



THE KENYA CEREAL ENHANCEMENT PROGRAMME (KCEP)

ADAPTATION AND DISSEMINATION OF AVAILABLE TECHNOLOGIES FOR SMALLHOLDER ADOPTION



KALRO-KCEP SOIL FERTILITY MANAGEMENT TRAINING AND EXTENSION MANUAL

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Table of Contents

Acknowledgements.....	iii
1 Introduction to soils and its composition	1
1.1 What is soil?.....	1
1.2 Soil properties.....	1
1.3 Soil physical properties.....	1
1.3.1 Soil texture	1
1.3.2 Soil structure, Bulk density and Porosity	1
1.4 Soil Chemical properties	2
1.4.1 Soil reaction (pH).....	2
1.4.2 Cation exchange capacity.....	2
1.4.3 Organic matter.....	2
1.4.4 Soil nitrogen.....	2
1.5 Biological properties	3
2 Soil sampling and basic soil parameter measurements	3
2.1 What to consider when undertaking soil sampling.....	3
2.2 Frequency of soil sampling and number of samples	3
2.3 Soil analysis reports	4
3 Local soil fertility indicators	4
4 Plant nutrients and their roles on crop production	5
5 Important nutrients sources.....	8
5.1	8
5.2 Organic sources (organic matter).....	8
5.2.1 Characteristics and benefits of organic manure	8
5.3 In-organic sources.....	8
5.3.1 Characteristics of fertilizers	8
5.3.2.....	9
5.3.3 Classification of inorganic fertilizer products.....	9
5.3.4 Calculating fertilizer requirement	9
6 Soil fertility degradation and amelioration.....	10
6.1 Nutrient mining.....	11
6.2 Soil acidity.....	11
6.3 Soil compaction	11
6.4 Soil erosion and conservation practices	11
6.5 Leaching.....	11
7 Take Home Messages.....	11
8 Further reading.....	12

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Overview

The purpose of this module is to familiarize participants on the importance of soil management and recognition that healthy and fertile soils are essential for crop value chains.

Training Objectives

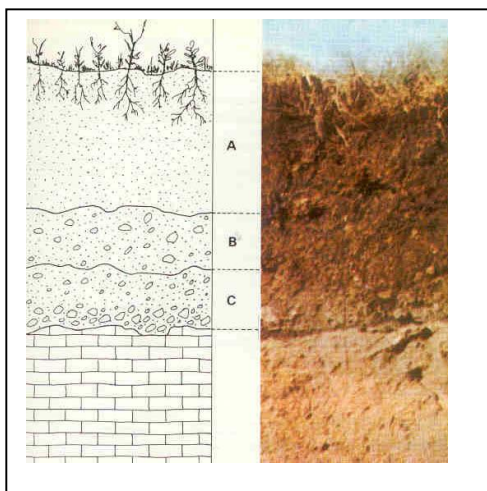
1. To understand the value and importance of maintaining healthy soils
2. To impart knowledge and skills on sustainable management of agricultural soils.
3. To package technologies for land reclamation and rehabilitation of degraded and contaminated soils.

1 Introduction to soils and its composition

1.1 What is soil?

To a farmer: soil provides the medium where plants grow.

To a soil scientist: soil is unconsolidated mineral or organic material characterized by horizons/layers. Also composed of water and air



1.2 Soil properties

Soil is composed of mineral particles, weathering products of the parent material, and organic matter, (e.g. residues from plants and animals), air and soil water. The solid particles are categorized size into: gravel and stones (>2 mm in diameter), sand (2.0 to 0.02 mm), silt (0.02 to 0.002 mm) and clay (< 0.002 mm). Soil properties are dependent on the relative composition and arrangement of soil particles.

1.3 Soil physical properties

1.3.1 Soil texture

Soil texture is the relative proportions of sand, silt and clay contained in a soil. Soils are described as sands, sandy loams, loams, clay loams, clays depending on their texture.

Importance to agriculture

Sandy soil has good workability and drainage but poor water holding capacity and nutrients retention. Clay soil is difficult to work with and prone to drainage problems. Loams and silts are good soils for cultivation. Have good drainage, easy to work with and has higher nutrients retention capacity.

1.3.2 Soil structure, Bulk density and Porosity

Soil structure refers to the arrangement of the sand, silt and clay particles into aggregates. Bulk density is an indication of soil compactness. Porosity is the ratio of the volume of the pores to the total soil volume and is inversely related to bulk density.

Importance to agriculture

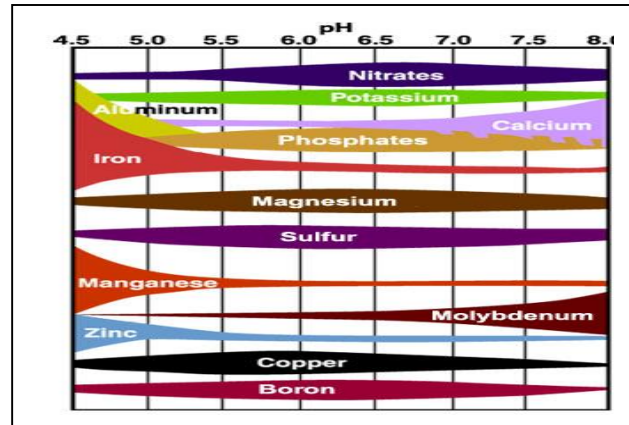
Structure, bulk density and porosity soil ability to retain water and nutrients. They influence drainage and root growth. Structural stability is the soil's ability to maintain its structural form despite the application of stresses due to tillage, machinery or raindrop impact. A well-structured

moist soil contains about 50 percent of solid material by volume and 25 percent each of air and water.

1.4 Soil Chemical properties

1.4.1 Soil reaction (pH)

Soil pH is a measure of acidity or alkalinity of a soil. The pH for acidic soil is below 5.5 while alkaline soils are above 7.5. A pH range between 6.5- 7 indicates that the soil is neutral and it is within this range that most plant nutrients are available for most of the crops. Soil organisms are hindered by high acidity. Most agricultural crops do best with mineral soils of pH of between 5.5-7.5.



Effect of Soil pH on soil nutrient availability

1.4.2 Cation exchange capacity

Cation-exchange capacity (CEC) is the maximum quantity of total cations that a soil is capable of holding, at a given pH value, available for exchange with the soil solution.

Importance to agriculture

CEC is therefore used as a measure of fertility and nutrient retention capacity. In general, the higher OM and clay content, the higher the CEC. Sandy (coarse) soils usually have a low CEC while clay soil has higher CEC

1.4.3 Organic matter

Organic matter (SOM) is plant and animal wastes and microorganisms at various phases of decomposition.

Importance to agriculture

SOM increases the CEC and the water-holding capacity and it contributes to the structural stability of clay soils by helping to bind particles into aggregates. It prevents nutrient leaching and produces organic acids that make minerals available to plants. It also buffers soil from strong changes in pH.

1.4.4 Soil nitrogen

Nitrogen is one of the most important elements obtained by plants from the soil. Nitrogen is available soil as either the cation ammonium, NH_4^+ , or the anion nitrate, NO_3^- .

1.5 Biological properties

Soil contains a wide range of soil organisms (fauna and flora). These organisms include micro-organisms (e.g. bacteria, fungi, protozoa and nematodes) and meso-fauna (e.g. acari and springtails), as well macro-fauna (e.g. earthworms and termites).

Importance to agriculture

Through their activities in the soil, the organisms decompose organic matter to give humus, aggregate soil particles to give a better structure, enhance soil carbon sequestration and nutrient recycling, produce hormones that help plants grow. Hence soil organisms are important in maintaining soil fertility and good crop production.

2 Soil sampling and basic soil parameter measurements

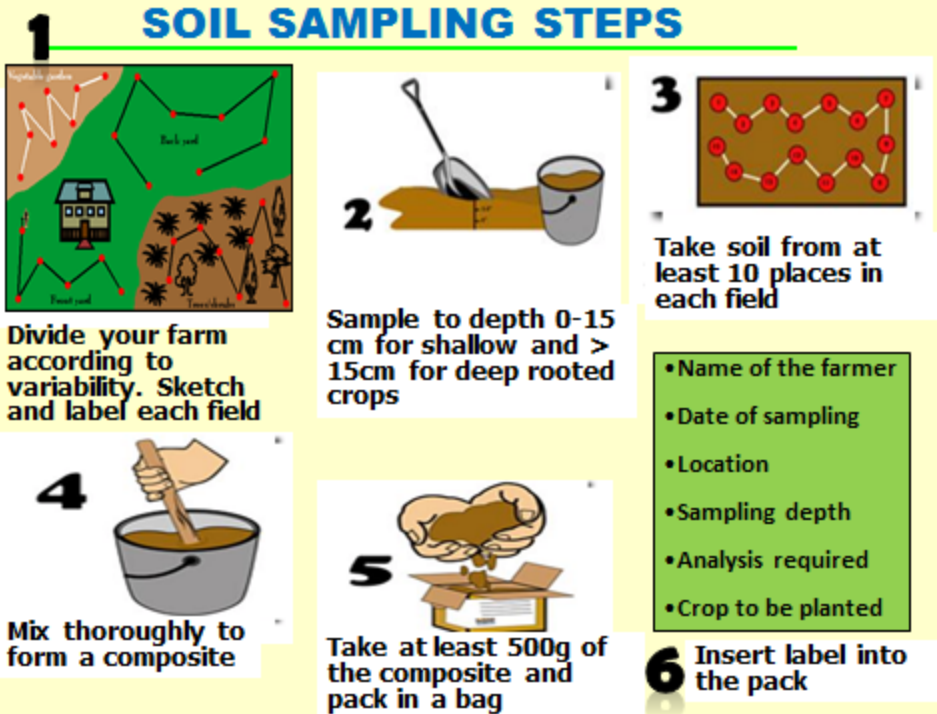
2.1 What to consider when undertaking soil sampling

Identify soil fertility variability. This is associated with;

- Topography, soil types, Soil color
- Land degradation intensities,
- Sharp physical discontinuities (e.g. rocky outcrops),
- Land-use history or distance from the homestead and livestock facilities.

2.2 Frequency of soil sampling and number of samples

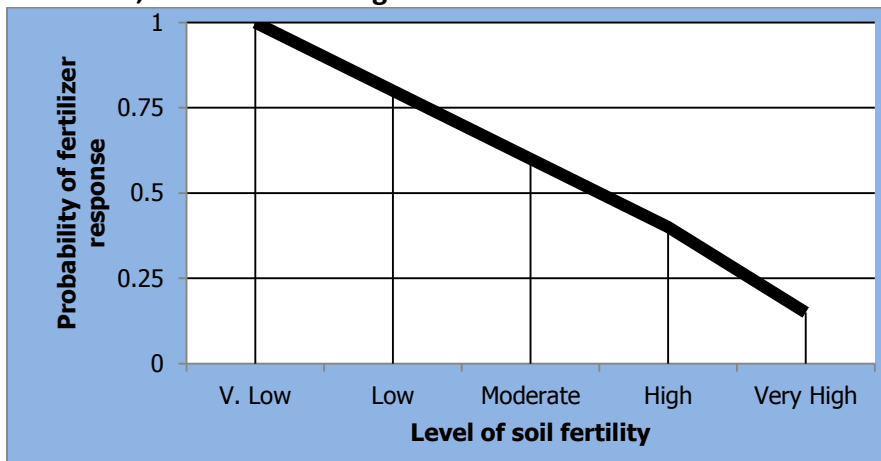
- New land- done yearly for first few years until you understand the soil
- Cultivated land- Every 2-3 years, unless concern for environmental problems
- Sample at least one month before onset of rains to provide enough time for analysis/amendments
- Number of samples— one sample per 5 ha (12.5 acre) if land uniform, otherwise the number of samples should be determined by land variability.



2.3 Soil analysis reports

- When the soil is analyzed in a credible laboratory, soil analysis report is always provided
- Soil test reports contain values that indicate the nutrient levels in the soil. A summary of these levels implies in terms of nutrients availability (low moderate and high fertility). A soil fertility replenishment recommendation is given based on the soil analysis report and the intended crop to be grown.

What low, moderate and high means



3 Local soil fertility indicators

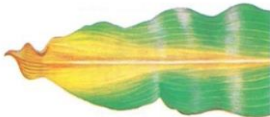




Local indicators for a fertile soil include: farmers use indigenous knowledge to judge a poor versus a fertile soil. Common local indicators include:

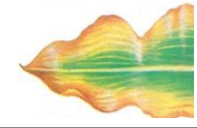


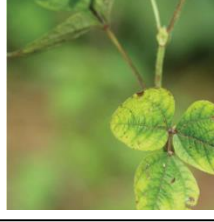


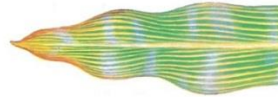


- Structure – a soil with big clods indicates a fertile soil


- Weed species associated with either a poor or a fertile soil e.g. the grassy weed called poverty grass (*Rhynchosyris repens*) occurs in very infertile soils
- Dominance of certain weed flora (e.g. *Commelina benghalensis*, *Bidens pilosa*, *Galinsoga parviflora*, *Commelina diffusa* and *Amaranthus* spp.) imply high fertility
- Dominance of soil fauna (e.g. earthworms) also imply high fertility

4 Plant nutrients and their roles on crop production

Nutrients have important functions in plant growth. Nutrient deficiencies in crops result in poor crop growth. Table 1 shows the function of plant nutrients and deficiency symptoms

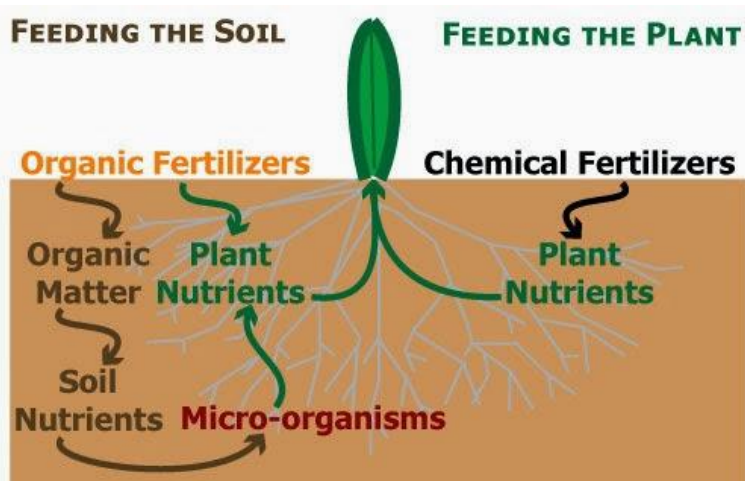
Table 1. Functions of nutrients in plant growth and deficiency symptoms		
Nutrients	Functions and deficiencies	Deficiency symptoms
<i>Major Nutrients</i>		
Nitrogen	<p>Function</p> <ul style="list-style-type: none"> - formation of chlorophyll - Vegetative growth of the plants. - Proteins synthesis. <p>Deficiency symptoms</p> <p>Stunted plants</p> <ul style="list-style-type: none"> - Yellow discoloration of leaves from tip backward (tip chlorosis, older leaves brown). 	 <p>Maize</p>  <p>Millet</p>  <p>Sorghum</p>  <p>Beans</p>  <p>Green gram</p>
		<p>Phosphorus</p> <p>Function</p> <ul style="list-style-type: none"> - Development of the root system. - Grain formation and ripening <p>Deficiency symptoms</p> <ul style="list-style-type: none"> - Stunted growth and purpling of leaves/stem from tip backward on the edges - Plants slow to ripen, remaining green. - Fruits may be misshapen, grain is poorly filled

<p>Potassium</p>	<p>Function</p> <ul style="list-style-type: none"> - Tolerance to moisture stress. -Improves the quality of fruits, vegetables, and grains, -Early ripening of crops. -Resistance to diseases <p>Deficiency symptoms</p> <ul style="list-style-type: none"> - Stunted growth and outer edges of leaves becomes yellow or reddish, becoming brownish or scorched and dead (edge necrosis); leaves wilted. - Lodging. 	<p>Maize</p> 	<p>Sorghum</p> 
		<p>Beans</p> 	<p>Green grams</p> 
<p><i>Secondary Nutrients</i></p>			
<p>Calcium</p>	<p>Function</p> <ul style="list-style-type: none"> - Improving the cell structure and fast division of plant cells, leading to faster growth <p>Deficiency symptoms</p> <ul style="list-style-type: none"> - Young leaves yellowish to black and curved or cupped (brown spots). <ul style="list-style-type: none"> • Plants appear to wilt. • Fruits may appear rotten (tomato). • Roots are malformed 	<p>Maize</p> 	<p>Beans</p> 
<p>Magnesium</p>	<p>Function</p> <ul style="list-style-type: none"> - Chlorophyll <i>formation</i> - Energy transfer <p>Deficiency symptoms</p> <ul style="list-style-type: none"> - Yellowish discoloration between green leaf veins (typical stripe chlorosis; followed by blotching and necrosis (death of tissues), starting at lower old leaves 	 <p>Maize</p>	 <p>Beans</p>
<p><i>Micronutrients</i></p>			
<p>Zinc</p>	<p>Function</p> <ul style="list-style-type: none"> - Protein synthesis - Accelerates enzymes activity 		<p>Maize</p>

	<p>Deficiency symptoms</p> <ul style="list-style-type: none"> - Stunted growth of leaves. <ul style="list-style-type: none"> • 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 (very similar to P deficiency) 	 <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="border: 1px solid black; padding: 2px 10px;">Sorghum</div> <div style="border: 1px solid black; padding: 2px 10px;">Beans</div> </div>
<p>Boron</p>	<p>Function</p> <ul style="list-style-type: none"> - Helps in the development of cell wall and promotes seed setting. <p>Deficiency symptoms</p> <ul style="list-style-type: none"> - Terminal growth shows resetting, dieback, discoloration and cessation of growth - Youngest leaves become pale green losing more colour at the base than the tip (chlorosis) - Thickened wilted curled leaves - Buds, flowers and fruits fall prematurely 	
<p>Copper</p>	<p>Function</p> <ul style="list-style-type: none"> - Helps in hydration of plant tissues. - Activates the enzyme activity. - chlorophyll. formation <p>Deficiency symptoms</p> <ul style="list-style-type: none"> - Terminal growth deformed, dieback may occur with rosetting of leaves - Stunted growth, distortion of young leaves necrosis of apical meristem - Plant may wilt from lack of water due to insufficient lignification of xylem vessels - Flower production fails 	

5 Important nutrients sources

Plant nutrients can be obtained from organic and in-organic sources



5.1

5.2 Organic sources (organic matter)

Organic matter is any material that is part of or originated from living organisms. Examples of organic matter include farmyard manure, green manure, chicken manure, urban waste.

5.2.1 Characteristics and benefits of organic manure

- Main source of organic matter and also supply macro, secondary and micronutrients.
- improves soil structure,
- Enhances water-retaining capacity
- Creates favorable conditions for soil micro-organisms
- Unlike inorganic fertilizers that provide nutrient immediately, organic manure has to decompose fast to release nutrients.

5.3 In-organic sources

In-organic fertilizers or mineral fertilizer is a manufactured product that contains a minimum of one plant nutrient that is essential for plant growth. They are concentrated sources of essential nutrients in a form that is readily available for plant uptake.

5.3.1 Characteristics of fertilizers

- Rich sources of plant nutrients.
- When exposed to the atmosphere, tend to cake by absorbing moisture.
- Nitrate-based fertilizers (such as ammonium nitrate) can become explosive in nature if not stored properly.
- Majority provide only one plant nutrient, such as N, P, or K.
- Do not contain organic matter.
- Show a quick response and become available to plants immediately on application.
- Mineral fertilizers need proper handling and storage.

5.3.2

5.3.3 Classification of inorganic fertilizer products

On the basis of nutrient contents, mineral fertilizers are grouped as indicated in Table 2.

Table 2. Classification of Mineral Fertilizers	
Category of fertilizers	Corresponding fertilizer products
Nitrogenous (N)	Ammonium Nitrate (AN), Ammonium Sulphate (AS), Urea, Calcium Ammonium Nitrate (CAN)
Phosphatic (P ₂ O ₅)	Single Super Phosphate (SSP), Triple Super Phosphate (TSP)
Potassic (K ₂ O)	Muriate of Potash (MOP), Sulphate of Potash (SOP).
<i>Note: The above three types of fertilizers are also called straight fertilizers.</i>	
Compound or Mixed Fertilizers containing two or more primary nutrients	Di-ammonium Phosphate (DAP), compound 23:23:0

5.3.4 Calculating fertilizer requirement

Step 1: Fertilizer recommendation in maize in Western Kenya - 60 kg N and 60 kg P₂O₅ / ha
Basal (planting fertilizer) = 60 kg phosphate/ ha

Step 2: Fertilizer type – DAP (18-46-0)

Step 3: Determine number of bags/acre

- 46 kg P₂O₅ is contained in 100 kg DAP
- 60 kg P₂O₅ contained in $100/46 * 60 = 130$ kg DAP/ha
- How many bags of DAP/acre = $130 / 2.5 = 52$ kg DAP/ac ≈ 1 bag

Topdressing fertilizer 60 kg N / ha

Remember 9% N was applied at planting from DAP

- Amount at topdressing = $60 - 9 = 51$ kg N
- If source is CAN (26-0-0); 100Kg CAN has 26 kg N
- 51 kg N will be provided by = $100/26 * 51 = 196$ kg CAN/ha
- Bags of CAN/acre = $196/2.5 = 78$ kg CAN ≈ 1.5 bags/acre

Based on fertilizer recommendation rates of 60 kg N + 60 kg P₂O₅ for Western Kenya region and 40 kg N + 40 kg P₂O₅ for Eastern Kenya region, fertilizer application schedules for both regions are given in Tables 3 and 4.

Table 3. KCEP fertilizer recommendation rates for Western Kenya region			
Choice	Maize		Maize/bean intercrop
	Planting	Top dress	Planting
Choice 1	NPK (23-23-0) 2 bags/acre	Top-dress with CAN (26-0-0) 1.5 bag/acre	NPK (23-23-0) Extra 25 kg/acre
Choice 2	MEA Mazao (10-26-10 + 25% Ca and micronutrients) 2 bags/acre	Top dress CAN (26-0-0) 1.5 bag/acre	MEA Mazao Extra 25 kg/acre
Choice 3	Mavuno Basal (10-26-10 + Ca and micronutrients) 2 bags/acre	Top-dress with Mavuno 1.5 bag/acre	Mavuno basal Extra 25 kg/acre

Table 4. KCEP fertilizer recommendation rates for Eastern Kenya region		
Choice	Sorghum/Millet	
	Planting	Top dress
Choice 1	NPK (23-23-0) 1 bags/acre	Top dress CAN (26-0-0) 1bag/acre
Choice 2	MEA Mazao (10-26-10 + 25% Ca and micronutrients) 1bags/acre	Top dress CAN (26-0-0) 1 bag/acre
Choice 3	Mavuno Basal (10-26-10 + Ca and micronutrients) 1bags/acre	Mavuno top-dress 1 bag/acre

6 Soil fertility degradation and amelioration

Soil fertility degradation is the loss of the capacity of soil to supply nutrients in adequate amounts. Common causes of soil degradation include nutrient mining, soil acidity, erosion, leaching, poor tillage and loss of organic matter.

6.1 Nutrient mining

Removal of nutrients from soil through crop residues/harvests. It results in the exhaustion of any nutrient required in moderate to large amounts. The amount of these nutrients removed by cropping depends on type of crop grown, part of crop harvested, and the stage of growth at harvest. Corrective measures such application of manure and inorganic fertilizers should then be taken to improve soil fertility.

6.2 Soil acidity

Causes of soil acidity include acidic parent material, leaching of basic cations and crop removal of cations, use of ammonium forming nitrogen fertilizers, acid/excessive rain and industrial emissions e.tc. Corrective measures include, liming with pure calcium carbonate or dolomitic lime, use of wood ashes and manure.

6.3 Soil compaction

Occurs as a result of poor tillage methods such as ploughing and hoeing which result in the degradation of soil, water, and air qualities. Corrective measures include; sub soiling and ripping to break the impermeable plough-pan, avoid ploughing when the soil is very wet. In addition, mulching and addition of manures improve soil structure in compacted soil.

6.4 Soil erosion and conservation practices

Soil erosion is defined as the wearing away of the top layer of soil. Corrective measures include, increased vegetation, use of embankments, contour cultivation, strip cropping, use of cover crops and conservation tillage.

6.5 Leaching

Leaching is carrying away of soil nutrients beyond the reach of crop roots. It is very common in areas with high rainfall intensity (>30 mm/day) and in coarse-textured sandy soils (>35% sand). Corrective measures include application of manures and nutrient replenishment

7 Take Home Messages

- To improve crop production, it is important that farmers understand their soil and soil fertility status
- This can accurately be determined through soil testing
- However soil analytical services are not easily accessible, are expensive.
- Recommendations can also be based on local soil knowledge systems which should not oppose but complement soil testing reports
- Deficiency symptoms can often be confused with disease and field condition and thus it's important to combine with fertility indicators /soil testing

8 Further reading

African Organic Agriculture Training Manual (2012). Module 02 Soil Fertility Management. FiBL, Research Institute of Organic Agriculture, Switzerland. ISBN 978-3-03736-197-9

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