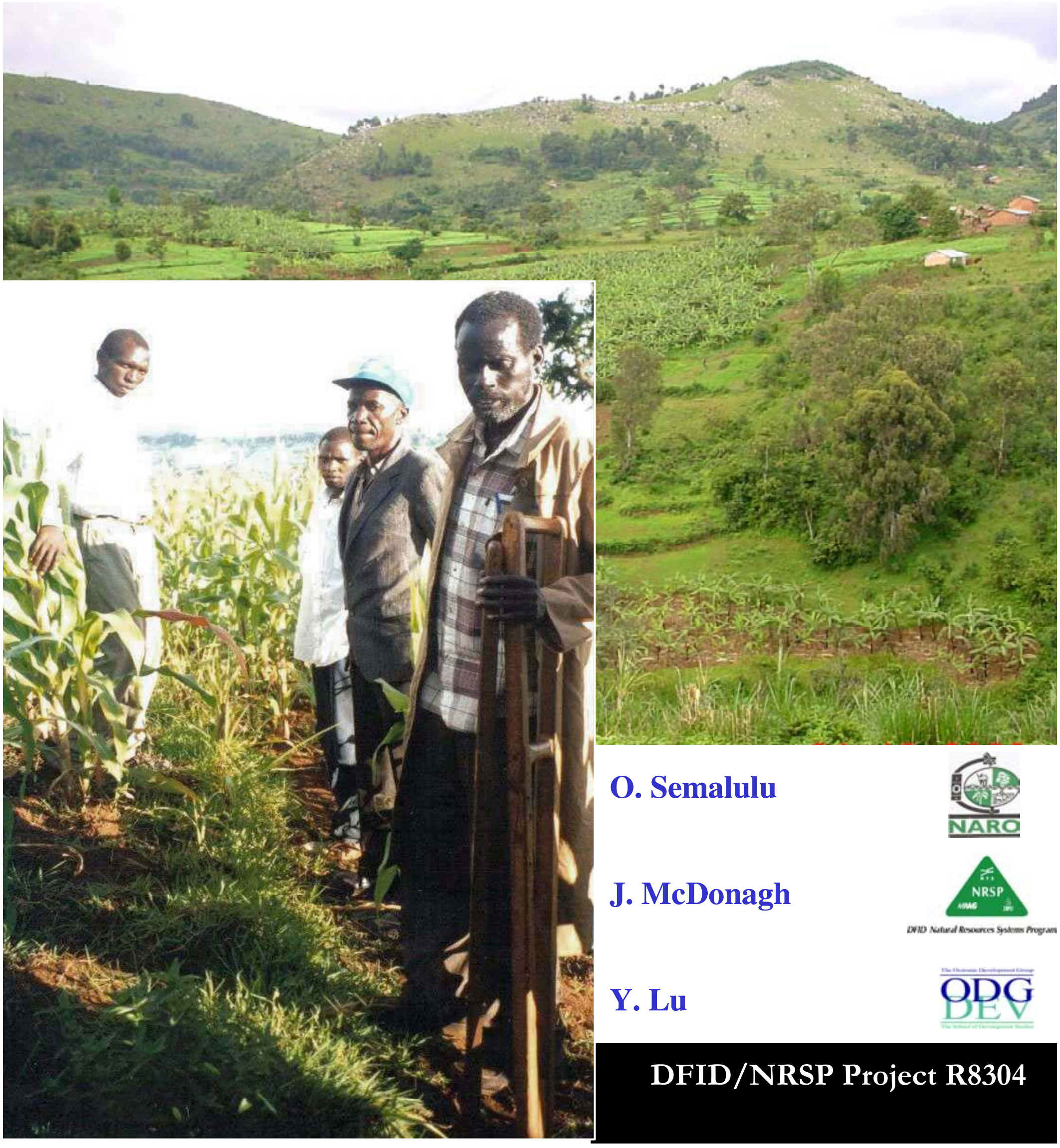
Bridging Research and Development in Soil Fertility Management

Practical Tools and Approaches for Better Soil Management in East Africa



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Introduction

Although agriculture contributes to the livelihood of most people in East Africa, crop yields are often limited by soil management-related factors, reflected in extensive soil erosion, declining soil fertility and nutrient mining. Ironically, while a wealth of information exists locally and regionally on good soil management practices, local professionals (agricultural service providers, extension officers, NGOs, contact farmers) are often constrained by lack of such information.

Practical tools and approaches are needed to assist local professionals and farmers in working with soil management. This field handbook describes some practical tools and approaches developed and tested for use by extension officers in East Africa especially in the hillsides environments. These were developed during a 3-year DFID-NRSP supported project R7517 (2000-2003) which aimed at developing simple, field-based tools and approaches for local professionals dealing with soil management related issues. The current project R8304 is an extension of this and similar other work carried out in Uganda and Kenya, to promote wider use of the products generated out of these projects.

About this handbook

The handbook is meant to serve as a field reference material for service providers, and provides brief theoretical information backed up by field-based visual tools on soil related issues commonly encountered in the field. Features of the handbook:

§ largely visual with simple format and text supported by figures, photographs, etc.
§ locally relevant with local indicators, images and management options incorporated where possible; and
§ practically oriented, linking field assessment of a problem to intervention recommendations.

The handbook contains two sections. Section 1 deals with field diagnosis of common soil-related problems, presenting some technical options. Section two is an extension of section 1 and presents a wide range of technical options to soil management available in the region. A number of simple, low cost options for soil management are illustrated, for easy reference by the field extension worker. Lastly, it presents a brief on financial appraisal, a tool that could assist in making decision about a particular soil management option to adopt. It is anticipated that by reference to both sections, the service provider will exhaustively address soil management-related issues commonly encountered in the field.

Disclaimer

This information handbook was produced by an NRSP-DFID funded project R8304. The views expressed here are not necessarily those of DFI

Section 1: Diagnosis of Soil Management Problems

1.1 Soil and soil fertility

Soil is a medium for plant growth. It is made up of soil particles (sand, silt and clay), organic matter, living organisms, water and air. The composition of different soils gives soils different physical, chemical and biological characteristics.

Soil has many functions essential to crop production:

- Provides the space for rooting and support for plants
- Supplies nutrients, water and air required for plant growth
- Regulates the rooting environment (moisture, temperature, aeration, pH, etc) for plant growth

Soil fertility, in its broad sense, is the capacity of a soil to do the above. Soil fertility management is the combination of management options that affect soil productivity.

To fulfill the above functions, soil needs to have some essential characteristics, e.g.:

Soil structure is the arrangement of soil particles. Soil particles can be unattached as in a very sandy soil, or they can be closely packed together as in clay soils. Usually the particles are held together in aggregates (or 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.

Soil texture is the relative proportion of the mineral particle sizes (sand, silt, clay) contained in a soil. Soils can be described as sands, sandy loam, loam, clay loam, clay, etc. (Table 1). Based on their workability, soils can also be referred to as "light" (coarse textured), "medium" or "heavy" (high clay). Light soils are easy to cultivate, while heavy soils are more difficult.

A clay soil has higher capacity to retain nutrients and water, but may have inadequate drainage and aeration. A sandy soil has better drainage and aeration, but has a lower capacity to retain nutrients and moisture. Increasing organic matter can improve a sandy soil's ability to retain nutrients and water, and can improve drainage and aeration in a clay soil.

Table 1 *Simple method to estimate soil texture in the field*

<table>
<tr><td colspan="3">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. Try to form the different shapes below, using your moist soil sample. The shape you can make roughly indicates the texture of your soil.</td></tr>
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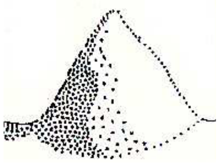
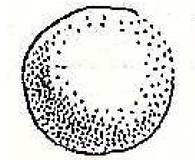
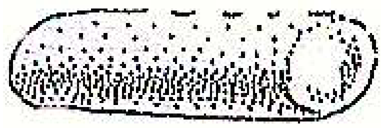
</td><td>2
</td><td>3
</td></tr>
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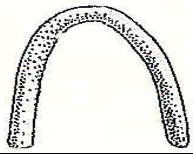</td><td>6
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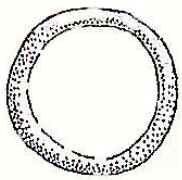
<tr><td>7
</td><td colspan="2">1. sand – soil remains loose and single grained and can only be heaped into a pyramid
2. loamy sand - soil contains sufficient silt and clay to be shaped into a ball
3. silt loam - soil can be rolled into a short cylinder
4. loam - soil can be rolled into a cylinder, about 15cm 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. clay – soil can be bent into a circle without cracks</td></tr>
</table>

Organic matter in the soil consists of living plants and animals or their remains after death. Humus is organic matter that is well decomposed, usually broken into very small particles (no structure so cannot be identified as roots or leaves etc.) and dark in colour. Humus contributes to soil structure and water holding capacity. The major source of nutrients in soil is the decomposition of fresh organic matter, thus it is important to apply organic matter to the soil regularly (e.g. each year). Organic matter contributes to soil fertility in the following ways:

§ Provides nutrients during decomposition
§ Increases the soil's capacity to hold onto nutrients
§ Builds soil structure, increasing water infiltration and crop water use
§ Protects the soil against rapid changes in pH.

The organic matter content of a soil depends on:

§ **Soil type and climate** – determines rate of breakdown of recently added organic materials by soil organisms
§ Amount of **organic material** added as manure or in crop residues
§ Method and frequency of **tillage** - tilling soil increases organic matter breakdown
§ Soil organic matter can be increased through reduced tillage, planting cover crops, addition of crop and animal residues, composts, farm yard manure, mulching, etc.

1.2 Soil fertility decline

For most tropical soils, soil fertility is associated with soil organic matter in the surface layers. Soil fertility can be lost through several ways:

Soil erosion

§ Loss of topsoil reduces the capacity of the soil to function and restricts its ability to sustain future production.
§ Erosion removes the most productive topsoil layer, a layer with the greatest 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 selective removal of fine soil particles e.g. clays, small organic particles. Structure breakdown reduces water infiltration and accelerates erosion.
§ Erosion makes tillage difficult by forming gullies and exposing the subsoil.

Crop cultivation and grazing

§ Plants and grazing livestock both extract mineral nutrients (fertility) from the soil.
§ Continuous cultivation with no or a 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.

- Soil fertility decline reduces crop yields, increases problems with crop diseases (because plants are weaker) and results in lower quality of crop produce.
- Returning crop residues and animal waste, adding mineral fertilizers to the soil, planting legumes and crop rotation can help prevent large nutrient losses.

1.3 Indicators of soil fertility decline/degradation

1.3.1. Local Perceptions

Table 2. Local perceptions: *Soil problems and indicators perceived by farmers in east Uganda*

Soil problems	Indicators
Soil erosion	• Gullies/rill formation • Exposed sub-soil and underground rocks • Shallow soils • Land slides • Siltation • Crops washed away • Yellowing of crops

***Table 2**: continued*

Soil problems	Indicators
Poor fertility	• Exposure of red soils • Weed infestation • Crop yield decline • Stunted crops • Severe disease attack • Yellowing of crops
Soil dryness	• Cracking of soil • Quick loss of soil moisture after rains • Soil appearing dusty and sandy • Compaction • Soils being hard to plough • Premature drying of crops and weeds • Stunted crops • Wilting of crops and weeds
Soil shallowness	• Shallow plough layer • Flooding in rainy seasons • Rocks near surface or exposed • Red soils exposed • Quick wilting of crops during dry season • Short and stunted weeds and grasses
Soil heaviness	• Water-logging • Soil difficult to work when it rains (heavy) • Soil sticks on to hoe when digging • Hoe feels heavy when digging
Soil stoniness	• Soil has rocks and gravel

1.3.2 Soil indicators

Soil erosion is the process of losing topsoil by action of water and/or wind, resulting into progressive decline in soil productivity, and leading to reduced crop yields. Water-induced erosion can be sheet, rill or gully, depending on the severity. Below are some visual indicators of soil degradation.

Armour layer

Fine soil particles have been selectively removed by erosion, leaving coarser soil particles, which are then concentrated on the soil surface. The thickness of the layer may indicate the seriousness of erosion.

Formation of armour layer on soil surface, Kapchorwa, Uganda

Rills

A rill is a shallow linear depression or channel in soil that carries water after recent rainfall. Rills are usually aligned perpendicular to the slope and occur in a series of parallel rill lines. In a particular area the total length, depth and width of the rills indicate the seriousness of erosion.

Rills on bare slope soil, Kapchorwa, Uganda

Gully

A gully is a deep depression, chan0nel or ravine, 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.

A gully in a banana field on the lower slopes of a hill, Kapchorwa, Uganda

Crop/tree root exposure

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

Banana roots exposed by erosion, Kapchorwa, Uganda

Rock exposure

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.

Rock exposed by erosion, Kapchorwa, Uganda

Soil colour

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 the sub-soil.

Change in soil colour after applying green manure, Kapchorwa, Uganda

Sheet erosion

Description

§ Sheet erosion is soil movement caused by raindrop splash resulting in the breakdown of the soil surface structure and surface runoff.

§ 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.

Tables 3 and 4 give some aids for interpretation of sheet and rill erosion.

Table 3: Sheet Erosion detection and interpretation.

Ranking	Degree	Description
X	Not apparent	No obvious signs of sheet erosion, but evidence of minor sheet erosion may have been masked, e.g. by tillage.
0	No sheet erosion	No visual indicators of sheet erosion.
1	Slight	Some visual evidence of the movement of topsoil particles down-slope through surface wash; no evidence of pedestal development only a few superficial roots exposed.
2	Moderate	Clear signs of transportation and deposition of topsoil particles down-slope through surface wash; some pedestalling but individual pedestals no more than 5cm high; some tree and crop roots exposed within the topsoil; evidence of topsoil removal but no subsoil layers exposed.
3	Severe	Clear evidence of the wholesale transportation and deposition of topsoil particles down-slope through surface wash; individual pedestals over 5cms high; extensive exposure of tree and crop roots; subsoil horizons exposed at or close to the soil surface.

Likely causes

§ Continuously cultivation of soils with no fallowing.
§ Soils that are bare through overgrazing are particularly susceptible.

Options for intervention

§ Retain vegetation cover to avoid leaving soil bare, especially during periods of high-intensity rainfall.

Sheet erosion in Kapchorwa, Eastern Uganda

§ Keep land covered with vegetation even in the dry season. (perennials are good).

§ Improve fallow, cultivation & rotation of cropland. Reduce grazing pressure.

§ Improve vegetation and soil management to maximize rainfall infiltration and use by vegetation.

Rill erosion

Description

§ Rill erosion results when surface runoff concentrates forming shallow linear depressions or small well-defined channels, normally less than 30 cm in depth.
§ The small channels can be smoothed out 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 will often extend to the depth of the tilled layer.

Table 4: Rill Erosion detection and interpretation

Ranking	Degree	Description
0	No rill erosion	No rills present within the field.
1	Slight	A few shallow (< 100mm depth) rills affecting no more than 5% of the surface area.
2	Moderate	Presence of shallow to moderately deep rills (< 200mm depth) and/or rills affecting up to 25% of the surface area.
3	Severe	Presence of deep rills (up to 300mm depth) and/or rills affecting more than 25% of the surface area.

Some simple options for field diagnosis and control of rill erosion

Likely causes

§ Rill erosion is common on agricultural land without vegetation and is often seen in cropped areas after tillage.
§ Following intense rainfall, cultivated top-soils overlying denser cohesive sub-soils often show rill erosion.

Options for intervention

§ Modify cultivation and rotation of cropping land.
§ Control (reduce) grazing pressures
§ Improve vegetation cover and soil management to increase

§ organic matter and promote water infiltration and evapo-transpiration by plants

Examples of rill erosion

Small rills in Kapchorwa, Uganda, formed after a single storm, when the soil surface is bare or poorly covered

Deep rills can be found at slope bottoms where runoff concentrates, Kapchorwa, Uganda

Gully erosion

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.

§ The depth of the channels is over 30 cm.

Likely causes

§ Gully erosion often occurs on lower slopes, but can form quite high in the landscape in susceptible areas.

- Areas commonly affected have easily erodable subsoils when exposed.

Options for intervention

- Grass planting along waterways
- Diversion structures (channels that are constructed across slopes which cause water to flow to a desired outlet)
- Attempt to reduce the amount of water reaching the gully by increasing plant water use where the rain falls, so reducing run-off.

Gully in Kapchorwa District

Gully in Mbale District

Control depends on size & scope of the problem, but include diversion banks, drop structures and retention dams. In association with earthworks, replace vegetation to stabilize banks and exclude grazing animals.

1.3.3 Crop growth indicators

Nutrient deficiency

Soil nutrient deficiencies can be caused by excessive removal of nutrients from the soil (crop harvesting, erosion, leaching, etc), inadequate inputs to the soil, or other factors, which may prevent nutrient uptake by crops. The symptoms may include changes in colour, morphology (shape or size of the whole plant or a particular part) and growth vigour. Visual symptoms are useful in signalling nutritional disorders. Once the availability of one or more soil nutrients falls below a certain level, crop growth is affected. However, once the symptoms appear, crop growth and yield has already been affected and it is not cost effective to try and correct nutrient deficiencies in a crop already showing symptoms. The information is useful for planning the cropping and management strategies for the next season. Soil test and plant tissue analysis (if available) can provide early warning; crop performance in the previous year, fertilizer addition experiments and plant observation are also good indicators of overall nutrient sufficiency.

Different crops respond differently to nutrient deficiencies. The following figures show the commonly observed symptoms of nutrient deficiencies, their causes and possible management options, for banana and maize:

Nitrogen (N) Deficiency - Banana

Symptoms

Generalized leaf yellowing

Description

- Generalised yellowing (chlorosis) of leaves, with stronger than normal rose tints on the petiole[1] wings.
- Stunted growth; the rate of leaf production decreases, internodes[2] are short, plant tends to become engorged and bunches are small.

Likely causes

- Leaching due to excessive rainfall, as in sandy soils with low organic matter.
- Soil erosion and runoff.
- Harvest of plant products and removal of crop residues.
- Poor management (weed competition, inadequate mulching).
- Excessively dry or wet conditions.
- Damage to crops by pest and disease attacks may reduce N uptake.

Options for intervention

- Timely planting and weeding to increase N uptake by the crop
- Plant legume cover crops, apply compost, manure and chemical fertilizers.
- Soil & water conservation to prevent N losses through runoff and erosion.

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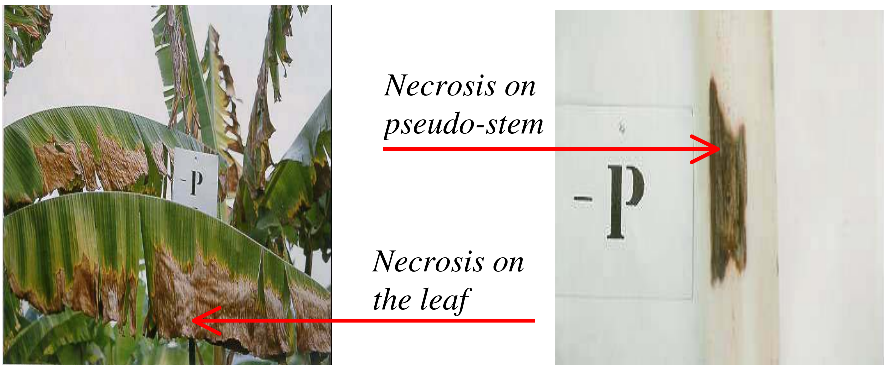
1 **Petiole:** the stalk attaching a leaf to a stem.
2 **Internode:** the part of the stem between leaves or branches.

Phosphorus (P) Deficiency - Banana

Symptoms



Description

- Dark green leaves with progressive leaf necrosis[1] (leaves die).
- Symptoms are similar to damage caused by the fungus ***Cordana musae***. Necrosis on pseudo stem.

Likely causes

- Soils with high clay content.
- Soils with low or high pH. P availability in most soils is at a maximum near pH 6.5; when pH is lower than 6 or higher than 7, P availability is reduced.
- Soils lacking in nitrogen: N promotes P uptake by plant.
- Removal of harvested crops without return of residues.
- Surface runoff and soil erosion.
- Phosphate leaching.

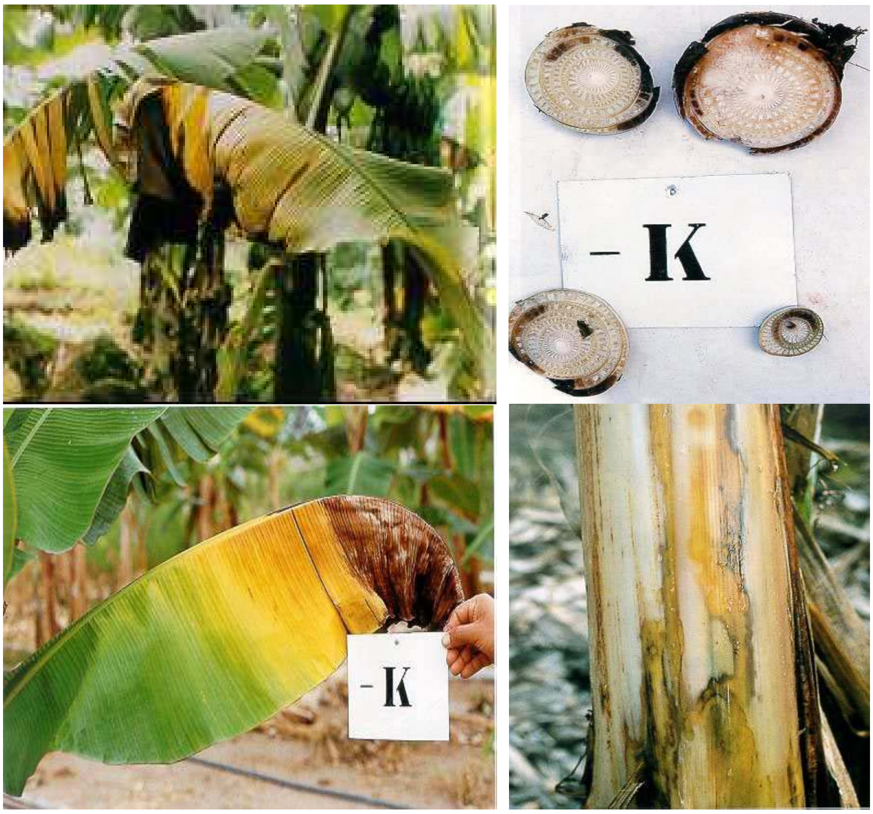
Options for intervention

- Incorporate farmyard manure, chicken manure or green manure.
- Apply mineral fertilizer, phosphate rock, compost.
- Soil and water conservation to prevent P looses through surface runoff and soil erosion.

[1] *Necrosis*: brownish discoloration of leaves or parts of leaves, indicates dead tissue. Cannot be cured through nutrient application.

Potassium (K) Deficiency – Banana

Symptoms



Description

- Very rapid yellowing (orangey-yellow) of leaves 5 or 6 (number 1 leaf is the last completely unfurled leaf).
- Leaf ribs are often broken two-thirds of the way along their length.
- Symptoms often appear at the time of flowering.
- The leaf sheaths of the pseudo stem rot early and smell of decay.

Likely causes

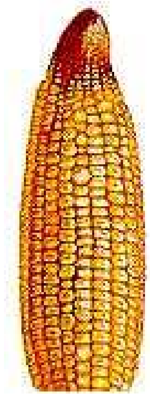
§ Highly weathered acid, sandy, or compacted soils with poor aeration.
§ Both drought stress and excess moisture reduce plant uptake of potassium.
§ High pH soils (pH 7.0 and above); nitrogen or other nutrient stresses.
§ Heavy potassium removal by previous crop.

Options for intervention

§ Apply plant residues to the banana field immediately, as mulch.
§ Apply potassium fertilizer two to three months prior to the estimated flowering date.

Nitrogen (N) Deficiency – Maize

Symptoms



Description

- Stunted plants, yellowing (chlorosis) of lower leaves first, yellowing begins at leaf tips and progresses along midrib.
- Ears are small and protein content is low.
- Kernels at tip do not fill.

Likely causes

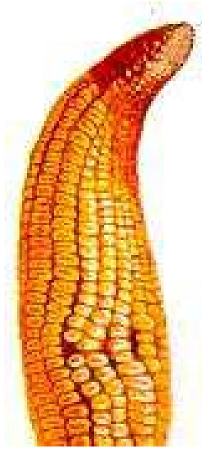
- Leaching from excessive rainfall, such as in sandy soils with low organic matter.
- Soil erosion and runoff.
- Crop harvest and removal of crop residues.
- Poor management (e.g. competition with weeds) or damage to crops by pest and disease attacks may reduce N uptake by plant
- Very dry or wet conditions.

Options for intervention

§ Good crop management (timely planting, weeding, ensuring good drainage).
§ Apply compost, manure and chemical fertilizer or plant legume cover crops.
§ Soil and water conservation to prevent N losses through runoff and erosion.

Phosphorus (P) Deficiency – Maize

Symptoms



Description

- Reddish-purple colour of leaves, particularly in young plants.
- Stunted overall growth and poor root development is also common.
- Ears are small and often twisted, irregular kernel rows, imperfectly developed ear tips.

Likely causes

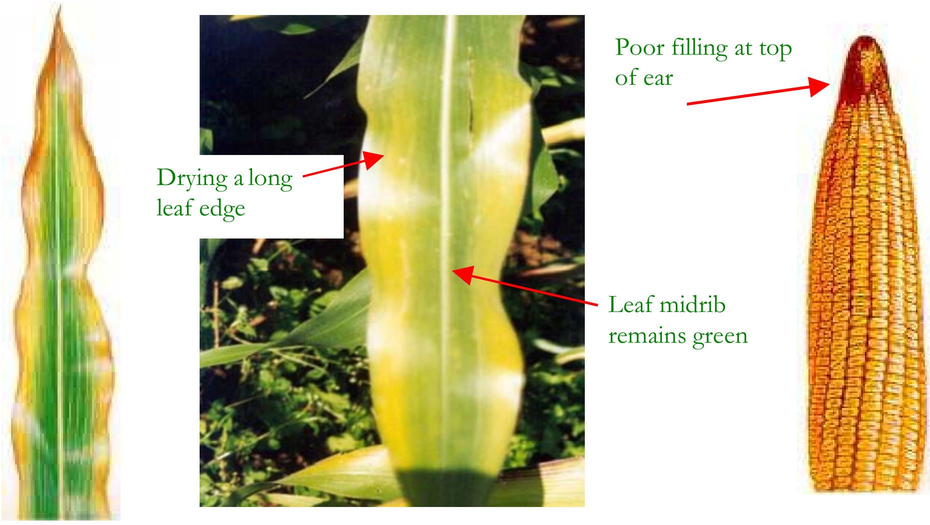
- Soils with high clay content.
- Soils with low or high pH. P availability in most soils is at a maximum near pH 6.5, P availability is reduced when pH is lower than 6 or higher than 7.
- Soils lacking in N, because N promotes P uptake by plant.
- Removal of harvested crops without returning residue.
- Surface runoff and soil erosion.
- Phosphate leaching.

Options for intervention

- Incorporate farmyard manure, chicken manure or green manure (e.g. Tithonia leaves)
- Apply mineral fertilizer, compost or phosphate rock
- Soil and water conservation to prevent P looses through surface runoff and soil erosion.

Potassium (K) Deficiency – Maize

Symptoms



Description

- Drying along the tips and edges of older leaves as K is moved by the plant to younger, developing leaves.
- The leaf midrib usually remains green.
- The crop has small ears that fail to fill at the tip.

Likely causes

- Highly weathered acid soils, sandy soils, compacted soils with poor aeration.
- Both drought stress and excess moisture reduce plant uptake of potassium.
- High pH soils (pH 7.0 and above); nitrogen or other nutrient stresses.
- Heavy removal by previous crop.

Options for intervention

- Apply chemical fertilizer: e.g. muriate of potash.
- Apply crop residues, ash from the fire or compost/ash mix.
- Mulch the field to prevent drought stress, or drain the field to prevent water logging.

Other nutrient deficiencies

Magnesium (Mg) deficiency

- Yellowish discoloration between green leaf veins (typical stripe chlorosis; Mg is a key part of the green plant pigment, chlorophyll, needed for photosynthesis), finally followed by blotching and necrosis (death of tissues), starting with the lower old leaves.

Sulphur (S) deficiency

- Whole plant is yellow (often mistaken as N deficiency).
- Yellowing of upper leaves, even on newest growth.
- Delayed crop maturity.

Calcium (Ca) deficiency

- Young leaves yellowish to black and curved or cupped (brown spots).
- Plants appear to wilt.
- Fruits may appear rotten (tomato).
- Roots are malformed.

Boron (B) deficiency

- Leaves frequently misshapen and crinkled, thick and brittle, white, irregular spots between veins.
- Growing tips of buds die, with bushy growth near tips, extension growth inhibited with shortened internodes.
- Water-soaked, necrotic spots or cavities in beet and other root crops and in the pith of stems.
- Fruit small and poorly formed, often with corky nodules and lesions.
- Low seed production due to incomplete fertilization.

Zinc (Zn) deficiency

- Stunted leaf growth.
- Fruit trees with typical shortened bushy shoots.

- Chlorotic stripes (white bleached bands) between the leaf veins in lower part of leaf.
- In some cases leaves have an olive green or greyish green colour (similar to P deficiency).

Iron (Fe) deficiency

- Young leaves with typical chlorosis between green veins, along the entire length of leaves (usually on calcareous soils).

In addition to insufficient nutrients from the soil, nutrient deficiency symptoms could be due to some other factor (soil, climate, biological, etc.) reducing crop's ability to take up nutrients. Box 1 gives likely reasons to investigate before taking any intervention.

Box 1

Checklist for participatory diagnosis & detailed understanding of soil-related problems	
1. Are other agronomic factors satisfactory?	2. Are other soil factors satisfactory?
§ seed quality	§ pH,
§ planting date	§ organic matter content
§ weed control	§ soil structure
§ plant protection (pest and diseases)	§ compacted layer
§ water (drought, water-logging)	§ drainage
§ previous cropping history, etc.	§ salinity, etc.

1.3.4 Yield trends

Crop yield is an important indicator used by farmers to assess changes in soil fertility. Changes in crop yield may be caused by many factors: extreme weather, pests/diseases, decline in soil fertility, etc. However, the effect of soil fertility on crop yield is usually gradual. Reconstructing a crop yield time line can help to identify the causes of yield change and the extent of the impact of the change.

A crop yield trend can be constructed with the community using the following steps:

- Explain the purpose to all participants. Find key informants who know about the past and present conditions, and willing to contribute. Include community elders.

- Discuss how far back in time participants would like to talk about these issues. Draw a time line of particular events, e.g. drought, significant pest/disease attack, conservation/management practices, change of variety etc. The time line of particular events helps participants to remember and also helps to explain the change of crop yield over time.
- Draw a village resource map and identify different land units based on slope gradient, different management levels or length of cultivation history. Decide the location to be discussed. Focus on a crop that has been cultivated for a long time in the community and for which yield is easy to measure. For example, although banana is the main crop in eastern Uganda and has been cultivated for a long time, participants find it difficult to recall yield changes since there is no fixed time for harvesting and yield is generally measured in bunches, which are variable in size. Farmers recall yields of maize and coffee more easily than banana.
- Participants can then write down the crop yield for 1950,1960,…, 2000 etc., comparing the yields from different years. Use farmers' own units, for example, the number of bags per acre, but it is useful to convert these units into standard units (e.g. kg/hactare) when the exercise is completed. Record the information in Table 5 and visualise the yield trend by constructing a bar or line chart. Repeat the exercise for different land units.

- Discuss the yield-time lines with participants; attempt to assess the contributions of soil fertility decline, drought, diseases, etc. to the changes and fluctuations of crop yield. Discussion topics to be covered:

  - If we have good rainfall now, can we get a yield as high as 20 years ago without using fertilizer?
  - *(if no)* What inputs are required to get a yield as good as yields 20 years ago?
  - If the yield has increased in the last 20 years, what are the main reasons for the increase?
  - What is the highest yield in this area for a particular crop?

Table 5:Example; Change in coffee yield in Namaitsu village, Mbale District

Time	Yield (kg/acre)	Events
1999	150	Good year
1994	200	Good year
1990	250	Good year
1986	270	Good year, but coffee neglected due to poor market
1976	300	Good year
1970	500	Good year

1.4 Nutrient Flow Mapping

1.4.1 The nutrient flow

Change in nutrients stock at the farm level depends on the balance between input and output (fig 1). When the total input is higher than output, the nutrients stock increase, if the total input is lower than total output, the nutrient stock of the farm decreases. Nutrient stock of a farm system can be maintained either by increasing the input or reducing the output or both. A third way to indirectly increase the nutrient stock of the farm system is to increase the use efficiency of the nutrient use.

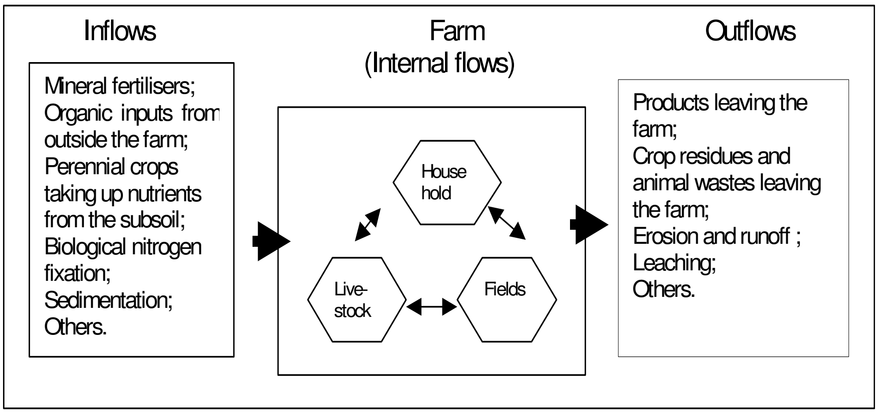


***Figure 1** Framework for nutrient flow mapping at farm level.*

Different methods can be used to maintain and increase the nutrient stock:

1. **Add nutrients to the farm**

- Fallow
- Applying mineral fertilizers
- Applying rock phosphate
- Mixed cropping, crop rotation (cereals and legumes)
- Others

2. **Reduce losses of nutrients from the farm**

- Cover crops
- Mulching
- Shifting cultivation/Fallowing
- Agroforestry
- Hedgerows
- Grass strips
- Contour cultivation
- Terraces
- Reduced tillage
- Others

3. **Improve nutrient recycling and increase efficiency of nutrient uptake**

- Composting
- Applying manure, urine, plant tea
- Incorporating crop residues
- Selecting crops to match soil fertility level
- Others

Section 2: Selection of Soil Management Techniques

Once a specific soil related "problem" has been identified the service provider should be able to recommend to farmers one or more soil management options with resource requirements that are reasonable for the local community. Such recommendations should fit within the farmers' circumstances (resource base, farming enterprises, production constraints) and the different recommendation domains that exist in the communities, then tailor advice and management options to each of them. It is advisable to offer farmers a number of general options for soil management that they can then experiment with and adapt to their specific conditions. These can be identified and assessed using criteria jointly agreed on by researchers, service providers and farmers regarding their usefulness and accessibility. Criteria should include: potential benefits, resource requirements, limitations, potential risks, the range of biophysical and socio-economic conditions under which the techniques can be implemented, etc.

It is important to remember that local farmers are the key informants in identifying and assessing soil fertility related problems. Selection of soil management techniques should therefore be based on a broad understanding of the biophysical and socio-economic situation of farmers and farmer groups rather than rigidly promoting specific messages on individual information sheets. In any case, farmers make the final decisions on which soil management option should be taken; farmers lead the fine-tuning/on farm research process; service providers are the facilitators, supporting farmers' soil management decisions.

Farmers are most concerned with soil productivity, e.g. changes in crop yield and inputs required to maintain yield. Selection of soil management options should therefore focus more on soil productivity improvement, rather than on preventing soil loss per se. Good soil management options will prevent soil degradation through improving soil productivity and enhancing the soil's resistance to degradation.

When a list of soil management options are presented and discussed at group meetings, farmers select the techniques that best fit their situation. During this process, service providers are the facilitators; farmers make the final decision on what soil management measures are to be taken.

Table 6 presents some of the main technical options for soil management in the hillsides.

Table 6: *Main generic options for soil management in East African hillsides with options for modification and experimentation*

Practice	**Options for East African hillsides already tried locally**	**Other options developed and tested elsewhere and new to the area.**
1. Contour bunds and ditches alone or with vegetation strips and/or field boundaries .	Napier grass planted as contour strips on sloping land. Planted to stabilize contour ditches (*Fanya juu*) or bunds where rapid run-off control is required. Inaction by up-slope farmers can frustrate farmers lower down in their SWC attempts.	§ Mixing fruit trees (e.g. citrus, avocado), suitable agroforestry trees (*Sesbania sesban, Grevillea robusta*), local useful species (e.g. *Tithonia diversifolia*) and cash crops (e.g. passion fruit vines) in with the hedges to increase value and incentive for their protection. This is to address the major problem of losing grass strips through dry season grazing. § *Tithonia diversifolia* can give a similar maize yield response to 60 kg/ha urea, and is effective when used as a split dose. *Tithonia diversifolia* supplies more potassium (K) than *Sesbania sesban.* § Alternative grasses include: *Pennisetum purpureum* cv. Bana grass, *Panicum maximum* cv. guinea grass, *Panicum coloralum* cv. macaricarience, *Chloris gayana* cv. Boma Rhodes. When compared to trashlines and fanya juu terracing for controlling soil erosion farmers rated the grasses higher than other methods as they were effective in erosion control and less labour demanding than the other methods. *Chloris* was preferred, being more persistent when grazed. § Where Napier and other grass fodder banks are repeatedly cut this represents a substantial nutrient off-take; need to fertilize the grasses if productivity is to be maintained.

Table 6: (Continued)

Practice	**Options for East African hillsides already tried locally**	**Other options developed and tested elsewhere and new to the area.**
2. Mulching	Mulching banana with any organic material available.	§ Mulching: Already long-practiced, mostly in banana plantations. Most organic materials can be used.
3. Terracing	Develops from 1 if well maintained	§ Mechanical methods well-known and unpopular but some options in 1) above can lead to less labour intensive 'bio-terracing'
4. Multi-purpose trees	*Sesbania sesban* & *Grevillea robusta* as shade trees for coffee. Eucalyptus and pine popular for woodlots.	§ Use of known and alternative agroforestry trees shade and fruit trees flexibly in dedicated plots or along field boundaries or contours.
5. Cover crops, forage crops and green manures	Species eg. Mucuna pruriens, Lablab purpureus, Crotalaria ochroleuca and Canavalia have been tested in many areas	§ Possible forage legume species for zero or thethered grazing systems *Desmodium intortum, Desmodium uncinatum, Stylosanthes guyamensis, Medicago sativa, Vicia sativa, Lupinus albus, Choris gayana.* § 'Best bet' cover crops widely used in E. Africa include *Canavalia insiformis, Crotalaria juncea, Crotalaria ochroleuca, Crotalaria grahamiana, Desmodium intortum, Desmodium uncinatum, Lablab purpureus, Mucuna pruriens, and Tephrosia vogelli. Mucuna & Crotalaria* are planted between maize rows, two weeks after planting maize, and left as mulch after harvesting maize. § *Tephrosia vogelli* undersown to maize and *Mucuna puriens*/maize rotations are among best options.

Table 6: (Continued)

Practice	Options for East African hillsides already tried locally	Other options developed and tested elsewhere and new to the area.
6. Rotation: e.g. maize/beans	A number of rotations are practiced: beans, groundnut, cow pea.	§ Integrated grain legume systems using pigeon pea, intercropped or relay cropped with main crops (maize, groundnut, soyabean) in addition to *Tephrosia vogelii*, have proved effective in Malawian research.
7. Fertilizers (DAP, NPK and Urea available)	Field friendly advice on fertilizer choice and basal and top dressing application can be got from service providers	§ Use of specific fertilizers to target identified nutrient deficiencies. § **Rock P:** Minjingu rock P (deposits near Arusha, Tanzania) is the softest and most soluble. Studies have shown it as effective a P source as TSP, even in neutral soils. Busumbu rock P (a Ugandan source), is less effective, but its availability can be enhanced by mixing it with compost or other organic materials (e.g. *Tithonia diversifolia, Lantana camara*, coffee husks etc.). Work in W. Kenya has led to the production of 'PREP-PACs' comprising 2 kg Minjingu rock P, 0.2 kg Urea, legume seed, rhizobial inoculant and instructions for use to treat 'low fertility patches' of 25-50 m^2. These have so far yielded good responses, reflected in maize and bean yields. On P deficient soils in W Kenya 2 t/ha tithonia plus 250 kg P/ha as rock P increased maize yields (from 0.8-4.9 t/ha)

Table 6: (Continued)

Practice	Options for East African hillsides already tried locally	Other options developed and tested elsewhere and new to the area.
8. Kraal manure	Widely used	§ Can be combined with compost, crop residues, rock P, etc. to bulk up and reduce nutrient losses.
9. Liquid manure	Used by a small number of farmers using cattle urine, *Tithonia*.	§ Some liquid organic fertilizer commercially sold; some farmers crush and mix fresh plant leaves with water to make liquid fertilizer (plant tea); farmers who practice zero grazing usually trap cattle urine, which is stored, diluted and applied to crops. Research on use of human urine in agriculture is ongoing, but studies have so far indicated good crop response to diluted urine.
10. Retention ditches	Known in some areas	§ A cheap way to harvest roadside runoff for crop production onto the farm. Requires collective action within the community since inaction by some can frustrate efforts of others.
11. Compost pits	Practised by some	§ More efficient ways of building compost piles/pits and combining materials.
12. Fallow	Traditional practice	• **Improved fallows:** *Alnus acuminata*, *Calliandra calothyrus* for 2-3 year fallow; *Tephrosia vogelii & Sesbania sesban* for 1 year fallow; *Lupinus mutabilis* and *Vicia spp.* for short fallows (3 months). • Recent research in western Kenya recommend a number of 'best bet' options for improved fallows: - *Sesbania sesban* + *Crotalaia grahamiana:* for recycling of deep soil N, high inputs from BNF, fuel - *Sesbania sesban* + *Macroptilium atropurpurem* (siratro): to maximise fallow biomass and fodder

Table 6: (Continued)

Practice	Options for East African hillsides already tried locally	Other options developed and tested elsewhere and new to the area.
		- To produce a food crop during fallow: *Sesbania sesban* + groundnut, *Cajanus cajan* + groundnut (groundnut yield is about half of pure groundnut stands). - *Sesbania* + *Tephrosia vogelii* . Farmers are however encouraged to test other combinations for their suitability for their particular needs. To ensure optimal use of the fallow the subsequent maize should be fertilized with 50 kg P/ha for P deficient soils plus 50 kg K/ha for K deficient areas

2.1 Testing and adapting of soil management options

Farmers usually need to test a new management option out before fully adopting it and when implemented, it is often modified in some way to suit their own circumstances. A farmer might:

§ *Adapt the timing of soil management activities* - so that they do not conflict with other farming activities.

§ *Modify the method of implementation of an activity* - so that it fits with the resource availabilities (labour, space etc.) in the household.

§ *Remove implementation constraints* - by using other available resources because the optimum ones are not available.

Service providers should be able to facilitate this process, by suggesting modifications that have worked elsewhere and improving the process of farmer experimentation so that results can be more clearly seen and interpreted.

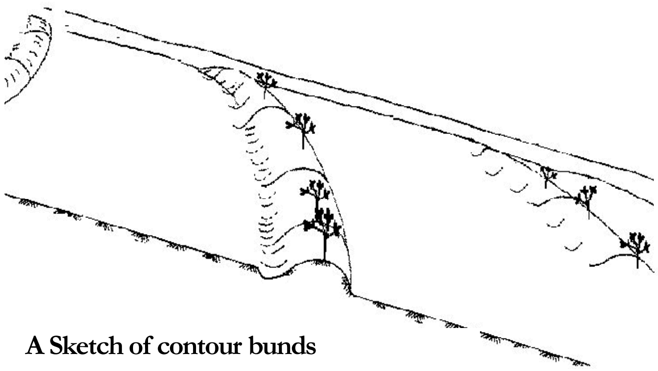
Contour bunds for soil and water conservation

What are they?

- § A contour bund is an embankment along the contour, made of soil and/or stones, with a basin at its upper side.
- § Contour bunds are of two categories: level bunds and graded bunds.
- § A graded bund, differs from a level bund in that it slopes towards a waterway (drainage channel, stream etc.).

How they work

- § Contour bunds conserve soil and water by reducing the length of the slope and acting as a barrier to water flow.
- § As the slope is cut into sections by bunds, the runoff formed between two bunds cannot combine to form large volume flows. The risk of erosion is thus reduced.
- § Soil eroded between two bunds is deposited in the basin behind the lower bund. When the basin is full of sediment, the bunds must be raised, in this way a bench terrace can be developed after a numbers of years



A Sketch of contour bunds

Establishment

- Using an A-frame, contour bunds can be constructed on slopes up to 50%.
- The optimum height, width and spacing of bunds depends on slope.
- Bunds can be up to 0.5-0.75 m high with a base width of 1-1.5 m. As the slope increases, the distance between two bunds should be less.
- The distance between two bunds should also allow farmers to cultivate.

Management and maintenance

- Plant grasses or trees on the bunds to stabilise them and produce extra benefits such as fodder, manure, and nitrogen fixation from the air. This may compensate for the loss of cropping area due to bund construction.
- Napier grass, Sesbania and Tithonia are good species for bund stabilisation. Increase the bund height annually until bench terrace is formed.
- Close any breaks on the bunds as soon as possible.

Potential constraints to wide adoption

High on labour demands for construction and maintenance; high risk of breaking which may cause severe runoff and erosion; land taken by the bunds.

Napier Grass Strips

General features: Napier grass

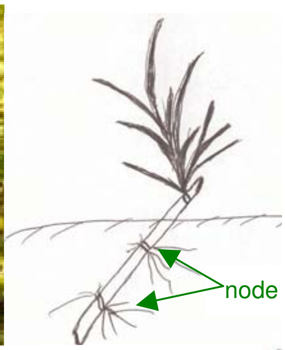
§ A tall, tufted grass, excellent species for grass strips and bund stabilization.

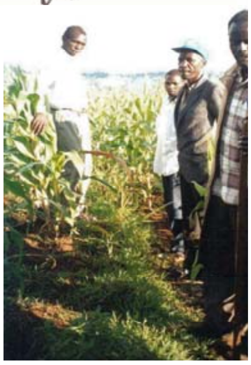
§ Napier produces high quality (protein-rich) forage.

§ If planted with maize, Napier can reduce damage from stem-borers by producing a sticky glue that traps and kills their larvae.

§ Napier grass is best suited to high rainfall areas, but it is drought tolerant and can grow well in drier areas, but not in waterlogged areas.

Planting





Napier grass can be grown along contour lines, terrace risers, or along field boundaries. Plant Napier grass using cuttings as follows:

1. Cut/sharpen the bottom part of a stem into pieces of about 30 cm long. Each piece should have at least three nodes.
2. Push the sharpened end of the stem into the ground (alternatively dig a hole 25 cm wide & 25 cm deep), at 30-50 cm intervals along the contour line (terrace or bund).

3. Plant the stems at an angle in the soil, with two of the nodes in the soil and leave one above the ground.
4. If any of the cuttings die, fill gaps with new ones.

Maintenance

- If well established, a single row of Napier grass can form a 30-50 cm wide strip, which effectively reduces runoff and traps eroded soil in front of the strip.
- Napier grass is ready for harvest when it is 1 metre high (normally 3-4 months after planting); harvesting can continue at intervals of 6-8 weeks for 3 - 5 years.
- Leave a stem length of 10 cm in the ground after cutting.
- Prevent animals grazing directly on the Napier grass; do not allow the grass to grow too high (over 120 cm) as older stems and leaves are less palatable for livestock.

Grass strips can also be established using other grass species e.g. Vetiver grass (not palatable to animals), Guatamala or Giant setaria (both fodder species).

Contour Hedgerows

What are they?

Contour hedgerows are a form of "alley cropping" where rows of trees/shrubs are planted along the contour with crops cultivated between the rows in the "alleys".

Advantages

- Reduce soil erosion
- Provide green manure & mulching material
- Improve soil structure and water infiltration
- Improve soil fertility and moisture
- Provide fodder for livestock
- Provide fuel wood, construction materials

Disadvantages

- Loss of land for cultivation due to establishment of hedgerows
- Hedgerow growth may be excessive - labour requirements for pruning large
- Hedgerow plants may be hosts of pests
- Hedgerows can compete with crops for light, soil nutrients and moisture

Establishment and maintenance

- Hedgerows are normally established along contours.
- Hedgerows can also be used as windbreaks in which case their orientation is perpendicular to the direction of prevailing winds.
- The recommended inter-row spacing is 5-10 meters, depending on the slope
- The hedge should, if possible, consist of two lines of trees 0.5 meter apart. Trees within the lines should be planted at 0.3-0.5 meter spacing.
- Periodic hedge pruning is necessary

Hedgerow tree species characteristics

- Rapid growth & biomass production
- Deep and vertical rooting
- Easy to establish
- Widely adaptable and stress tolerant

Sesbania

- High re-sprouting ability after pruning
- Nitrogen fixation
- Free from pests and diseases
- Multipurpose
- **Recommended species:** Gliricidia sepium, Sesbania sesban, Calliandra calothyrsus, Grevillea robusta, Euphorbia balsamifera, Tetradenia riparia, sisal (drier areas).

Nutrient Mobilisation with Tithonia

- Tithonia (*Tithonia diversifolia),* also known as Mexican Sunflower and False Sunflower, is a prolific shrub with dark green leaves and bright yellow flowers.
- It is commonly found in hedges around farms/households, along roads and in wastelands

Uses

Tithonia has multiple uses including:

- Fodder
- Soil conservation
- Ornamental value
- Fencing (hedges)
- Organic fertilizer
- Honey production
- Fuel wood
- Medicine

Propagation

- *Seed* – sow at shallow depth and cover with a thin layer of sandy soil. Covering with a layer of grass (a grass mulch) improves germination.
- *Stem cuttings* – produce stem cuttings 20-40-cm in length and insert upright in soil. Plant cuttings into moist soil immediately after collection.
- *Transplanting* – dig up seedlings from under the tithonia canopy and transplant to other areas.

Tithonia hedge and its detailed view (above)

Application

The green biomass of tithonia is an effective source of nutrients to crops, and it is often used to correct phosphorus deficiency in soils. The tithonia green biomass (leaves and tender stems) can be used in several ways:

- Collect the green biomass, carry to the field and incorporate directly into the soil at any cultivation stage.
- Collect the green biomass and add to a compost pit, then return to the field when the compost is ready.
- Cut young tithonia plants, soak them in water and make a liquid fertilizer for top-dressing crops. Tithonia hedges can grow back rapidly after cutting and withstand repeated cuttings.

Constraints

- *Labour* – considerable labour is required for cutting and transporting biomass to fields.
- *Availability* –wide-scale use of tithonia will likely be constrained by limited availability
- *Nutrient mining* – the intensive use of tithonia as a crop amendment will mine nutrients from field edges or other areas where the tithonia grows. This is unlikely to be sustainable in the long term.
- *Potential to become a pest* – if uncontrolled, tithonia might become a weed in crop fields and thereby increase labour costs for weeding.

Composting

Composting is the process that brings together plant residues or animal wastes to produce a nutrient-rich organic fertilizer through decomposition**.**

Compost pile near a banana field

- It can be used in all soils with or without the use of chemical fertilizers.
- Application of compost improves soil fertility and soil structure and can help the soil hold on to moisture for longer.
- Making and transporting compost can be labour intensive. Material supply and labour are frequent constraints to compost use.

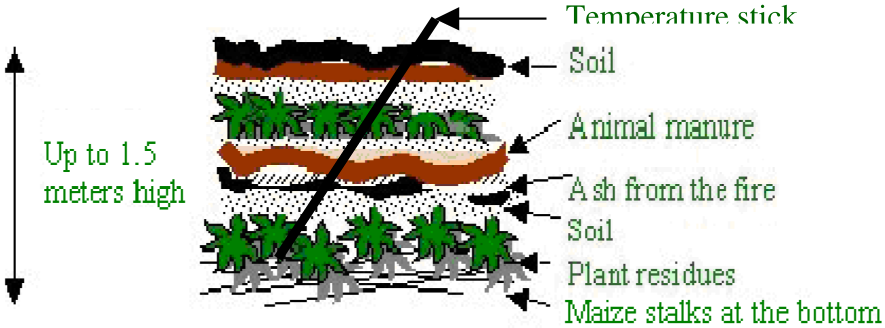
Compost pit near the field

- Compost can be prepared in many ways: in a pit, above ground, in a field, near a livestock pen etc.
- The choice (pile or pit) depends on the weather, the source of materials and the distance to the fields. The pile method may be suitable for rainy areas while the pit method may be more suitable for dry areas.
- The location of the pile/pit could be either

Small compost pit in the field

near the field where the compost will be applied or near the source of materials.

§ Shelter the compost site from wind, sun, rain and runoff. Start the pile by loosely putting a 15cm bottom layer of rough materials e.g maize stalks, then plant materials (e.g. maize straw, dry banana residue, coffee husks), and animal wastes (chicken, farmyard manure) in alternate layers; first chop plant materials for faster decay.



Sprinkle topsoil and kitchen ash between each two (plant & animal residue) layers. Repeat the layers until the pile is about 1.5 meters high. Cover the whole pile with a layer of soil to prevent plant nutrients escaping from the pile. Keep the pile moist by watering regularly (depending on the weather). Compost is ready when the "heat" stick feels cool when removed.

Mucuna as soil improving cover crop

General features

- Mucuna (or **velvet bean)**, is a high biomass- producing legume, widely used as green manure, for fodder production, and suppressing weeds.
- Adapted to a broad range of soil, precipitation (optimum range of 1000 – 2500 mm/yr) and elevation (0-1600 m asl) conditions.
- Tolerates a relatively narrow range of temperatures (19-27^{o}C), does not like water-logged, very infertile or acid soils, (pH 4.5 or less).

Mucuna planted as sole cover crop

Planting

- For quick germination, soak seeds over-night before planting.
- Mucuna can be planted as a sole cover-crop or inter-cropped.
- For severely degraded fields, plant mucuna as a pure stand at the start of the rainy season.
- Sow mucuna in a clean seed bed with two seeds per hole spaced at approximately 60 cm x 75 cm.
- The mucuna will need to be weeded once before it can compete with weeds.
- To intercrop with maize, sow mucuna 4-5 weeks after planting maize to prevent competition with maize.
- Sow one seed in each hole between the rows of maize with 50 cm between the holes

Soil change after mucuna fallow

§ Mucuna intercropped with maize should benefit subsequent crops, but may reduce the yield of associated maize in the first year.

Maintenance

§ When mucuna is used as fodder, harvest the above ground biomass before flowering to get high quality fodder. Do not cut stems too close to the base to allow rapid re-growth.

Mucuna-maize intercropping

- When used as cover crop, kill mucuna at flowering or milking (pod filling) stage so it won't become a weed for the next crop.
- For seed production, allow a small portion of the mucuna field to grow and produce seed for use during the following season. Collect the dry pods to keep seeds, leave the residues in the field to decompose.

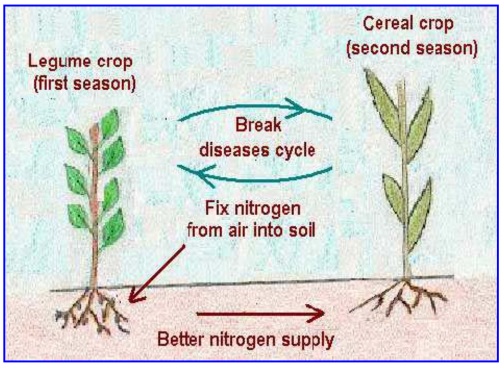
§ Mucuna seeds, although high in protein, contain toxic compounds and therefore, are not suitable for human consumption without special treatment.

Crop Rotation

What is it?

A crop rotation is a widely adopted management practice where two or more different crop species are grown in sequence, one after another, in the same part of the or field.

Crop rotations can help to:



- Maintain and improve soil fertility.
- Diversify crop production.
- Reduce soil nutrient mining.
- Control diseases, pests and weeds.
- Control soil erosion.
- Recycle nutrients through growing of deep and shallow rooted crops alternately.

How it works

- Each crop places different demands on the soil in which it grows.
- Likewise, each crop leaves some amount of beneficial residue or has some effect on the soil structure.
- A good crop rotation combines crops that compliment each other by making different demands on the soil and by contributing to the soil in different ways.
- A good rotation will also match farmers' preferences for diet, marketing potential etc.

Implementation

- The following aspects need special attention when adopting a crop rotation:
- All crops in the rotation must be suited to your soil.

§ Crops suffering from the same root diseases should not be sown in succession, e.g. tobacco should not be planted following tomatoes.
§ The continuous growing of cereals or legumes should be avoided.
§ Including a legume crop (e.g. groundnut) in the rotation is beneficial.
§ Arrange the rotation to provide residues at required times.

Potential constraints

§ Demands more skill and planning from farmers than normal cropping.
§ Can have a higher labour demand.
§ May require farmers to plant a crop which is not their first choice crop.
§ Can produce increased income in the long run, but may give lower income in the short run.

Agro-forestry

Trees can provide shade, fruit, fodder, fire-wood and construction wood. They can also reduce soil erosion and improve soil fertility.

Where to plant

Depending on the tree species and the purpose of planting, trees can be planted as a pure stand; along road or field boundaries; along bunds and terraces; or in the field mixed with crops.

- Some trees like **eucalyptus, pine** and **cypress** should not be grown very close to crops as they take too much water and nutrients from the soil and leave little for the crop. These trees are best grown on their own in wood lots, if possible on land less suitable for crops.
- Some other types of trees are particularly good for the soil because their leaves are rich in important nutrients like nitrogen (legume trees like **Sesbania, Calliandra, Leucaena, Albizzia**) and phosphorus (e.g. **Grevillea**). These can often be grown with crops such as coffee, banana and maize. They can also be mixed with napier grass strips.
- Some fruit trees also grow well in mixture with crops or napier grass strips e.g. **avocado, citrus**.

Sesbania hedge

How to plant

- Trees should be planted during the rainy season as they need water to establish.
- Trees should be positioned where it will be most useful and not compete with crops.
- If possible obtain seedlings rather than seed as seedlings will establish more quickly.

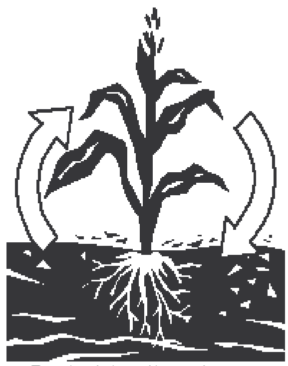
- Transport tree seedlings with care, put enough moist soil around root.

- When planting seedlings a hole should be dug and, if possible some compost, manure or fertilizer mixed into the soil in the hole.
- The tree seedling should be placed in the hole and soil/compost packed in around the seedling. Be sure the soil is firmly packed down.
- Protect the small tree from grazing with a simple fence.
- If sunlight is very strong a simple grass roof should be used on top of the fence to protect the young tree from burning for the first few weeks.

Why Apply Fertilizer?

Chemical fertilizers are applied to:

- Correct nutrients deficiency rapidly.
- Replenish nutrients lost by the removal of plant products or by leaching, erosion etc.



Replenish soil nutrients to improve crop yield

Methods of Application

- **Broadcasting:** applying fertilizer evenly to an area, usually before planting or germination (basal application).
- **Top dressing:** broadcasting fertilizers on fields of growing crops, suitable for crops planted in dense rows or non row-planted crops. Minimize fertilizer contact with crop. Top dressing should be done with fertilizers that do not harm the crop, and are very soluble e.g. C.A.N. Urea and ammonium fertilizers must be incorporated.
- **Side dressing:** applying fertilizer to the soil surface in bands or strips next to the rows of crops.
- **Placement:** when fertilizer is required to be concentrated in specific parts of the soil, for example in strips, or to the side of or below the seed. Take care not to place the fertilizer too close to the seed or the germinating plants to avoid burning of the seedlings.
- **Foliar Application:** fertilizers are applied as foliar sprays. Nutrients are absorbed and used by the plant quickly. Suitable for supplying micronutrients, which are needed only in small quantities and may become unavailable if applied to the soil. To reduce the risk of leaf scorch, spraying should preferably be done on cloudy days and in the early morning or late afternoon.

Make It Profitable

- The profitability of fertilizer use can be simply judged by "Value/Cost Ratio (VCR)", the ratio between the value of the extra yield obtained by using fertilizer and the cost of the fertilizer applied.

- To make sure fertilizer application will be profitable, it is recommended that the ratio should be at least two, i.e. the value of the extra output obtained should be at least double the cost of the input.

Integrate with Good Farming Practices

Good response to fertilizer application can only be achieved if it is integrated with other good farming practices, check if the following factors are satisfied:

- Appropriate crop varieties.
- Proper and timely preparation of seedbed.
- Optimal seeding time & correct seeding rate.

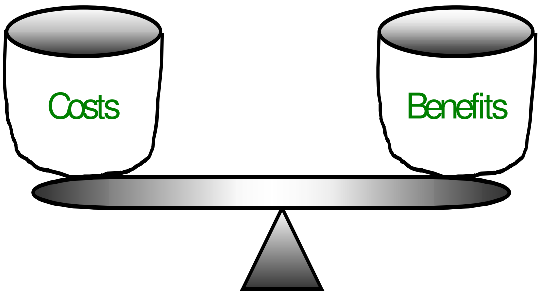
- Sufficient moisture & adequate drainage.
- Control of weeds & crop diseases/pests.
- Maintenance of soil organic matter & soil structure.

2.2 Financial appraisal of soil management measures

What is it?

Financial appraisal in soil management serves to: to estimate the losses to farmers caused by soil degradation/fertility decline and the net benefits of a certain practice if implemented to halt soil degradation or declining soil fertility. Decline in crop yield is commonly due to soil erosion and nutrient depletion. An appropriate soil management measure may reduce both of these and therefore maintain crop yields. However, implementing a soil management measure often requires extra resources from a household. Financial appraisal can help to identify, quantify and analyze resource inputs (costs) and outputs (benefits) over time for a particular soil management measure; and compare several different soil management measures.

How does it work?



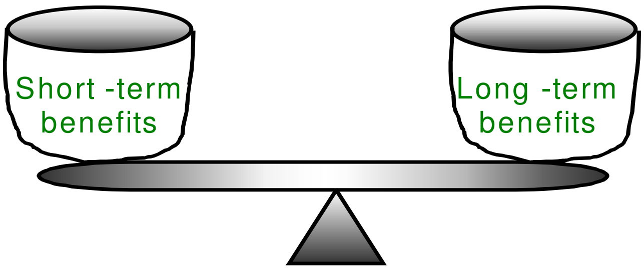
Financial appraisal of a soil management measure compares the costs of implementing and maintaining the measure with the extra income benefits arising from the measure. When the income exceeds the costs, implementing the measure may be profitable. For soil management measures with benefits lasting longer than one year, the analyses need to be carried out on a year-by-year basis.

Costs	Benefits
• Labour to § transport seedlings § plant seedlings § cut and carry fodder • Buy seedlings • Reduces the area for maize planting	§ Reduce soil erosion § Stabilise bunds § Formation of natural terraces § Increase crop yield § Produce fodder and mulching material § Sale for cash

Example: *these are costs and benefits identified by Kapchorwa farmers for planting Napier grass strips in maize fields. Some costs and benefits can be quantified and priced directly, others cannot. It is important to have farmers' perspectives in weighting the costs and benefits when making a comparison, particularly for items that cannot be priced directly.*

Decision making

Some soil management measures can yield an immediate benefit after implementation but have little or no long-term effects on soil fertility. Others require large investments (labour, materials etc.) in the first year of implementation, and full benefits realised several years after implementation. A soil management strategy should meet farmers' immediate needs whilst also improving soil fertility in the medium/longer-term



Apart from financial appraisal as a decision-making tool in soil management, other factors e.g. labour availability, land tenure, crop prices & market have to be considered as well.

2.2.1. Procedure for participatory financial appraisal

This section outlines the cost-benefit analysis for a soil management technology. In practice, some of the steps could be merged and carried out simultaneously.

Step 1. Identify the costs and benefits

Here we are concerned with the additional costs (including new costs & lost income) and additional benefits (including cost savings & new income) involved when adopting a new soil management practice, compared with the situation before. Tabulate all the costs and benefits. Example in Box 2 shows the costs and benefits of planting napier grass strips as identified by farmers in Mbale, Eastern Uganda.

If the participants want to stop the appraisal at this step then discuss the results with participants. The possible topics of discussion include:

- Which costs are the most prohibitive? Why?
- How do/might you deal with the costs?
- Which benefits is the most valued?
- If there is (or is no) subsidy, will you adopt the practice

Box 2: *The costs and benefits of grass strips, identified by farmers in Mbale and Kapchorwa*

Costs	**Benefits**
• land • weeding • labour for planting • transport material • seedlings • etc	• reduce soil erosion • fodder to cattle • mulching material • sale to get income • better crop yield • manure • increase the value of land

Step 2. Quantify the cost and benefits

For each item of the costs and benefits identified in step 1, ask the participants how much that cost or benefit would be. For some items an estimate has to be made. Convert local units into a common unit when filling in Table 7.

Table 7: Quantified costs and benefits (from example above)

Practice:						
No	**Costs**			**Benefits**		
	Item	**Unit**	**Amount**	**Item**	**Unit**	**Amount**
1	Land					
2	Weeding					
3	Labour					
4	Transport					
5	Seedling					
6	Other					

Step 3. Valuation of the costs and benefits

This process attaches a 'price-tag' to each of the items using local prices. Some items can be easily priced by farmers, others not. For items with no available market price, use substitute prices. For example, if a bunch of Napier grass is commonly exchanged for 1 kg of maize, then the value of a bunch of grass could be equated to 1 kg maize.

Labour cost can vary with time of year and opportunities for off-farm employment. If casual labour is hired to implement a technique, estimate the cost based on number of man-days required to complete the work and the daily rate of casual labour. If a farmer's own labour is used, the price of labour can be estimated according to the income that could be earned if alternative work had been undertaken, i.e. off farm employment. Another method for estimating labour costs is using the average labour return i.e. the value labour can produce in a year. Use the following guide questions:

§ How much do you earn if you work for other farmers in the village?
§ How much do you pay if you employ someone to work for you?

Add up all the items of costs and benefits. It is now possible to balance the costs against benefits of the proposed soil management practice. If the total benefits exceed total costs, the practice is profitable. Apart from economics other factors influence farmers' decisions on soil management, and need to be considered, e.g. whether the required inputs are locally available or affordable to some farmers.

Step 4. Calculate the net cash flow

Some soil management practices need a higher initial input and some need modest initial inputs but a continued input in subsequent years (Fig. 2). Case (1) represents a practice with high initial input, low maintenance cost; case (2) represents a practice with a modest initial input but a higher maintenance cost in subsequent years. The net benefit (or net cash flow) is the difference between the benefit and cost over a number of years. Table 10 is a sample worksheet for calculating net cash flow.

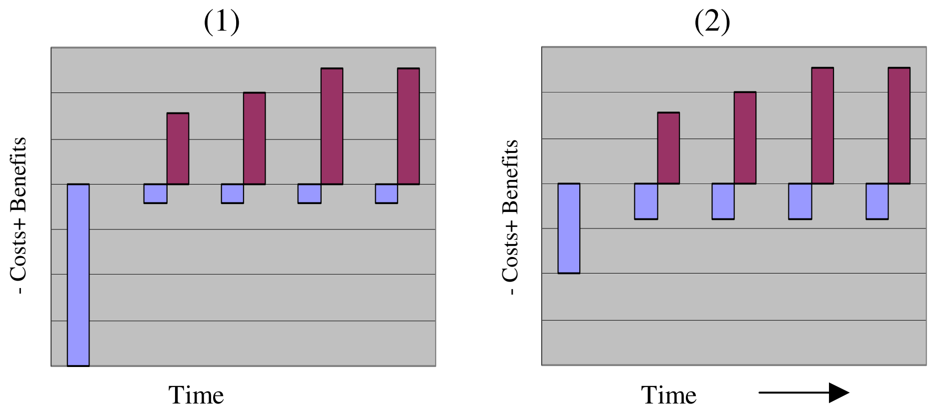


Figure 2: *Comparison of cost and benefit over time.*

Table 8. *Calculation of Net Cash Flow*

Practice:			
Year	Cost, **A**	Benefit, **B**	Net cash flow, **C = B-A**
1			
2			
3			
4			
5			
…			

Discuss the net cash flow with participants. Possible discussion questions:

- Are you happy with a practice with high initial cost with clear benefits some years later?
- How many years can you wait for the initial investment to be returned?

Example: Financial appraisal for Napier grass for soil erosion control.

The situation

Assuming 1 ha of maize is grown on a 15% slope and yields on average 3000 kg/ha per year. The maize is sold for Shs 200 per kg, at the local market. Soil erosion is recognised as a main constraint to crop production. There are no conservation measures implemented.

The suggested measure is to plant Napier grass strips on the contour in a strip 1 m wide and with 10 m interval spacing.

Costs	**Benefits**
Buy seedlings	reduce soil erosion
Transport materials	fodder for cattle
Land forgone	mulching material
labour for planting	sale for income
Labour for cutting	better crop yield
	provide manure material
	increase the value of land by conserving soil

Valuation of the costs and benefits

Land forgone

The strips will reduce the land for maize by 10%. Therefore a 10% reduction in maize output is assumed. The loss of income from maize will therefore be Shs 60,000.

Planting and maintaining the strips

The Napier grass is planted from splits. It is assumed that the saved cost of maize seed is equivalent to the cost of buying the splits. The work of digging up the splits, transporting them and planting them in contour strips takes 20 man-days per ha at a labour cost of Shs 3,000 per day, ie. a total of Shs 60,000, plus a transportation cost of 40,000 making a total of Shs100,000. Some filling of gaps will be required in subsequent years and 4 man-days per year (Shs12,000) are allowed for this.

Labour for cutting

It is assumed that the labour for cutting the grass is equivalent to the labour saved from management of the maize on the same area, so there is no extra cost for this.

Reduced erosion or increase yield

As erosion is reduced, crop yield decline is therefore reduced. It is assumed that comparing with the situation of non-conservation, yield declined is reduced by 2% of the original yield, i.e. 60 kg/ha per year. This is valued at Shs 12,000 per ha per year.

Fodder production

The Napier will yield an average of 20 tonnes of dry matter per ha per year after the year of establishment and on the 0.1 ha of land occupied by the fodder strips it would yield 2 tonnes (2,000 kg) of dry matter per year. This could feed one cow for 100 days. The cow produces 5 litres of milk that is sold at 400 Shs per litre.

Table 9: *Cost and benefit of planting Napier grass strip*

	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Cost of establishing grass	100,000					
Maintenance of grass		12,000	12,000	12,000	12,000	12,000
Reduction in maize output	60,000	60,000	60,000	60,000	60,000	60,000
Total costs	**160,000**	**72,000**	**72,000**	**72,000**	**72,000**	**72,000**
Income from milk		200,000	200,000	200,000	200,000	200,000
Yield increase		12,000	12,000	12,000	12,000	12,000
Net benefit from conservation	-160,000	140,000	140,000	140,000	140,000	140,000