SOIL FERTILITY MANAGEMENT

PRACTICES AND TECHNOLOGIES

AN ILLUSTRATED GUIDE FOR EXTENSION WORKERS

...titute of Organic Farming Publication

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A Kenya Institute of Organic Farming Publication

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Abbreviations

AB-DLO:	Research Institute for Agro-biology and Soil fertility
ESM:	Ecological Soil Management
EU:	European Union
KIOF:	Kenya Institute of organic Farming
NEDA:	Netherlands Development Agency
NUTNET	Improving Soil Fertility in Africa: Nutrient Networks & Stakeholders Perceptions
LEINUTS	Potentials of Low External Input and Sustainable Agriculture in attaining Productive and Sustainable Land Use in Kenya and Uganda
LEI-DLO:	Agricultural Economics Research Institute

Chapter 1

INTRODUCTION

At national level in Kenya, as do most countries in sub-Saharan Africa per capita food production has been on the decline (UNCTAD, 1996), a situation which has been partly ascribed to declining soil fertility. The decline in soil fertility has been attributed, in part, to continuous cropping with little or no inputs, crop removals, leaching, gaseous losses, soil erosion and a wide array of poor management practices. Addressing this seemingly bleak future not only calls for management of the widest variety of possible sources of fertility in the most efficient way, but also adoption of practical technologies applicable to farmers under specific and diverse settings (Altieri, 1997). Such technologies aimed at mitigating the declining soil fertility and offering of solutions to the emerging problems should encompass the following basic principles essential to sustainable soil management (Greenland, 1975)

- Replenishment of chemical soil nutrients removed or lost due to diverse reasons.
- Improvement and maintenance of soil physical conditions.
- Augmentation of soil pH to favourable levels while avoiding accumulation of toxic elements.
- Limiting the build up of weeds, pests and diseases.
- Conservation of soil and water resources.

The above concepts are embodied in the principles of ecological soil fertility management, (ESM). ESM proposes the development and promotion of practices and technologies based on the use of locally available resources, indigenous technical knowledge and modern scientific concepts. Based on this perception, this guide has been prepared as a tool to contribute to soil fertility management by giving insight to ***some of the technologies*** of soil fertility management applicable to small-scale farmers under diverse settings. The guide has been prepared in the hope that it will:

- Expose extension workers to diverse soil fertility management issues including soil fertility decline and some of the tools for diagnosing the same.
- Support and bring awareness on appropriate soil fertility management technologies under diverse environment and farmer situations.

While the guide does ***not claim "completeness"***, it addresses the theme of soil fertility management by recognizing the contribution of ***both indigenous technical knowledge and modern scientific concepts*** in attaining sustainable soil management. The guide further recognizes that technologies and practices that help minimize the loss of top soil (through soil erosion or otherwise), thus soil nutrients, are crucial in contributing to the wider aspects of sustainable soil management. Thus an overview of some soil and water conservation practices are included in the guide.

The guide comprises seven chapters. Chapter 1 gives introductory remarks while chapter 2 presents the concept of "poor" and "fertile" soils. It further underscores symptoms and indicators of soil fertility decline and introduces users of the guide to the following: farmers indicators of soil fertility based on indigenous knowledge, soil nutrient deficiency symptoms and soil analytical indicators of soil fertility and productivity (e.g. soil carbon, pH, soil nutrient levels for nitrogen, phosphorus etc.)

Chapter 3 explores the role of organic matter in improving soil chemical and biophysical conditions. The chapter further gives examples of strategies for improving soil organic matter content. Chapter 4 presents options for improving soil nitrogen, phosphorus and potassium balance while chapter 5 discusses practices and technologies for minimizing the loss of nutrients resulting from loss of top soil and soil moisture (accompanying practices and technologies). A summary of the main technologies discussed in the text is presented at the end of each chapter. Chapter 6 presents glossary of terms used in the text while chapter 7 presents references for further reading.

Chapter 2

UNDERSTANDING CONCEPTS OF "POOR" AND "FERTILE" SOILS

Concept of "Poor" and "Fertile" Soil

Soil is said to be fertile when it is able to supply adequate nutrients in the right proportion to crops. Thus soil fertility refers to the capacity of soil to produce crops by supplying nutrients (macro and micro nutrients/elements) in correct proportion and in adequate amounts overtime. Crop nutrients are mainly derived from two main sources: air and soil

Out of the above sources, nutrient supply from soil is critical. Inadequate and unproportional supply of nutrients leads to poor crop performance. The release of nutrients and availability of nutrients from soil reserves is influenced by a number of factors including the activities of soil organisms. These activities (of soil organisms) are in turn influenced or augmented by farm management practices. Efficient farm management practices should result in:

◊ Greater stimulation of activities of soil organisms.
◊ Nutrient additions to the soil.
◊ Minimal nutrient exports from the soil.
◊ Optimum nutrient recycling within the farming system.

Characteristics of Fertile Soils

Attributes of fertile soils include the following among others:

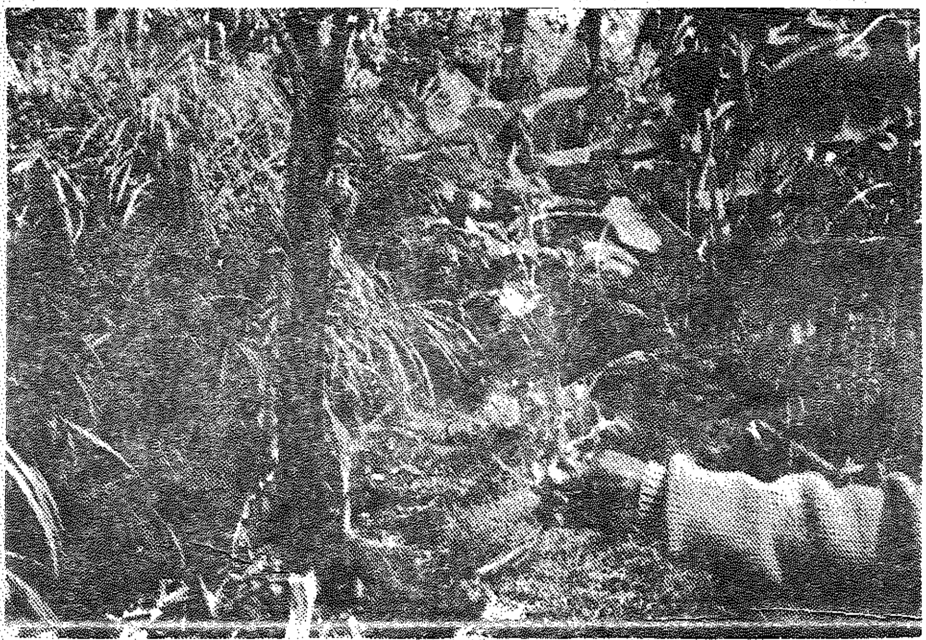
- Adequate supply of nutrients in the correct proportion resulting in sustained high crop yields.
- Good rooting depth.
- Good aeration.
- Good water holding capacity.
- Presence of soil organisms e.g. earthworms.
- Presence of adequate amounts of organic matter
- Absence of soil borne pests and diseases
- Right pH. Low pH and or high pH may lead to unavailability of certain nutrients in the soil e.g. Phosphorus fixation at low pH.

Indicators of "Poor" and "Fertile" soils

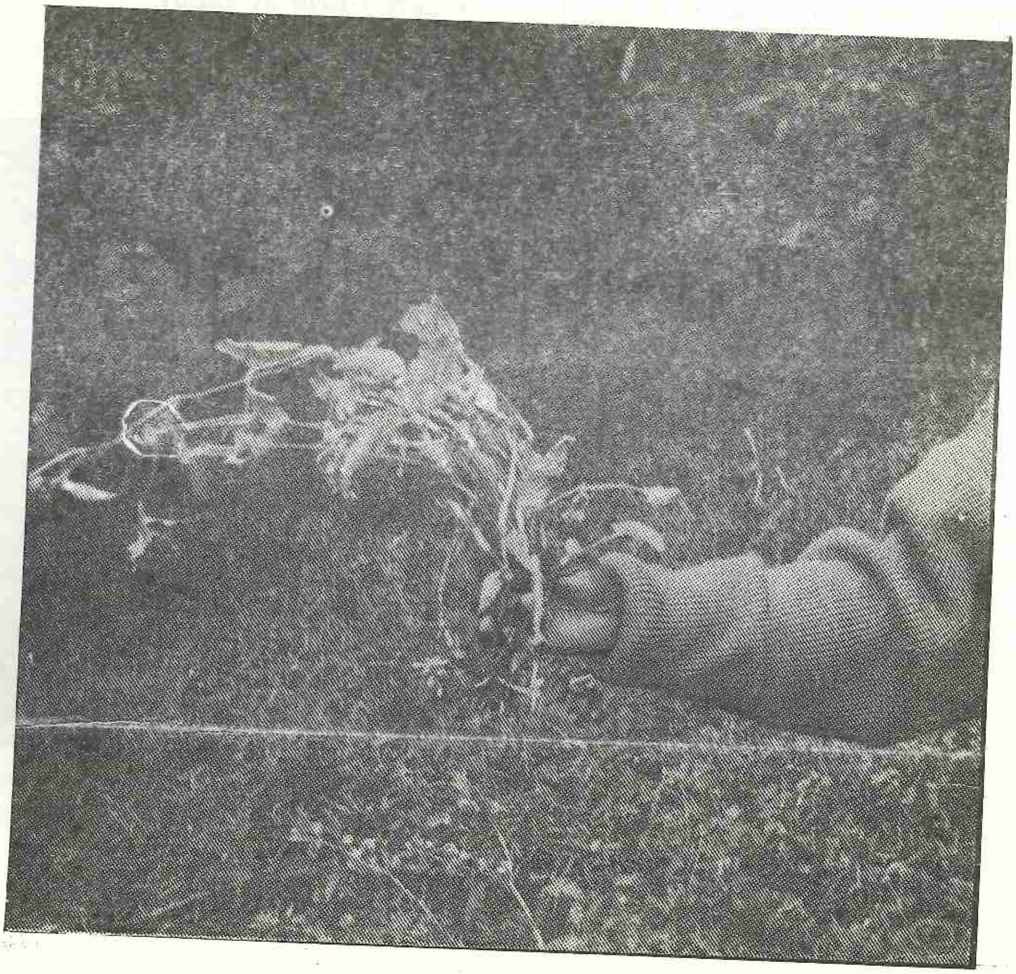
Farmers' indigenous technical knowledge about soils and soil fertility management is continuously being appreciated in the development of appropriate interventions in soil fertility management. This section underscores farmers' indicator plants for "poor" and "fertile" soils. These qualitative indictors emanate from the experiences and indigenous knowledge of farmers in medium and high potential areas of Kenya.

Indicators of high fertility

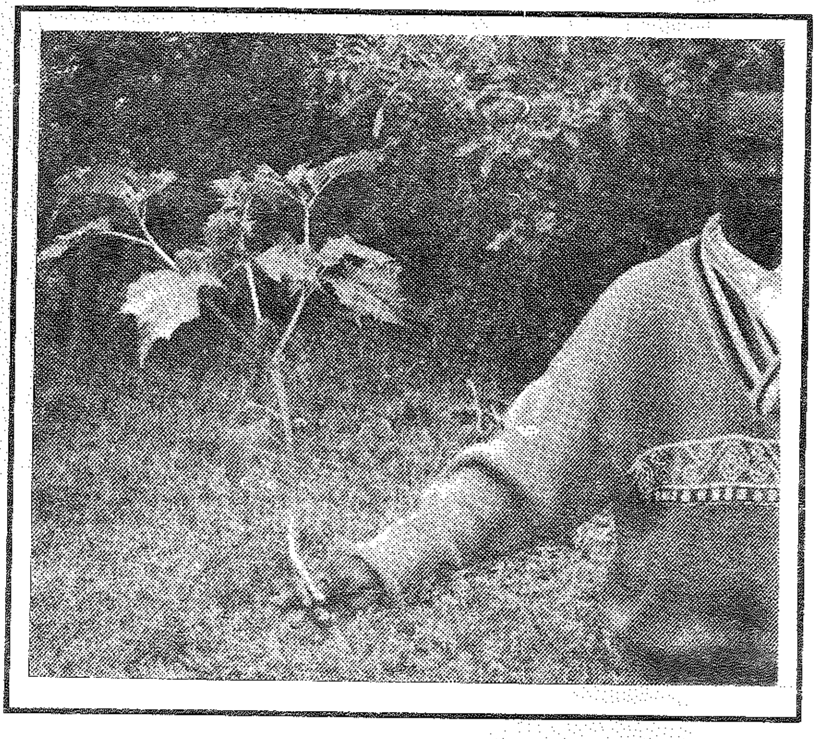
***Amaranthus sp.* (Pigweed).** *Amaranthus sp.* is annual plant growing in soils characterized by high organic matter content **(Figure 1-held by hand)**



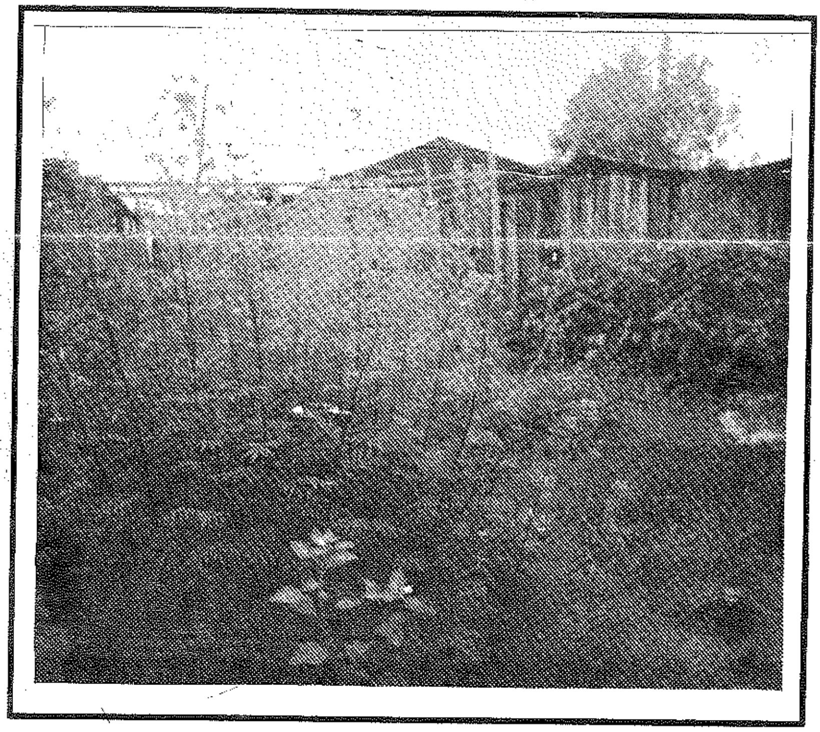
***Commelina Sp.* (Wandering Jew).** Wandering Jew is an annual trailing weed (Figure 2)



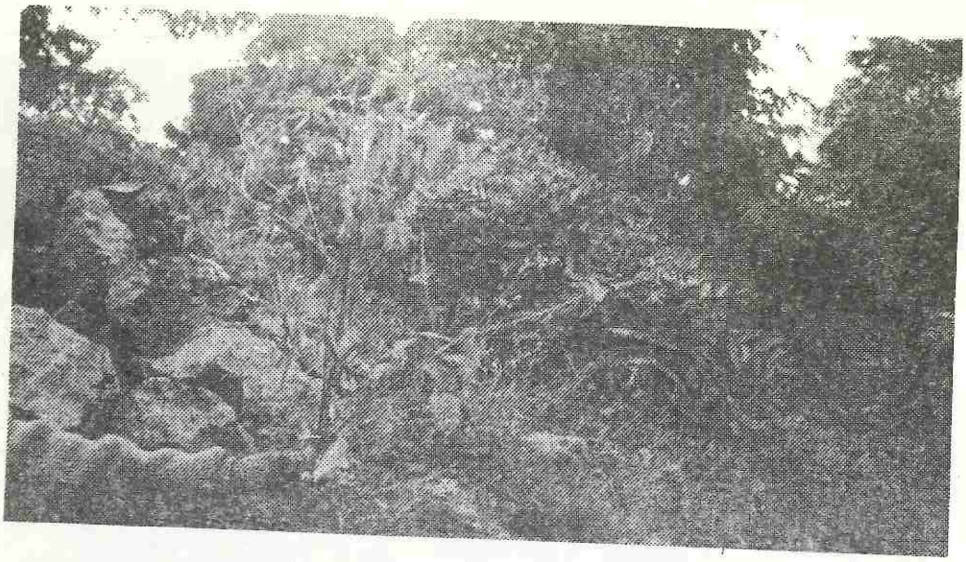
Datura stramonium (Thorn apple): An annual poisonous weed. It is perceived to sprout in soils rich in organic matter (Figure 3)



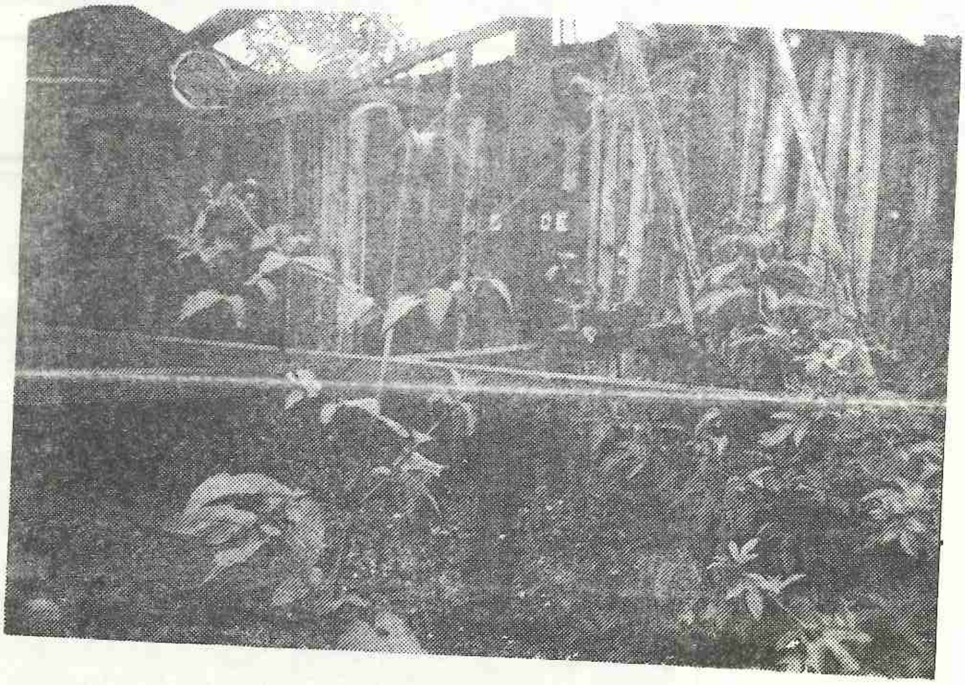
Tagetus minuta **(African marigold)** is an annual weed (Figure 4)



Galinsoga parviflora **(Gallant soldier; Macdonald eye)** is an annual weed **(Figure 5)**



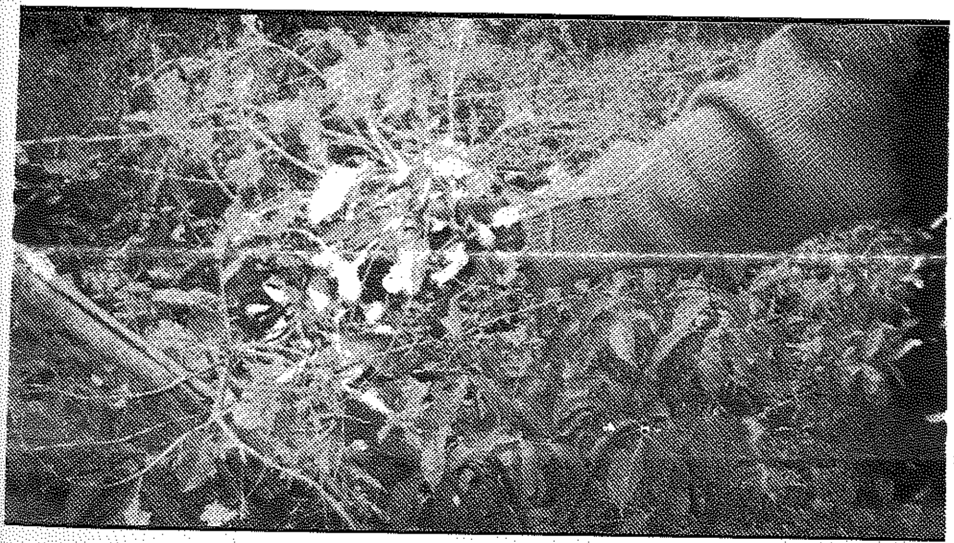
Bidens pilosa (Black jack) is an annual weed associated with "fertile" soils **(Figure 6)**



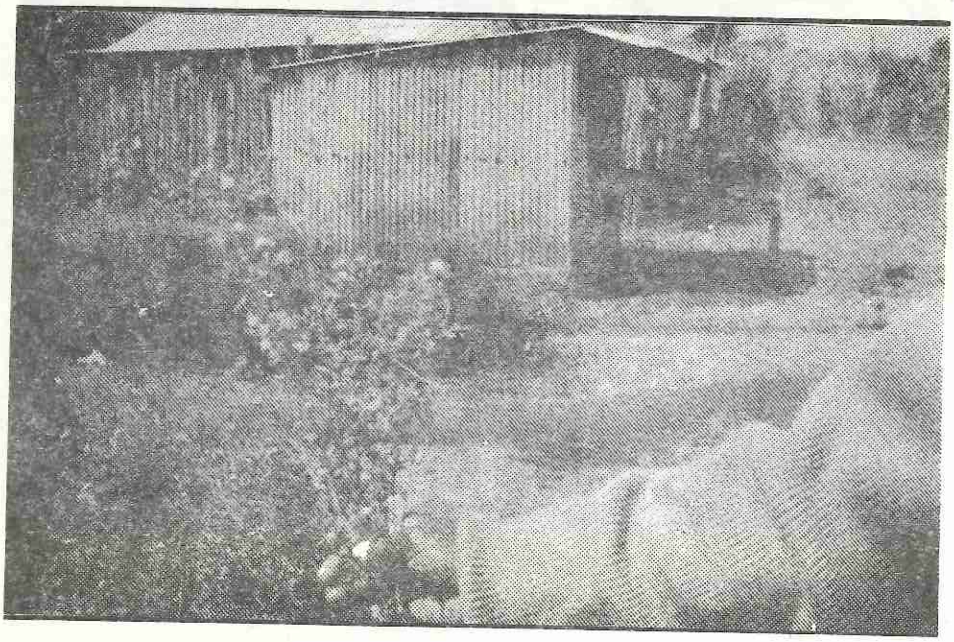
Nicandra physalodes (Chines lantern) is an annual weed **(Figure 7)**

Indicators of low fertility

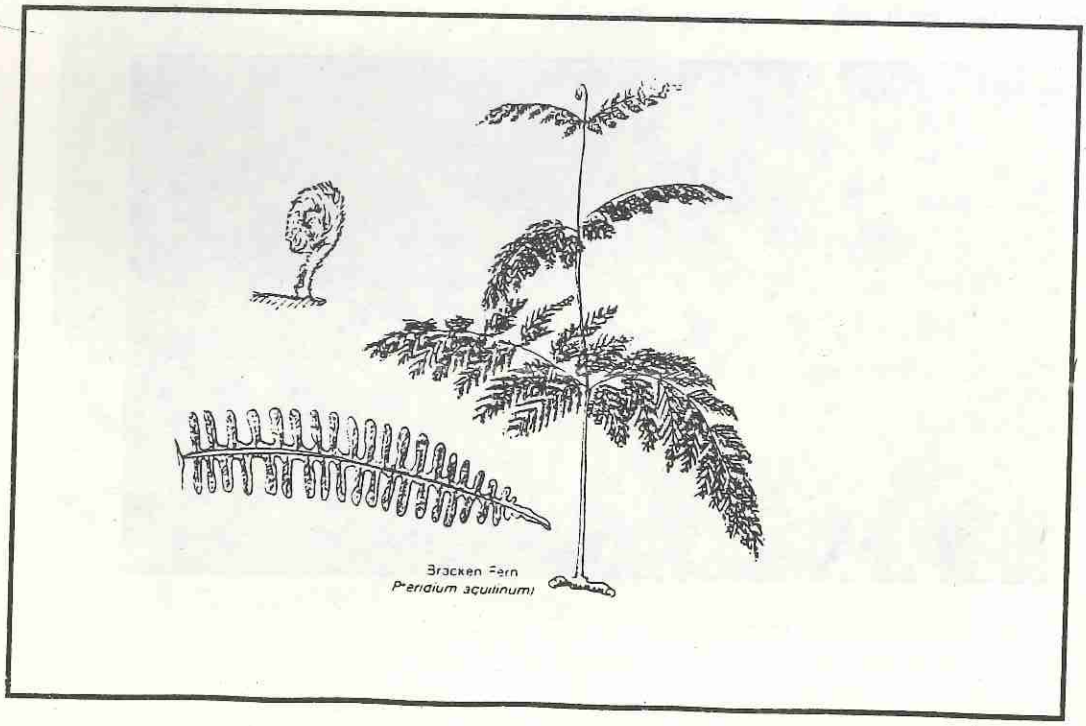
Oxygonium sinuatum (Double thorn) is perceived to grow in relatively "poor" soils (Figure 8-held by hand)



Alternathera pungens (Khaki weed, Figure 9-held by hand) is associated with poor soils



Pteridium aquilinum (Bracken fern) is associated with acidic soils **(Figure 10)**



Source: KIE, 1988

Striga hermontheca (Striga weed) is a parasitic annual plant associated with poor soils. Parasitizes cereals **(Figure 11).**

Source: Ayensu *et al.*, 1984.

(Poverty grass) is annual weed perceived to be growing in poor soils **(Figure 12)**

Nutrient deficiency symptoms

Plants rarely find nutrients in the correct amounts and proportions. The inadequate supply of nutrients from the soil to crops may result in symptoms of deficiencies expressed in different forms e.g. colour loss in plant leaves. These deficiency symptoms indicate great shortage of essential elements. In the guide, the roles and deficiency symptoms of three major nutrients (nitrogen, phosphorus and potassium) are presented.

Nitrogen

Roles:

- Plays part in protein formation
- Component of chlorophyll
- Promotes vegetative growth
- Increases the size of grains (cereals) and their protein content
- Regulates availability of phosphorus and potassium

Deficiency symptoms (Figure 13)

- Leaves turn pale-yellow to yellow
- Stunted growth; short roots
- In severe cases leaves fall off and flowering is reduced

Phosphorus

Roles:

- Promotes root development
- Essential for cell division
- Important in seed germination, flowering and seed and fruit formation
- Hastens ripening of fruits
- Strengthens plants and minimizes lodging in cereals
- Influences palatability of forage and vegetables

Deficiency symptoms (Figure 14)

- Purpling of leaves (increase in **anthocyanin**)
- Retarded development of actively metabolizing organs (e.g. roots)
- Stunted growth

Figure 13: Nitrogen deficiency symptoms

Figure 14: Phosphorus deficiency symptoms

Potassium

Roles:

- Strengthens plant structure/enhances plants ability to resist diseases
- Important in enhancing yields of root and tuber crops
- Neutralizes organic acids in plants
- Improves quality of fruits
- Enhances nitrate uptake
- Important in carbohydrate translocation

Deficiency symptoms

- Yellowing (chlorosis) along leaf margins
- May lead to leaf curling
- Scorching at leaf tips and leaf margins while the inside of leaves remain green
- Premature leaf fall, increased lodging

Quantitative indicators of soil fertility

Quantitative indicators are important in estimating the supply of nutrients to plants. These estimates are made through testing the levels of different parameters/nutrients in the soil. Information derived from such soil tests can be used to make decisions on soil fertility management. Such decisions and the resulting management strategies are aimed at ensuring that nutrients are supplied to plants in the right proportion and in adequate amounts.

Examples of quantitative indicators include:

- Soil organic carbon. Soil organic carbon influences soil physical and chemical properties. By measuring soil organic carbon an estimate of organic matter content can be made. Soil organic carbon has been used as an index of sustainable land management (Woomer *et al.*, 1994).
- Nutrient levels in the soil: Nitrogen, Phosphorus etc.
- Soil pH. Soil acidity influences availability of various nutrients from the soil to the plant e.g. phosphates are best available to crops at pH 6.5- pH 7.5. Each crop species require an optimal range of pH for its growth.

Table 1: Examples of optimal range of pH for different crops

Crop	Optimum pH
• Maize	5.5-7.0
• Sorghum	5.5-6.5
• Beans	5.5-6.0
• Cabbages	6.0-6.5
• Potatoes sp	4.5- 7.0
• Tea	4-5.5.5
• Banana	6.0-6.5
• Cotton	5.5-6.5
• Cassava	5.0-7.0
• Tomato	6.0-6.5
• Papaya	6.0-6.5

Source: Thomas *et al.*, 1997

Summary: Understanding concepts of "poor" and "fertile" soils

- A fertile soil is that which is able to supply adequate nutrients in the right proportions to crops. Inadequate and un-proportional supply of nutrients leads to poor crop performance
- Among others, characteristics of a fertile soil include good rooting depth, good aeration, good water holding capacity, presence of soil organisms, has adequate organic matter etc.
- Release and availability of nutrients from soil reserves is influenced by a number of factors including soil organisms
- There are qualitative and quantitative indicators of fertile and poor soils
- Qualitative indicators of soil fertility are diverse and include indicator plants and nutrient deficiency symptoms among others.
- Farmers' indicator plants for fertile and poor soils are diverse and are mainly drawn from farmers' experiences and local knowledge. While there are some indicator plants which may be universal, others may be different from region to region.
- Examples of indicator plants for fertile soils include *Amaranthus Sp., Commelina, Sp. Datura stromonium, Tagetus minuta, Galinsoga parviflora, Bidens pilosa, Sonchus oleraceous* etc.
- Indicators of low fertility includes *Oxygonium sinuatum, Digeteria sceslurum, Cyperus rotundus, Alternathera pungens, Pteridium aquilinum Hermonthica sp., Poverty grass* etc.
- Nutrient deficiency symptoms of Nitrogen include stunted growth and short roots, loss of leaf pigments (leaves turn pale yellow to yellow) and in severe cases leaves fall off and flowering gets reduced.
- Phosphorus deficiency symptoms include purpling of leaves, retarded development of actively metabolizing organs e.g. roots, stunted growth etc.
- Deficiency symptoms of potassium include yellowing along leaf margins, leaf curling, scorching at leaf tips and leaf margins while the inside of leaves remain green, lodging, premature leaf fall etc.
- Quantitative indicators of soil fertility are important in estimating the supply of nutrients to crops. They include soil carbon, nutrient levels (macro and micronutrients etc.), soil pH, soil nutrient balances etc.

Chapter 3

SOIL ORGANIC MATTER

What is Soil Organic Matter ?

Soil organic matter refers to the totality of organic materials ("matter") in the soil. It ranges from soil organisms (bacteria, fungi, algae, earthworms etc.), plant and animal tissues in their various stages of decomposition to the final end product of the decomposed organic materials, humus, **(Woomer *et al.*, 1994)**.

Role of Soil Organic Matter

a. ***Soil structure and the associated properties***

Improves soil structure and the associated soil properties: soil aeration, water holding capacity, root proliferation and water infiltration. Activities of soil organisms e.g. earthworms, ants, rodents etc. are important in improving the above soil properties. They aerate the soil by making burrows.

b. ***Soil erosion and regulation of other environmental factors***

Placement of organic materials on the soil surface reduces erosion and regulates soil temperature

c. ***Nutrient release, retention and storage***

- Organic matter stimulates the activities of soil organisms contributing to nutrient release (Nitrogen, Sulphur, Copper, Phosphorus, Boron etc.)
- Organic matter retains nutrients (Calcium, Phosphorus, Magnesium etc.) and absorbs water
  thus minimizes nutrient loss through leaching.
- Influences availability of phosphorus in acid soils
- Buffers soil pH by regulating the rate of chemical changes resulting from the additions of fertilizers and lime
- When dead, soil organisms decay and release nutrients

d. ***Smothering the effects of plant toxins***

Smothers plant toxins by reducing toxicities attibuted to:

- aluminium, manganese and iron concentrations
- continuous use of insecticides and fungicides

Options (practices and technologies) for Improving Soil Organic Matter

- Incorporation of litter and ***high quality*** crop residues into the soil.
- Using crop residues as animal bedding, composting them and incorporating the resulting compost into the soil.
- Mixing different types (qualities) of crop residues before incorporating them into the soil (maize stovers, green weeds, etc.).
- Incorporating compost made from different sources (livestock droppings, kitchen wastes residues from legumes etc.) into the soil.
- Green manuring: Growing crop for the purpose of incorporating it into the soil when it is still green and before flowering. Suitable green manure plants are those able to grow rapidly, highly vegetative, succulent, have high Nitrogen content or are easily decomposable.

Examples: Tithonia (*Tithonia diversifolia*), green succulent weeds, legume pruning, clover, sunhemp, green cereal residues etc.

- Incorporating into the soil, green materials or vegetation gathered from farm boundaries or from adjacent fields.
- Inclusion of nitrogen fixing deep rooted legumes in the cropping system

a. Hedge row intercropping

Hedgerow intercropping practice involves establishing rows of leguminous tree species in alternate arrangement with annual crops. Timely pruning from the legumes provide biomass that can be incorporated into the soil. Timely pruning also contributes towards minimizing competition for light, moisture and nutrients. The perennial legumes also improve soil fertility through biological nitrogen fixation, deep uptake of nutrients and improved soil structure.

Example of perennial legumes: *Sesbania sesban, Leucena leucocephala, Gliricidia sepium, Senna spectabilis* etc.

Figure 15: Hedgerow intercropping (Alley cropping) of *Sesbania Sp.*

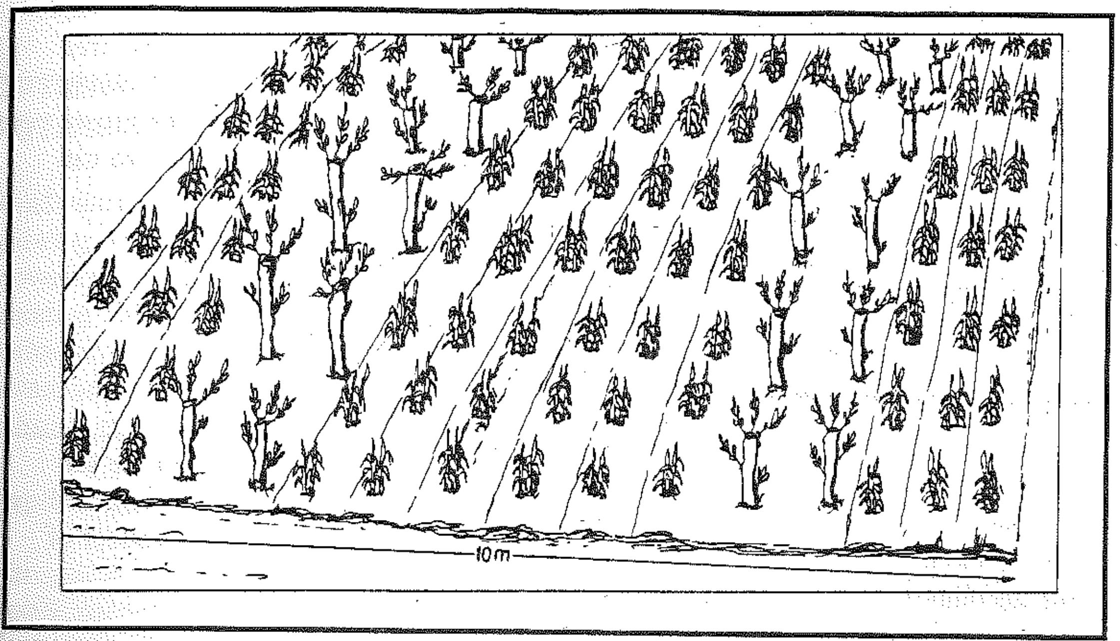


Figure 16 : *Tithonia diversifolia* **grown as a hedge**

b. Green manure grown as relay intercrops or in rotation

Relay intercropping involves growing a second crop when the first crop has either reached its reproductive stage or when it is still growing. This system involves growing tree legumes as annuals, **relay intercropped** e.g. between maize. At the end of the growing season, the tree biomass is incorporated into the soil. Leguminous trees can also be grown in rotation with other annual cops under **improved fallow system**. Cultivating maize can follow Two to three year fallow of pigeon peas.

Example of suitable legumes: *Crotelaria, sesbania sesban., and Mucuna pruriens (velvet beans), Dolichos lablab*, pigeon peas (*Cajanus cajan*) etc.

Summary: Soil organic matter

- Soil organic matter refers to the totality of organic materials ("matter") in the soil. It ranges from soil organisms (bacteria, fungi, alga, earthworms etc.), plant and animal tissues in their various stages of decomposition to the final end product of the decomposed organic materials (humus).
- Role of soil organic matter includes:
- Improvement of soil structure and the associated soil properties: soil aeration, water-holding capacity, root proliferation and water infiltration.
- Reduction of soil erosion and regulation of soil temperature when materials are placed on the soil surface
- Stimulating the activities of soil organisms contributing to nutrient release (Nitrogen, Sulphur, Copper, Phosphorus, Boron etc.)
- Retention of plant nutrients calcium, phosphorus, magnesium etc. and absorption of water.
- Influence on availability of soil phosphorus on acid soils
- Buffering soil pH by regulating the rate of chemical changes resulting from the additions of fertilizers and lime
- Smothering the effects of plant toxins
- Options for improving soil organic matter include incorporation of on-farm produced biomass into the soil, biomass transfer and litter fall on the soil surface.

Chapter 4

OPTIONS FOR IMPROVING SOIL NITROGEN, PHOSPHORUS AND POTASSIUM BALANCE

Availability and demand of the separate macro and micronutrients vary during the entire growing season, thus improvement of nutrient availability is usually along way to go. However, the challenge is first of all to trace and remove the major deficiencies i.e. mending the weakest links in the chain followed by fine tuning to address the other deficiency symptoms. The guide discusses options for improving nitrogen, phosphorus and potassium balances while recognizing the fact that the proposed options may not be exhaustive.

Improving Soil Available Nitrogen

Nitrogen is one of the most important nutrients needed for plant growth. However, it is a mobile nutrient in the soil and can be easily lost. Losses of nitrogen from the soil can be attributed to leaching, erosion, crop removals, burning and gaseous losses (in the form of ammonia, nitrogen gas or oxides of nitrogen). Improvement of soil available nitrogen requires the adoption and integration of technologies and practices that add nitrogen to the soil, recycle the available nitrogen and minimize nitrogen losses. Such strategies should also integrate practices for improving available soil phosphorus and potassium. Increasing nitrogen supply to crops depend a great deal on judicious and regular application of nitrogen inputs.

Technologies and practices

a. Use of nitrogen fixing legumes (woody trees and herbaceous cover crops) in the cropping system
   - Hedge row intercropping of woody legumes and annual crops.
   - Intercropping herbaceous cover crops with other crops.
     Examples: *Desmodium sp.* with nappier grass.
   - Short term fallow of legumes (e.g. *Sesbania sp.*) in rotation with cereal crops

b. Green manuring

c. Incorporating succulent crop residues, compost, animal manure and legume residues into the soil. Animal manure and compost should be covered or stored in pits to minimize loss of nitrogen through volatilization. Addition of straw or crop residue to manure also minimizes nitrogen losses.

d. Avoiding burning before ploughing. Burning of vegetation after clearance results in loss of much of the Nitrogen in the litter and plant biomass depending on fire intensity.

e. Application of natural forms of liquid feeds

Liquid feeds provide plants with additional nutrients during the crop-growing season. Natural liquid feed include "liquid manure" and "plant teas". The natural forms of feeds are applied around the base of the plant.

Liquid manure

Liquid manure is a top dressing product made from fermented fresh and culturally acceptable livestock droppings in water. It is a source of nitrogen for plants.

How to make liquid manure (Figure 17)

Materials needed

- Container e.g. drum (plastic or otherwise), pail etc.
- Water
- A mixture of fresh livestock droppings (droppings from poultry, rabbits, goats and sheep, cattle etc.)
- Wood ash
- Strong sack, gunny bag etc.
- Stirring rod

Steps in making liquid manure

⇒ Fill a gunny bag with 50 Kg of mixed livestock droppings (approximately ¾ full).
⇒ Tie the loose end of the bag with sisal twine to a rod as shown
⇒ Suspend the bag in a 200-litre drum
⇒ Fill the drum with clean water
⇒ Cover the drum
⇒ Stir the contents of the drum after every 3 days until the 15^{th} day by lifting the bag several times or rotating the rod suspending the bag
⇒ Wood ash can be added to the contents of the drum as soon as a strong smell is perceived to come from the mixture.
⇒ After sieving, the contents of the drum are diluted with water (1:2) before application

Plant tea

Plant tea is nitrogen rich product made from fermented succulent or leguminous plants in water.
Example of plants: *Tithonia diversifolia*, green succulent weeds etc.

Materials needed

- Container
- Water
- Wood ash
- Gunny bag or piece of cloth cover
- Stirring rod
- Succulent green plants, leguminous leaves

Steps (Figure 18)

- Fill a container half way with succulent plants, leaves from leguminous plants etc. chopped into small pieces
- Fill the container with water and cover
- Stir the contents of the container every after three days until the 15th day.
- Sieve to remove plant parts
- Dilute the remaining liquid with fresh water (1:2) before application

Figure 17: Making liquid manure

Figure 18: How to make plant tea

Source: Njoroge, 1994

Improving on Soil Available Phosphorus

Phosphorus is considered a major nutrient essential for crop performance. However, soil available phosphorus usually tends to be low thus conscious efforts to improve on soil phosphorus balance are usually a necessity. Improvement strategies should also include practices for improving available soil nitrogen. Losses of phosphorus are mainly through crop removals and erosion of topsoil.

Practices and technologies

- Incorporating *Tithonia diversifolia* into the soil. *Tithonia diversifolia* has high concentrations of phosphorus in its leaf biomass than most legumes used in agroforestry.

- Incorporating other sources of organic matter into the soil (on-farm and or off-farm produced). Organic cycling (involving the activities of soil organisms) transforms the unavailable forms of inorganic soil phosphorus into more available organic forms. Organic matter also improves on soil structure and facilitates root proliferation and thus uptake of available Phosphorus. It also stimulates the formation of fungus-plant root relations (mycorrhiza) which help in the capture of phosphate ions not normally available to crops.

Examples: Litter fall, green manure plants, crop residues, residues from leguminous tree pruning, compost, animal manure etc.).

- Amelioration of soil pH. Judicious and step-wise liming of highly acid soils increases soil pH and reduces level of phosphorus unavailability (fixation).

- Application of high reactive rock phosphates e.g. Minjingu rock phosphate which is effective in acid soils.

- Combined application of rock phosphate with organic inputs

    - Combining finely ground rock phosphate with compost

    - Combining finely ground rock phosphate with poultry manure or cattle manure prior to application in non-acid soils

    - Combining rock phosphate with *Tithonia diversifolia* (produced at farm boundaries or in adjacent farms)

- Adopting practices and technologies for minimizing loss of topsoil (soil and water conservation practices)

Improvement of Soil Available Potassium

Potassium is not normally lacking in most Kenyan soils. However, potassium can easily be lost through removal of harvested crop parts (leaves, roots, tubers etc.), loss of topsoil and leaching.

Practices and technologies

- Harvesting and recycling of livestock urine. The urine can be fermented and diluted before use (using similar strategies as that of making liquid manure)
- Covering manure heaps/compost to exclude exposure to rainfall
- Recycling of harvested crop products
- Improving soil organic matter content e.g. through application of manure, compost, litter etc. The associated improved cation exchange capacity helps in reducing potassium loss through leaching.

Summary: Technologies and Practices for improving soil Nitrogen, Phosphorus and Potassium balance

- Availability and demand of different plant nutrients vary during the entire growing season, thus the challenge is first of all to trace and remove the major deficiencies.

Soil nitrogen

- Major avenues for loss of soil nitrogen include soil erosion, crop removals, burning and gaseous losses (in the form of ammonia, nitrogen gas or oxides of nitrogen).
- Improvement of soil available nitrogen requires the adoption and integration of technologies and practices that add nitrogen to the soil, recycle the available nitrogen and minimize nitrogen losses.
- Strategies for improving available soil nitrogen should also integrate practices for improving available soil phosphorus and potassium.
- Examples of technologies and practices for improving soil nitrogen include:

a. Inclusion of nitrogen fixing legumes (woody trees and herbaceous cover crops) in the cropping system.
b. Green manuring.
c. Incorporation of organic matter into the soil
d. Avoiding burning before ploughing
e. Application of natural forms of liquid feeds: Liquid manure, plant tea

Soil phosphorus

- Soil available phosphorus tend to be low in most soils in East Africa, thus conscious efforts to improve on soil phosphorus balance are usually a necessity.
- Losses of phosphorus are mainly through crop removals and erosion of topsoil.
- Practices and technologies for improving on soil available phosphorus include biomass transfer, cycling processes and application of fertilizers e.g. rock phosphates
- Incorporating *Tithonia diversifolia* into the soil. *Tithonia diversifolia* has high concentrations of phosphorus in its leaf biomass than most legumes used in Agroforestry.
- Incorporating other sources of organic matter into the soil (on and off farm produced):

a. Organic cycling transforms the unavailable forms of inorganic soil phosphorus into more available organic forms.
b. Organic matter also improves on soil structure and facilitates root proliferation and thus uptake of available Phosphorus.
c. It also stimulates the formation of fungus-plant root relations (mycorrhiza) which help in the capture of phosphate ions not normally available to crops.
d. Judicious and step-wise liming of highly acid soils increases soil pH and reduces level of phosphorus unavailability (fixation).

Soil Potassium

- Potassium is not normally lacking in most Kenyan soils. However, potassium can easily be lost through removal of harvested crop parts (leaves, roots, tubers etc.), loss of topsoil and leaching.
- Practices and technologies for improving on soil potassium balance include:

a. Harvesting and recycling of livestock urine. The urine can be fermented and diluted before use (using similar strategies as that of making liquid manure)
b. Covering manure heaps/compost to exclude exposure to rainfall
c. Recycling of harvested crop products
d. Improving soil organic matter content. The associated improved cation exchange capacity helps in reducing potassium loss through leaching.

Chapter 5

ACCOMPANYING PRACTICES AND TECHNOLOGIES

The effectiveness of soil fertility management strategies in addressing food needs is to a great extent influenced by adoption of sound agronomic practices and technologies of soil and water conservation. This chapter exposes some of the technologies aimed at minimizing the loss of topsoil and soil moisture through soil erosion. Topsoil and litter layer avail a large proportion of plant nutrients to crops, thus their loss not only result in loss of soil nutrients, but also a deterioration of soil physical structure.

Cultural and Biological Measures for Conservation of Soil and Water

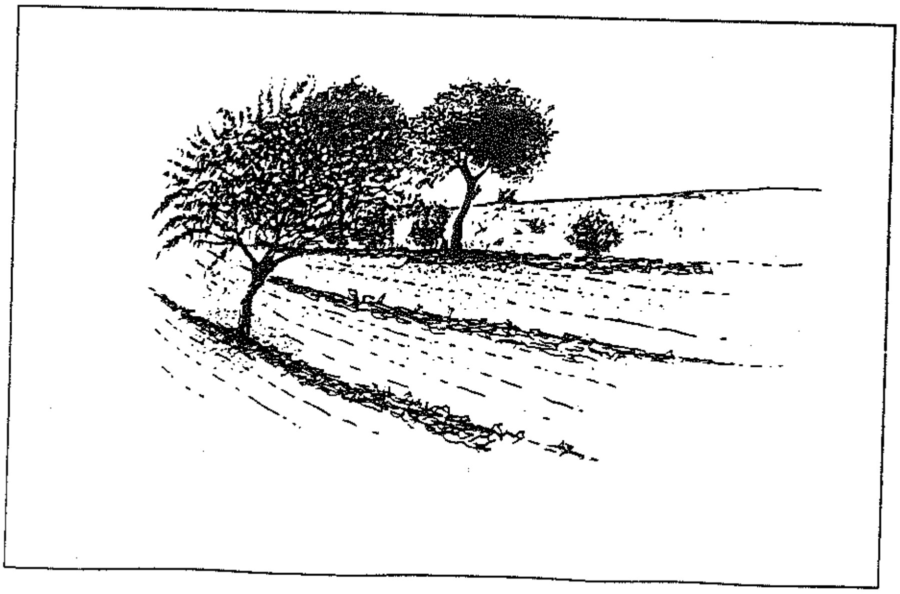
Mulching

Mulching is the placement of dead plant materials on soil surface or around plant stems. It protects soil surface from water and wind erosion, returns organic matter and nutrients to the soil, reduces surface sealing, regulates soil temperature, conserves moisture and suppresses weed growth.
Sources: Dry grass, dry leaves, straw etc.

Trash lines

Crop residues and plant remains are placed along the contour. Trash lines trap eroded soils, reduce speed of running water, facilitates water infiltration and decay to form organic matter.

Figure 19: Trash line along the contour



Incorporating Different Sources of Organic Matter into the Soil

The following are some methods of incorporating compost into the soil as a source of organic matter and for improving soil conditions:

Ex-situ compost application

Compost made in one site is transported to a different site/field where it is incorporated into the soil. It is important to incorporate compost into the soil rather than surface placement. This minimizes gaseous losses. Compost can be applied in planting hole, in furrows, mounds or ridges during planting.

Figure 20: Maize grown along the contours using compost

In-situ compost application

These methods involve compost preparation in the sites where it is being used. The prepared and planted compost is not transferred to new planting site.

Basket composting

Basket composting is a method of making compost in circular holes (0.6 m x 0.6 m x 0.6 m). Crops are planted around the hole. The technology conserves moisture, improves on soil conditions and can be gradually used to fertilize the whole farm when new baskets are made in different sites on the farm each season.

Figure 21: Basket compost with "spinach" planted along the outlines of the basket with a layer of dry grass as mulch for moisture conservation.

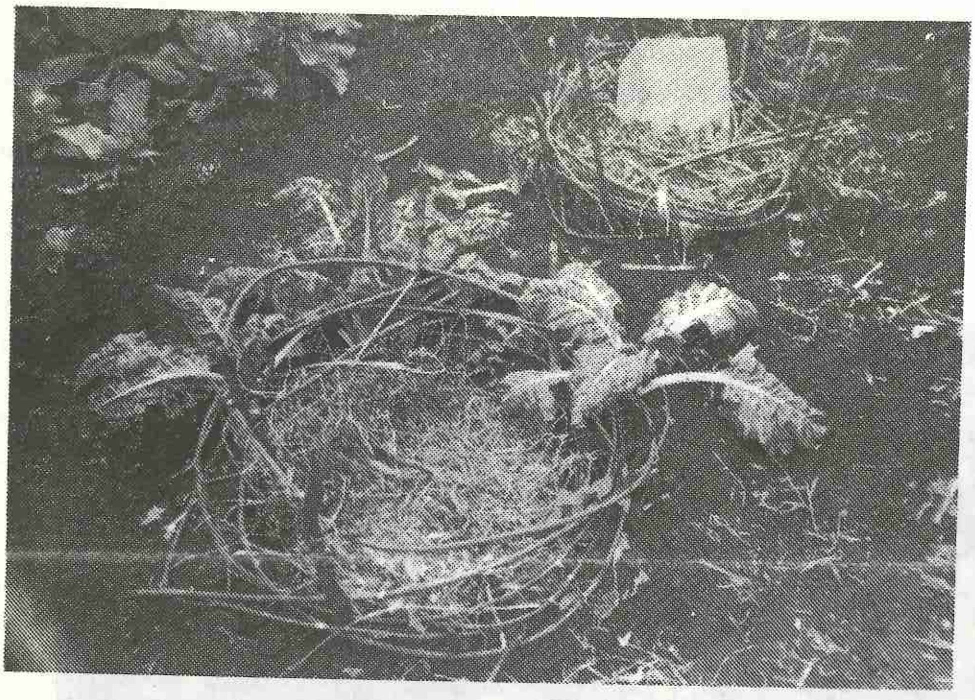
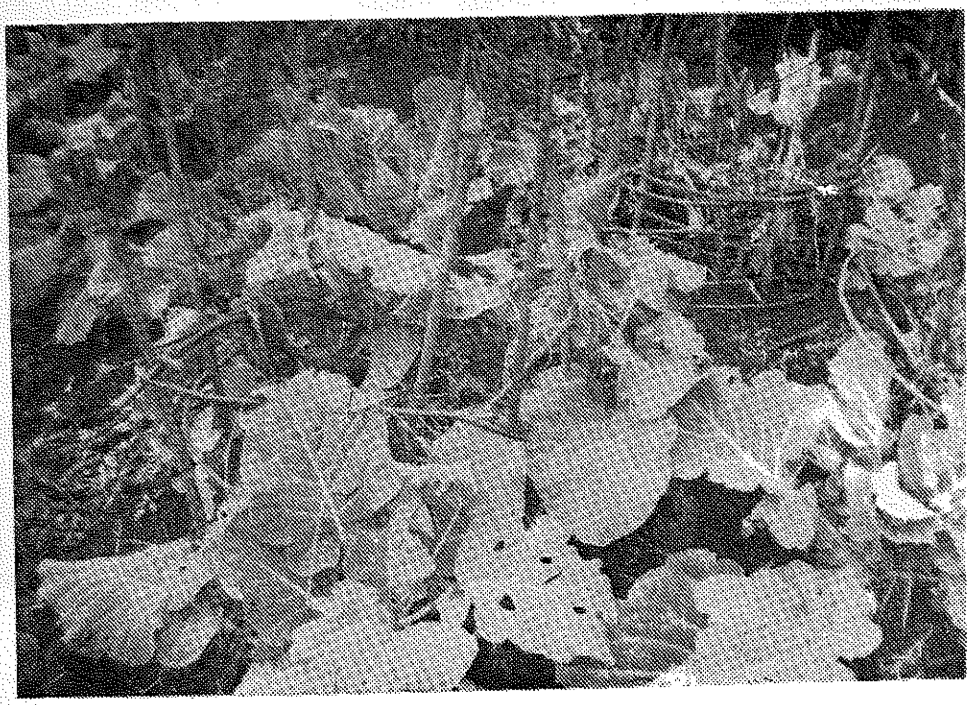


Figure 22: Basket composting with kales planted along the outlines of the basket with a layer of dry grass as mulch for moisture conservation



Trench compost

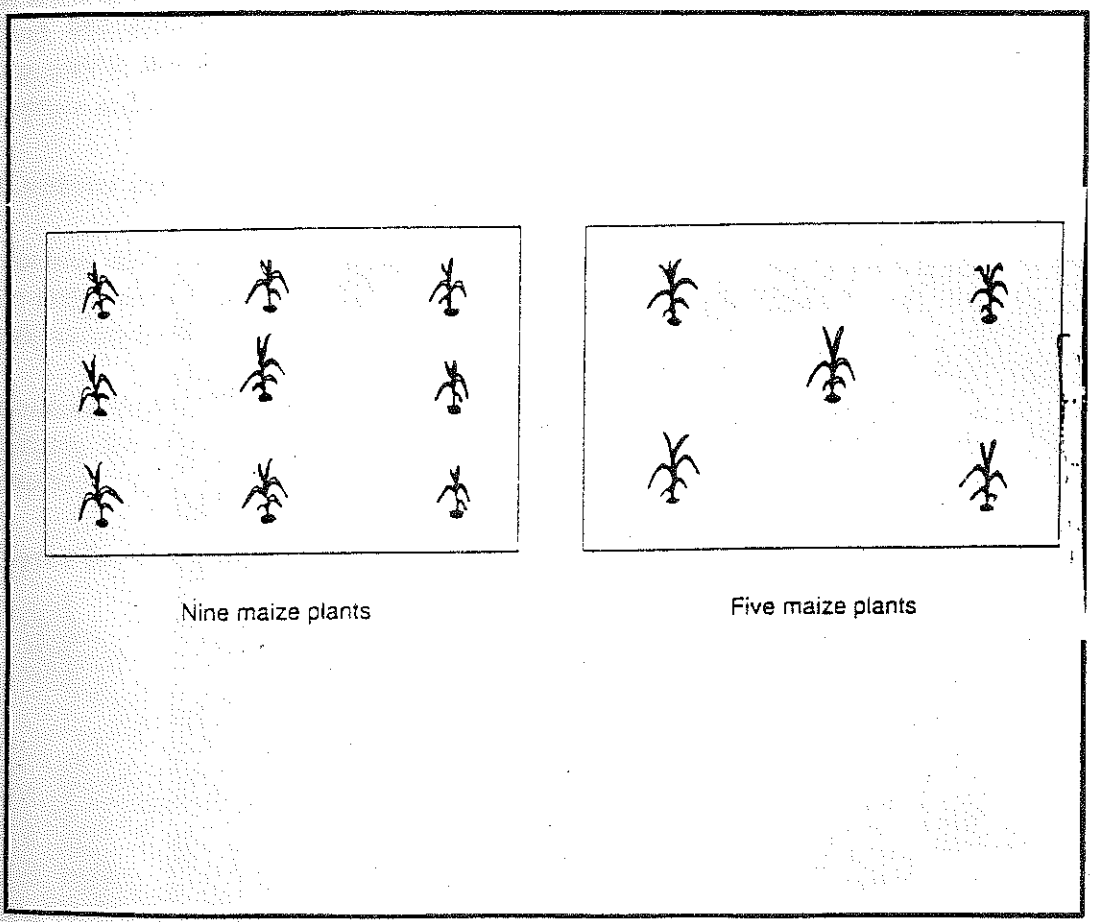
Compost is made by layering materials in a trench of 0.6m wide x 0.6 m deep and a convenient length. The excavated sub-soil is spread round the trench while the topsoil is used in the "layering" process and in covering the trench. Crops are planted round the trench. The technology is important for moisture conservation and for gradually fertilizing the whole farm as in basket composting. Vegetable crops and cereals e.g. maize are planted along the edges of the trench.

Figure 23: Kales planted along the edges of a trench compost

"5-9 maize" in one hole

The practice involves application of 1 "debe" (20-litre container) of ready-made compost into an excavated hole of 0.6 m x 0.6 m x 0.6 m. while the excavated sub-soil is spread around the outlines of the holes (to make a "basin"), the topsoil is mixed with compost before being returned to the hole. The hole is covered with mulch while planting of crop is done at the centre, at the corners and at the sides of the hole. The practice is important in moisture conservation and can be used to gradually fertilize the whole land when new such holes are made in different parts of the farm each season.

Figure 24: "5-9 maize" in one hole technique



Source: Njoroge, 1994; RSU/SIDA/Africa 2000 UNDP, 1997

Deep tillage

Deep tillage is important in soil and water conservation. It is important in soil moisture retention, water infiltration and soil aeration. Deep tillage can be done by use of a chisel plough or ripper, ox-drawn plough, chiseling or by digging deeper than "normal" using a fork "jembe". The latter is popular in smallholdings for vegetable cultivation. The following are examples of deep tillage practices under smallholdings focussed on vegetable production.

Double digging

Double digging is a tillage practice that combines the concept of deep tillage (60 cm deep), proper fertilization and availability of organic matter to improve soil chemical and biophysical characteristics. It aims at breaking the hard pan and optimizing crop production.

Figure 25: Kales and spinach planted on double beds

Mandala garden

Mandala gardens are rings of circular beds around a central hole, which are either deeply tilled or double dug. The circular beds are separated by "paths" or furrows which also acts as water distribution channels to "beds" further off from the central hole. The practice relies on deep tillage and proper fertilization using compost for improving soil chemical and biophysical conditions. It also acts as a water harvesting technique.

Crop rotation

It is the growing of different types of crops in a particular sequence on the same piece of land. Different types of crops can be grown. Inclusion of deep-rooted nitrogen fixing legumes in the rotation is important in improving soil nitrogen balance, sub-soil nitrate capture and improvement of soil organic matter through litter fall.

Contour cultivation

Contour cultivation is the carrying out of farming activities "across" the slope rather than up-and down the slope. Such practices may include ploughing, planting, weeding, ridging, strip cropping etc.

Contour ridging

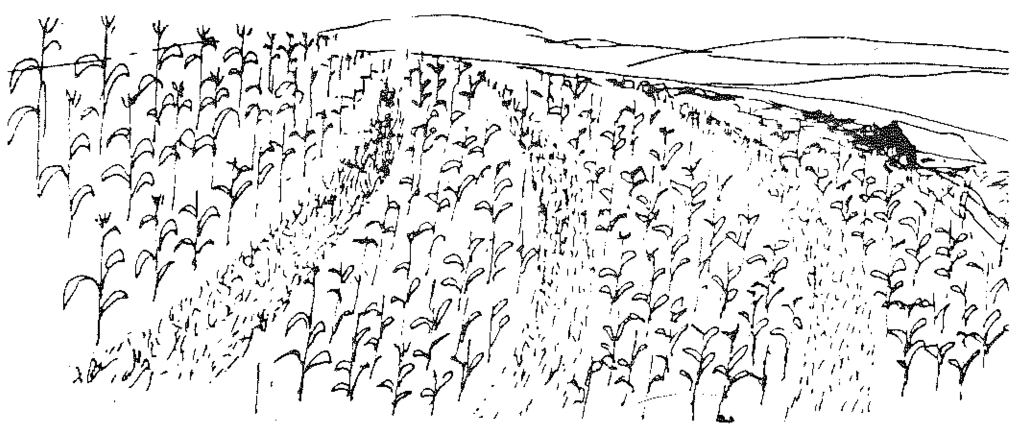
Ridging for potatoes is often done during weeding. Between the ridges are furrows trapping rain-water

Figure 26: Potatoes grown on contour ridges

Contour strip cropping

Planting alternate strips of crops along the contour in the same field. It is suitable for slopes less than 20 % and can be used to control water and wind erosion.

Figure 27: Strip cropping-crops planted between grass strips



Crop planted between grass strips

Source: INADES Formation Kenya, 1991.

Cropping practices

Judicious cropping practices help in reducing soil erosion, improvement of soil structure and fertility.

Cover cropping

Cover crops protect cultivated ground from high energy of raindrops, regulate soil temperature and add organic matter to the soil through leaf decomposition. Cover cropping reduces erosion caused by raindrops, splash and overland flow.

Figure 28: Broad-leafed cover crops plated with main crop, maize

Source: INADES Kenya, 1991.

Figure 29: Sweet potatoes used as cover crops

Companion planting

Growing two or more crops (benefiting from each other) simultaneously in the same field and in the same season.

Examples: Planting nitrogen fixing legumes and cereals together. Fast growing legumes such as beans provide soil cover early in the season before maize (cereal) develops adequate canopy to protect the soil from the impact of raindrops. Nitrogen fixing legumes make the Nitrogen available to other crops for use e.g. through leaf fall, root exudates etc.

Figure 30: Companion planting of maize and beans

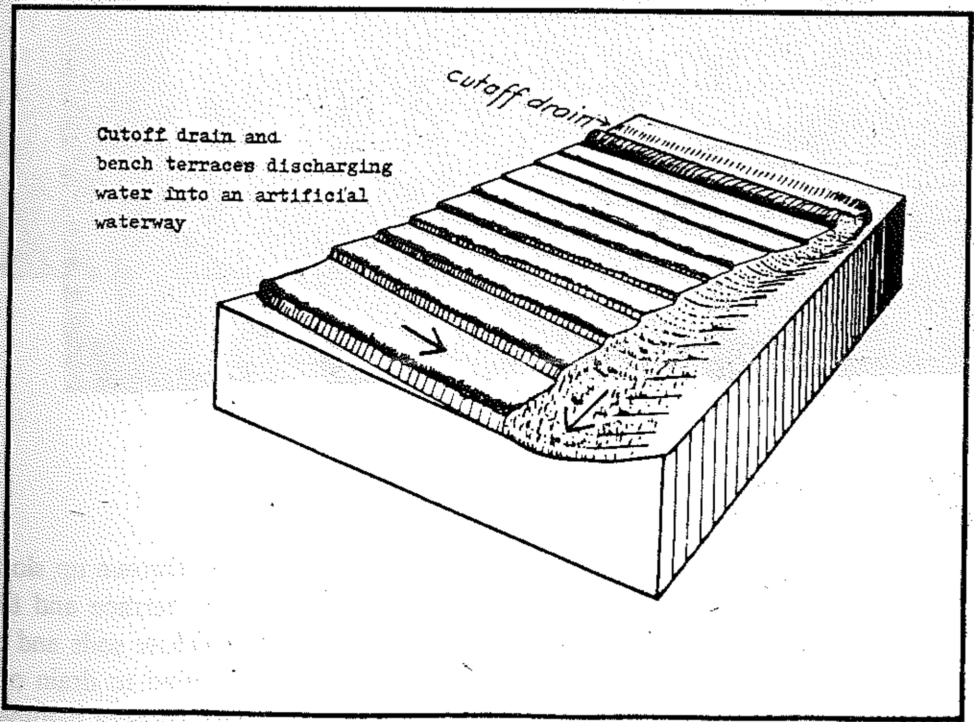
Physical Measures

Physical measures combined with good cultural and biological measures are important in controlling speed of running water and in reducing soil erosion. The guide presents examples of cut-off drains and terraces as physical measures of controlling soil erosion

Cut-off drain

Cut-off drain is a large graded channel made to arrest surface run-off water and lead the water to a waterway or non-erodable land. It is usually the top most soil conservation structure on a slope. The excavated soil is thrown on the lower side to form a ridge or embankment. It is applicable to steep slopes where there are large volumes of water flow. The channel is shaped like a trough (trapezoidal) with variable dimensions dependent upon the volume of water to be discharged. Grass, sweet potato, nappier grass etc. can be planted to stabilize the embankments. The upper edge of the terrace should be planted with grass to prevent inflow of sediment.

Figure 31: Cut-off drain and bench terraces discharging water into an artificial Waterway



Source: Wenner, 1981

Bench terraces

Bench terraces are level like steps constructed along the contour and separated by embankments. They are suited for deep stable soils and steep slopes of about 12% - 55%. In Kenya, they are popular in coffee areas. They reduce the length of the slope and facilitate water infiltration. They can be made from "fanya juu" terraces, excavated or developed from grass strips. The embankments can be stabilized using grasses, closely spaced nitrogen fixing legumes, sweet potatoes etc.

Figure 32: Bench terraces-terrace embankments stabilized with nappier grass

"Fanya juu" (converse terrace)

"Fanya juu" is a terrace of 0.6 m deep x 0.6 m wide with excavated soil thrown up slope to form an embankment. A space of 15 cm-30 cm is left between the terrace and the embankment to prevent soil sliding into the trench. It is suitable for shallow soils and in slopes less than 20 %. The terrace can be level (to retain water) or graded to drain out excess water. Terrace embankment can be stabilized using grass, closely planted legumes etc. Holes dug inside the terraces (micro-catchment) can be used to plant fruit trees e.g. bananas.

Figure 33: "Fanya juu" terrace with banana planted inside the terrace. Terrace embankments stabilized with nappier grass

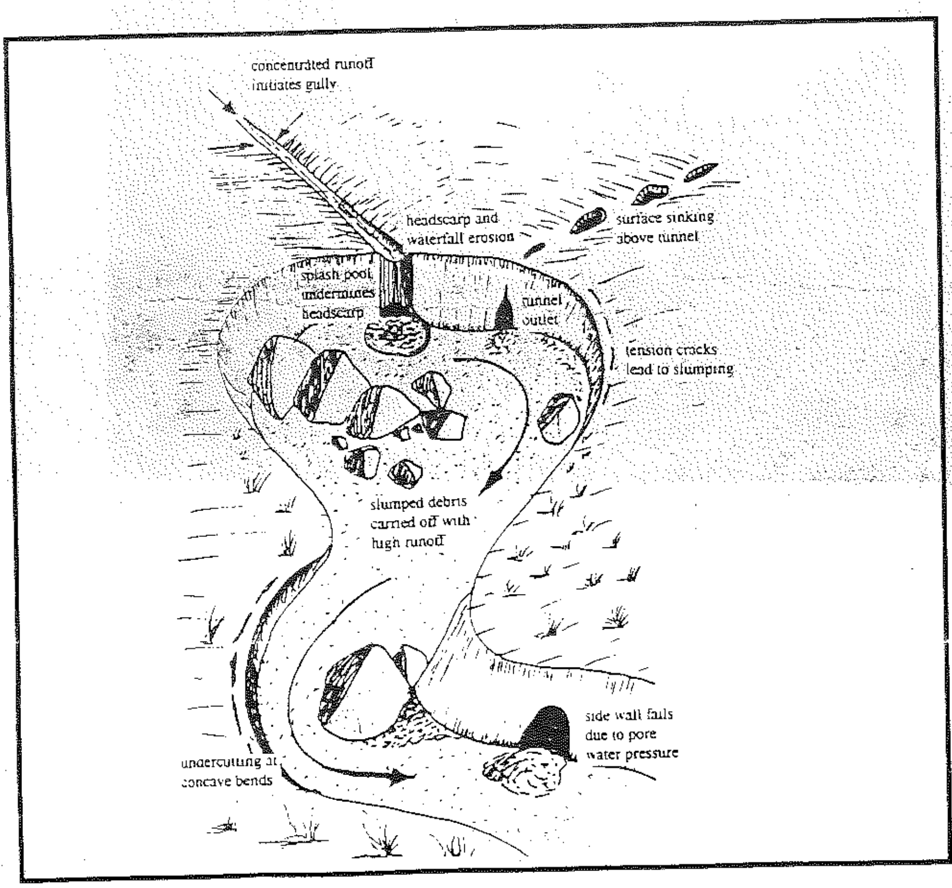
Gullies

Gullies develop when mild forms of erosion are not controlled. It is common in eroded soils where rills deepen to form gullies.

Preventive measures

e. Making diversion ditches
f. Planting trees along the contour to prevent sides of the valley from widening
g. Use of solid check dams to reduce water velocity in steep and narrow valleys
h. Piling straw and brush wood to prevent waterfall erosion at gully heads

Figure 34: Gully



Source: Thomas, 1997

Summary: Accompanying practices and technologies

- The effectiveness of soil fertility management practices and technologies in enhancing food production is greatly influenced by accompanying practices and technologies.
- Accompanying practices and technologies include sound agronomic practices and technologies of soil and water conservation
- The loss of topsoil and litter layer through soil erosion leads to loss of plant nutrients and a deterioration of soil physical structure.
- Practices of soil and water conservation can be divided into three categories: cultural measures and biological measures (Agronomic practices) and physical measures.
- Physical measures combined with good cultural and biological measures are important in controlling speed of running water and in reducing soil erosion
- Examples of cultural and biological measures include:

a. Mulching
b. Trash lines
c. Incorporation of different sources of organic matter into the soil e.g. compost
d. Deep tillage practices e.g. double digging, Mandala gardens
e. Crop rotation
f. Contour cultivation practices e.g. contour ploughing, planting, ridging, strip cropping etc.
g. Cropping practices e.g. alley cropping, cover cropping, companion planting etc.

- Physical measures for soil and water conservation include cut-off drains, Bench terraces, "fanya" juu terraces etc.

Chapter 6

GLOSSARY OF TERMS USED INN THE GUIDE

Anthocianin: A pigment giving plants a purple green colouration

Basket composting: A method of preparing compost in circular holes of 0.6-m diameter and 0.6 m deep. Crops are planted round the hole to make use of nutrients from the circular holes

Bench terrace: Level like steps constructed along the contour and separated by embankments (risers) to control soil and water erosion.

CEC (Cation Exchange capacity): The total number of negative charges (cation adsorption sites) per unit weight of soil

Chlorosis: Loss of plant pigments (chlorophyll) e.g. in cases of extreme shortage of essential Nutrients

Companion planting: Practice of growing two or more crops, mutually benefiting from each other, simultaneously in the same field and in the same season.

Composting: Bio-degradation of organic materials under aerobic conditions to form humus end product

Contour cultivation: Entails practicing farming activities across the contour rather than up-and- down the slope

Crop rotation: The practice of growing crops with different demands (e.g. for soil nutrients) in a particular sequence (each season a different crop) on the same piece of land.

Cover cropping: Practice of growing crops that cover and protect the soil from high-energy raindrops and overland flow

Cut-off drains: Large graded channel made to arrest surface run-off water and lead the water into a waterway.

Double digging: A deep tillage (60cm deep) practice aimed at breaking down the hard pan and creating a deep layer of lose fertile soil.

"Fanya juu" terrace (Converse terrace): A terrace of 0.6m deep x 0.6m wide with excavated soil thrown up slope to form an embankment

Five to nine maize in a hole: The practice of planting five to nine maize seeds in a hole of 0.6m cube filled with one "debe" (20-litre tin) of compost

Green manuring: The practice of incorporating young and green plants into the soil for decomposition and addition of organic matter before planting of crops

Hedge row intercropping: Involves establishing rows of trees and or shrubs (e.g. leguminous plants such as *Sesbania Sp.*, shrubs such as *Tithonia diversifolia*) in alternate arrangement with annual crops.

Leaching: The loss of dissolved nutrients in water draining below maximum plant rooting depth

Liquid manure: A top dressing product prepared from fermented ethically acceptable fresh livestock droppings in water.

Mandala garden: Comprises rings of circular deep dug or double dug beds prepared around a central hole and is aimed at creating a deep layer of loose fertile soil and harvesting of water for crop production.

Macronutrients (Primary nutrients): Are elements required in large amounts for plant growth e.g. Nitrogen, Phosphorus etc.

Micronutrients (Trace, Minor, Rare or secondary nutrients): Elements required for plant growth in small quantities e.g. Copper, Zinc, Iron etc.

Mulching: Placement of materials on soil surface or around plant stems to protect the soil surface from erosion, return organic matter and nutrients to the soil and to trap eroded soils.

Mycorrhiza: A group of fungi living in the soil that penetrates the roots of plants forming a bridge between the sap flow in the plant and decomposing organic material. The symbiotic relationship facilitates the absorption of nutrients.

Nutrient: Substance absorbed by living organism to help it grow.

Organic Matter: The "totality" of organic materials in the soil ranging from soil organisms, plant and animal tissues in their various stages of decomposition to the final end product of the decomposed organic materials, humus.

Plant tea: Top dressing product prepared from succulent plants fermented in water.

Relay intrercropping: Practice of growing a second crop in the same piece of land when the first crop has either reached its reproductive stage or when it is still growing.

Soil erosion: A physical process resulting in detaching and transporting soil materials from one location to another.

Soil fertility: The quality of a soil that enables it to supply nutrients in adequate amounts and in the correct proportion to a crop

Soil pH: pH stands for potential of hydrogen and is a measure of acidity or alkalinity of the soil solution. Soil pH influences availability of nutrients from the soil to the plant.

Soil structure: The arrangement of soil aggregates (peds). Such an arrangement influences air and water penetration into the soil.

Sustainable soil management: Manipulation or management of soil physical, chemical and biological properties to enhance soil fertility and productivity.

Tithonia diversifolia: A herbaceous plant, native of Mexico and found at middle elevations throughout tropical Africa.

Trash lines: Plant residues or trash placed in lines along the contours to slow surface run-off and trap eroded soils

Trench compost: An in situ compost preparation method in a trench of 0.6 m wide x 0.6 m deep by a convenient length. Crops are planted around the trench.

Chapter 7

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KENYA INSTITUTE OF ORGANIC FARMING (KIOF)

The vision of Kenya Institute of Organic Farming (KIOF) is to achieve environmentally conscious and socially just communities of men and women empowered with knowledge and skills of organic farming for sustainable livelihood in the rural areas. Thus in its mission statement, KIOF believes in food security as a vital ingredient for the self-determination of resource poor rural communities. To address this concern KIOF is committed to the promotion of organic farming as an environmentally friendly approach to sustainable food production. We do this through training of small-scale farmers using participatory approaches and special emphasis on sensitization of our partners, collaborators and friends.

Organic farming refers to a system of agricultural production, which promote provision of healthy food and protection of the environment, among other things. It relies on laws of nature to enhance production cycles and induces sustainability by reducing the use of external inputs.

Central to organic farming, and indeed any production system, is soil fertility management. Soil fertility decline has been mentioned as one indicator of soil degradation and as a major constraint to farming in many countries. Plants rarely find nutrients in the correct amounts and proportions. Addressing this situation not only calls for management of the widest variety of possible sources of fertility in the most efficient way, but also the adoption of practical technologies applicable to farmers under specific and diverse settings while protecting the environment. The guide presents practices and technologies of soil fertility management based on the use of locally available resources, indigenous technical knowledge and modern scientific concepts.

This guide has been developed as a training and extension tool to assist extension workers and various stakeholders to initiate a debate on soil fertility management. It encourages those concerned to look for options addressing the emerging concerns. It further aims at contributing to soil fertility management by giving insight to some of the technologies of soil fertility management applicable to small-scale farmers under diverse settings.