



# **FARMER FIELD SCHOOLS FACILITATORS' MANUAL**

## **Volume 1 Integrated Soil, Water and Nutrient Management in Semi-Arid Zimbabwe**



**editors**

**O. Hughes and J.H. Venema**

Harare, February 2005

**Department of Agricultural Research and Extension  
Food and Agriculture Organization of the United Nations**

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*editors*

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2005

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A first draft of this manual was compiled in the second half of 2002 by a team of consultants from the Department of Soil Science and Agricultural Engineering of the University of Zimbabwe: Paul Mapfumo and Florence Mtambanbengwe wrote chapters on soil fertility management and Edward Chuma and Isaiah Nyagumbo chapters on soil and water conservation (Mapfumo et al. 2002). Subsequent drafts were made by Owen Hughes, Integrated Natural Resources Officer at FAO-SAFR, and by his successor Jan Venema.

The final version draws heavily on existing guides, manuals and text books, as detailed in the list of References. Significant detail and advice was also generously provided by Stephen Twomlow, Principal Scientist (Soil Fertility) at ICRISAT, Bulawayo.

# Preface

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The FAO and its partners are using the Farmer Field School (FFS) concept to promote integrated natural resource management in semi-arid areas in Zimbabwe curriculum developed. This manual was developed to support the FFS curriculum on Integrated Soil Water and Nutrient Management. The FFS curriculum in turn was developed jointly by the Department of Agricultural Research and Extension (AREX) of the Ministry of Lands, Agriculture and Rural Resettlement of the Government of Zimbabwe, the Food and Agriculture Organisation (FAO) of the United Nations, and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), under a collaborative project entitled *Integrated natural resources management in the semi-arid areas of Zimbabwe Project (TCP Zim/0169)*.

Poor soil fertility is arguably the most important constraint in smallholder agriculture in Zimbabwe. In semi-arid areas, the problem is further complicated by lack of soil moisture due to poor rainfall patterns. Smallholder farmers use a wide range of nutrient sources: cattle manure, mineral fertilisers, compost, crop residues, leaf litter and termitarium soil. These nutrient resources vary widely in the amount and types of nutrients they contain and, consequently, their effectiveness as fertilisers. Increasing human and livestock population pressure on land and other natural resources has led to land degradation and household food insecurity. Farmers must optimise their use of available nutrient resources in order to maximize returns (in the form of biological yield or cash) under a given set of environmental and socio-economic conditions. This involves minimizing losses from applied nutrients, and enhancing positive interactions between the various activities on the farm and between the farm and its immediate surroundings. The integrated soil, water and nutrient management approach aims to address these issues in order to maintain or improve smallholder farm productivity.

Recent advances in soil fertility research have shown the feasibility of manipulating soil biological processes in order to enhance the availability and use efficiency of both endogenous and externally added nutrients. Substantial knowledge has been generated on resource quality and its influence on nutrient mineralisation and immobilisation, management of spatial and temporal variability, and use of mineral fertilisers under variable rainfall. Advances have also been made in soil and water conservation/management where a number of technical options have been developed through farmer-participatory research. Some of this work has already demonstrated that soil and water conservation is an integral component of soil fertility management in semi-arid areas. However, some of these research findings have not yet been effectively communicated to the farmers, and there is still a wide knowledge gap between researchers/extensionists and farmers.

This Farmer Field School Manual is intended for extension or research staff involved in field-level farmer training, and for farmers trained as FFS Facilitators. The objective of the manual is to equip farmers with the basic principles of soil water and fertility management in order to enhance their capacity to manipulate soil processes and to make informed decisions about

allocation and use of their limited resources. The FFS concept is based on an innovative, participatory, learning-by-doing approach. The field is the primary learning stage, the farmer is the expert and the extensionist only acts as a facilitator. The manual is based on the same approach.

Following the development of the FFS curriculum in three semi-arid districts – Tsholotsho, Gwanda and Zvishavane – using the Participatory Curriculum Development approach in July 2002, project stakeholders and project management came to the conclusion that there was need for a resource manual to support and guide facilitators during training in the field. The writing of this manual was therefore guided by the curriculum. The purpose of the manual is to provide background technical information on specific topics and provide facilitators with guidelines on how to present the topics to farmers.

We hope the manual, when used in conjunction with a variety of other guides with similar objectives, will be a valuable asset for facilitators not only in Zimbabwe, but in other parts of Africa as well.

**Dr S. Mlambo**

*Director, Dept of Agricultural Research & Extension*

February 2005

### **How to use this manual**

This volume has two parts. Part 1 briefly explains the Farmer Field School (FFS) concept. Part 2 deals with technical subjects related to crop production, and is presented in the form of learning Modules. The idea is not to read the manual from cover to cover, but rather for each FFS to work with individual Modules as relevant to their needs.

Each Module includes a number of Field Studies or Exercises. These serve as guidelines for experiments to be carried out by the farmers in cooperation with the facilitator. FFS can make their own selection from the Field Studies presented here, and modify them as necessary.

### **Future development**

This edition of the manual should be considered a working document, ready to be tried out in the field. Feedback in the form of constructive criticism and practical tips would be highly appreciated and will be used in the next edition. Similar efforts to develop training material, also coordinated by FAO, are ongoing in East Africa. A facilitators' field guide will be published in mid 2005. In future editions the field guide and the manual will be combined into one product. Translation of parts of this document into vernacular languages will also be considered. Comments and requests for copies should be sent to the Integrated Natural Resources Officer, FAO (address given on the inside cover page).

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# Introduction to Farmer Field Schools

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## The Farmer Field School Approach<sup>1</sup>

The Farmer Field School (FFS) is a participatory agricultural extension approach, based on ‘learning by discovery’. The FFS approach was developed in the 1980s by an FAO project in Southeast Asia as a way for small-scale rice farmers to learn for themselves the skills required for, and benefits to be obtained from, adopting integrated pest management (IPM) practices in their paddy fields. Subsequently the FFS approach was extended to several countries in Africa and Latin America. Simultaneously, the IPM emphasis shifted from rice-based systems towards other annual crops, vegetables, and cotton; and other crop management aspects were added to the curriculum. In Zimbabwe a pilot FFS program was introduced in the late 1990s (Dande 2000) under the Training-of-Trainers component of the Integrated Production and Pest Management Project. More recently, pilot FFS have been established on integrated soil and nutrient management, and on dry-season feeding of livestock and poultry management in southern Zimbabwe. Junior Farmer Field Live Schools for HIV/AIDS orphans have also been piloted in Mozambique, Kenya and Zimbabwe.

It has been found that the FFS approach, although originally developed for IPM purposes, is an effective people-centred learning methodology. It allows farmers to learn about, and investigate for themselves, the costs and benefits of alternative crop and livestock management practices for improving farm productivity.

The FFS and other participatory extension approaches offer an alternative to traditional extension approaches. For example, under the old Training & Visit (T&V) system introduced in Zimbabwe by the World Bank, farmers are simply passive recipients. Extension messages are developed elsewhere and then demonstrated to farmers by field extension agents. In contrast, the FFS is a learning process where farmers are gradually presented with new technologies, new ideas, new situations, and new ways of responding to problems. The knowledge acquired during the learning process builds on existing knowledge, enabling farmers to adapt existing technologies to become more productive, more profitable, and more responsive to changing conditions, or to adopt new technologies. Over the past decade there is growing awareness that participatory approaches are required if extension is to respond usefully to farmers’ needs – technically, socially, environmentally and economically.

## Characteristics of Farmer Field Schools<sup>2</sup>

The characteristics of the FFS approach are as follows:

- **Farmers as experts.** Farmers ‘learn-by-doing’ i.e. they carry out for themselves the various activities related to whichever farming practice they want to learn about – annual crops, livestock/fodder production, orchards,

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1. Adapted from FAO (2000b), with additions on situation in Zimbabwe.

2. The following three sections are largely derived from material from the Indonesian National IPM Program, 1993. *IPM farmer training: the Indonesian case*. FAO-IPM Secretariat, Yogyakarta, Indonesia.

forest management, etc. The key element is that farmers conduct their own field studies and experiments. By discovering why different technologies and treatments perform differently, farmers become experts on the particular practice they are investigating.

- **The field is the primary learning place.** All learning occurs in the field and is based on the subject of study, i.e. a particular crop, field, rangeland or animal. Working in small sub-groups, farmers collect data in the field, analyse the data, make action decisions based on their data analysis, and present their findings to the other farmers in the field school for discussion, questioning, and refinement.
- **Extension workers are facilitators, not teachers.** The role of the extension worker is that of a facilitator rather than a conventional teacher. Once the farmers know what they have to do, and what they can observe in the field, the extension worker assumes a different role, only offering help and guidance when asked. Presentations during group meetings are the work of the farmers and not the extension worker. Members of each sub-group present their findings to their fellow school members. The extension worker may take part in the subsequent discussion sessions but as a contributor, rather than leader, in arriving at a consensus on what management action should be taken.
- **Scientists and subject matter specialists work with (instead of lecturing to) farmers.** The role of scientists and subject matter specialists is to backstop the facilitators and the FFS; and in so doing, learn to work in a consultative capacity with farmers. Instead of lecturing to farmers, they act as colleagues and advisers who can be consulted about specific problems, and who can provide new ideas or new information on locally unknown technologies.
- **The curriculum is integrated.** Crop husbandry, animal husbandry, horticulture, silviculture and land husbandry are considered together with ecology, economics, sociology and education to form a holistic approach. All these aspects are integrated in the context of actual problems encountered in the field.
- **Training follows a seasonal cycle.** Training is related to the seasonal cycle of the practice being investigated. For annual crops, training is conducted based on crop phenology, and extends from land preparation to harvest. For fodder production, training would include the dry season, so that farmers can evaluate the quantity and quality of fodder during this period (June-October in Zimbabwe), when livestock feed is in short supply. For tree production, and conservation measures such as hedgerows and grass strips, training would need to continue over several years so that farmers can see for themselves the full range of costs and benefits.
- **Regular group meetings.** Farmers meet at agreed regular intervals. For annual crops, meetings may be every 1 or 2 weeks during the cropping season. For other farm/forestry management practices the frequency of meetings would depend on what specific activities need to be done, or be related to critical periods of the year when there are key issues to observe and discuss in the field.
- **Learning materials are learner-generated.** Farmers generate their own learning materials, from drawings of what they observe, to the field trials themselves. These materials are always consistent with local conditions, are less expensive to develop, are controlled by the learners and can thus be

discussed by the learners with others. Learners know the meaning of the materials because they have created the materials themselves. Even illiterate farmers can prepare and use simple diagrams to illustrate the points they want to make.

- **Group dynamics/Team building.** Training includes communication skills, problem solving, leadership methods and discussion methods. Farmers require these skills. For activities to be successful at community level, farmers must have good leadership skills and be able to communicate their findings to others.

Thus, FFS create a learning environment in which farmers can master and apply specific land management skills. The emphasis is on empowering farmers to make and implement their own decisions in their own fields.

## Challenges Faced by Farmer Field Schools

- **Sustainability.** Many FFS activities are started up with assistance from donor projects, which may provide funds for training facilitators, initial running costs of newly established schools, external inputs for demonstrations and experiments. Once external funding stops, schools may find it difficult to sustain themselves. It is therefore important that every FFS finds its own source of income and that the FFS approach is institutionalised and fully supported by national extension services.
- **Monitoring and evaluation; quality control.** Once schools are on their own and new ones are formed spontaneously, ‘quality control’ may become a problem. It is important to ensure that the learning process remains intact, demonstrations and experiments are carried out correctly, and lessons are of high quality. For this to happen, strategies to institutionalise are important. Information exchange between schools, peer learning and continuing training of facilitators are also important.
- **Relevant learning materials.** If schools are to remain effective under ever-changing physical, social and economic farming conditions, then learning materials and messages should be continuously updated. This is a challenge for FFS facilitators (who must seek answers from specialists) and for AREX, which must develop and provide relevant, accessible materials.
- **Other participatory extension approaches.** FFS need to recognise and engage with other participatory approaches, such as Participatory Extension Approach (PEA), Participatory Technology Development (PTD) and People-Centred Development with a Livelihoods Perspective (PCD-L). All these approaches aim to promote farmer learning and development. There is a need for greater openness, interaction and learning among organisations using different approaches. For example, FFS can benefit from collaborating with other approaches in several areas: social mobilization, fostering and spreading local innovations, and development of farmer groups and organisations.

## Setting Up and Running a Farmer Field School

### The role of facilitators

The vast majority of professional extensionists have been trained in a traditional manner based on a ‘top-down’ approach – completely different to participatory

### **Box 1. Attitude and roles of a facilitator**

- to accept that monopoly on wisdom or knowledge the facilitator does not have.
- to listen to farmers and respect their knowledge, experiences and perceptions
- to give farmers the confidence to share their knowledge and experiences
- to create suitable conditions and activities from which farmers can learn
- to be responsive to farmers' needs and flexible in organising the course
- to increase farmers' knowledge, problem-solving ability, capacity for innovation and skills, so that the facilitator becomes redundant

approaches such as FFS. Consequently, the attitudes and skills of most trainers will need to be radically modified, if they are to successfully change from being 'instructors' to becoming 'facilitators'.

The role of the *facilitator* and his/her relationship to farmers is quite different from that of the instructor or trainer. The instructor imparts knowledge. Farmers play a passive role, merely receiving information. In contrast, a *facilitator* creates conditions for farmers to learn, by arranging opportunities for them to observe and interpret differences in soil conditions and crop performance, to carry out simple tests and exercises, and through discussions. The *facilitator* encourages farmers to play an active role in the learning process.

### **Requirements for an FFS**

Political support, appropriate policies, assured sources of funding to organise and implement the FFS, train facilitators and produce specific manuals on soil water and nutrient management... all these are essential if FFS are to become successful, widespread and sustainable. A budget must be prepared with detailed costs of inputs, training materials, refreshments and transport. Decision-makers at both national and local levels will also need to become aware, and convinced, of the greater benefits and impact of these new approaches. Participation of local government institutions, NGOs, and the private sector together with farmers in the development and promotion of improved technologies that are productive, profitable, conservation-effective and socially acceptable is to be encouraged.

Promoting integrated soil water and nutrient management (ISWNM) through FFS will require a 'bottom-up' rather than a 'top-down' strategy, a flexible curriculum that can respond to farmers' needs and interests, and emphasis on learning principles and processes rather than 'recipes'.

### **Getting started**

The way that an FFS program is initiated in an area will vary depending on local circumstances. In some cases the initiative will come from within the farming community: farmers recognise that they have a problem of declining soil productivity and ask for assistance to solve it. Alternatively the problem may have been identified by the research and/or extension services, who agree it could be addressed through the mechanism of an FFS. Irrespective of where the initiative came from, there is one common denominator – recognition of the benefits that could be gained from bringing farmers together to learn through discovery-based exercises about firstly, the nature of the problem, and secondly ways of solving it.

Initially the national government should identify broad target areas (i.e. in which districts, regions or provinces to mount an FFS program), using criteria such as poverty indices, access to infrastructure and markets, land degradation problems, agricultural potential etc. Final selection of villages/communities where FFS will be run, will depend on local interest and the seriousness of soil productivity problems in an area. However, two criteria should guide the final selection of communities for the FFS program:

- The community should be aware of the direct and wider implications of a declining natural resource base, and understand the importance of improving soil management in an ecologically oriented and integrated manner so as to sustain their livelihoods
- Within the community there should be sufficient scope for sustaining the FFS for as long as needed (potential for development of good local leadership, no strong opposing factions that hamper action and organisational growth, etc).

## **Integrated Soil, Water and Nutrient Management**

### **Why focus on soil, water and nutrient management?**

In semi-arid areas, the main biophysical factors limiting crop productivity are generally unavailability of soil nutrients and water for plant growth – though social and economic factors such as the lack of farm labour or market access may also have important effects.

Soil, water and nutrient management options for optimising crop productivity are also more complex than some other technical options (such as the introduction of a new variety). More complex systems and management options need a more intensive approach to ensure that farmers understand the relevant concepts, and master the application of the various options available to address these problems. For example, understanding the importance of nitrogen for plant growth, the various sources of nitrogen – inorganic, farmyard manure, legumes – and how these can be utilized to ensure good crop production. The FFS approach has proved to be effective in assisting smallholder farmers in understanding and applying complex concepts.

### **Principles of integrated soil, water and nutrient management (ISWNM)**

In this manual, the term ISWNM refers to soil, nutrient, water, crop, and vegetation management practices, tailored to a particular cropping/farming system, undertaken with the aim of improving and sustaining soil fertility and land productivity. ISWNM aims to optimise soil condition (physical, chemical, biological, and hydrological properties) in order to improve farm productivity, while minimizing land degradation. There is now greater awareness that ISWNM can not only increase crop yields, but also conserve the soil resource itself. ISWNM includes various field level management practices – use of farmyard manure, natural and mineral fertilisers, soil amendments, crop residues and farm wastes, agroforestry, reduced tillage practices, green manures, cover crops, legumes, intercropping, crop rotations, fallows, irrigation, drainage, plus a variety of other agronomic, vegetative and structural measures designed to conserve both water and soil.

The underlying principles of managing soils, nutrients, water, crops and vegetation to improve and sustain soil fertility and land productivity and their processes, are derived from the essential soil functions necessary for plant growth. The following are fundamental to the approach outlined in this manual:

- Loss of soil productivity is much more important than the loss of soil itself. Thus land degradation should be prevented before it arises, instead of attempting to cure it afterwards, i.e. the focus for ISWNM should be on sustaining the productive potential of the soil resource
- Soil and plant nutrient management cannot be dealt with in isolation but should be promoted as an integral part of a productive farming system
- Under rainfed conditions in semi-arid areas, soil moisture availability is sometimes the primary limiting factor on crop yields. Hence ISWNM includes rainwater management practices (conservation tillage, tied ridging etc) that will increase the effectiveness of rainfall and reduce risks of crop failure
- With declining soil organic matter levels following cultivation, it is important to adopt improved organic matter management practices for restoring and/or maintaining soil productivity (improved soil nutrients levels, moisture retention, soil structure resistance to erosion)
- Only after they have made improvements in the biological, physical and water-related properties of their soils, can farmers expect to get the full benefits from the supply of additional plant nutrients, in the form of mineral fertiliser

At the farm level, ISWNM therefore involves an integrated and synergistic approach:

- Matching the land use requirements of individual agricultural enterprises with the land quality in the area – i.e. the biological, chemical and physical properties of the soil, climatic conditions (temperature, rainfall etc) and topographic characteristics (slope, aspect, altitude etc) should match the bio-physical requirements of the land use practices
- Seeking to improve yields by identifying and overcoming the main factors limiting yield, beginning with the most important factor
- Better plant management, especially: (i) improved crop establishment at the beginning of the rains, so as to increase protective ground cover and thereby reduce splash erosion, increase infiltration and enhance biological activity; (ii) timely weeding to reduce yield losses from competition for nutrients and moisture
- Combinations of complementary crop, livestock and land husbandry practices which maximize additions of organic materials and recycle farm wastes, so as to maintain and enhance soil organic matter levels (which ideally should be at least 50-75% of the levels found under natural vegetation)
- Land management practices that ensure soil moisture conditions are favourable for the proposed land use (e.g. moisture harvesting/conservation in low-rainfall areas, drainage in high-rainfall areas, impoundment for paddy rice)
- Replenishment of soil nutrients lost by leaching and/or removed in harvested products. This can be done through integrated plant nutrition management, to optimise the benefits from all possible on- and off-farm nutrient sources (e.g. organic manures, crop residues, rock phosphate, mineral fertiliser, rhizobial N-fixation, uptake of P and other nutrients through root mycorrhizal fungi)

infestation, transfer of nutrients released by weathering in the deeper soil layers to the surface via tree roots and leaf litter)

- Combinations of crop, livestock and land husbandry practices that reduce rainfall impact, improve surface infiltration and reduce the velocity of surface runoff, thereby ensuring that any soil loss is below the 'tolerable' level for the soil type
- Conservation tillage, crop rotation, agroforestry and restorative fallow practices that maintain and enhance the soil's physical properties through maintaining an open topsoil structure, and breaking any subsoil compacted layer (hoe/plough pan) thereby encouraging root development and rainfall infiltration (e.g. use of ox drawn chisel ploughs, double dug beds, pasture leys, interplanting of deep rooted perennial crops/trees and shrubs)
- Where technically feasible and cost-effective, reclamation of farm land that has been severely degraded by gullyng, loss of topsoil from sheet erosion, soil compaction, acidification and/or salinisation.

## Think Differently: Soil is Life

*I never teach my pupils; I only attempt to provide the conditions in which they can learn.*

Albert Einstein

Farmers want to obtain a good harvest from their fields, so that they have enough to eat and have some surplus for sale or exchange. Therefore, it is important for farmers to provide the best conditions for growing a profitable crop. Crops and cultivation practices should be adapted to the natural conditions of the area. Soil and other natural resources should be used with care.

People who work with soils need to think differently. If the land is to give a good yield for many years, a good understanding of the environment above and below the ground surface is vital. Different thinking about soil and crop cultivation includes the following:

- Focus on saving pore space in the soil, more than saving soil particles
- Emphasize ‘increasing infiltration of water into the soil’ more than ‘reducing runoff’
- A field covered with crop residues looks much better than a ‘clean’ field
- On seeing a muddy river in flood, it is more sensible to ask ‘why so much water?’ than to comment at the amount of sediment being transported
- Consider ‘Water and soil conservation’ before ‘Soil and water conservation’
- First think of what you are trying to achieve, before choosing specific practices
- Instead of thinking how much fertiliser farmers should apply to maximize yield, ask how best the small quantity they can afford should be used (what kind of fertiliser, applied how and when) to maximize returns on their investments
- Remember that whatever nutrients are removed from the soil by the crop, they need to be returned if soil fertility is to be maintained. Consider the many ways of returning nutrients to the soil through the use of stover, manure, organic household waste, legumes, mineral fertilisers, etc
- Reduce risks of failure due to drought, rather than complain about the increased severity of drought
- Build soil from top downwards, particularly by favouring biological activity and increasing organic matter content.

When we talk of keeping soils healthy for good crop growth, we need to think always of what the soil needs to sustain soil fertility and productivity. This means understanding the many soil functions and how best to work with them. This manual discusses several principles for growing a healthy crop:

- Keep the soil covered to enhance infiltration of rainwater, increase biological activity and reduce erosion
- Practice reduced tillage
- Practice good weed control
- Supplement nutrients supplied by organic sources with mineral fertilisers
- Maintain crop diversity and introduce legumes into the farming system



- Use the land according to its suitability
- Improve crop production by identifying and rectifying the most crucial limiting constraints
- Minimize the use of crop protection chemicals (pesticides) so as to not kill healthy life in the soil.

Many people think that rainfall, and thus soil moisture availability, is the most important constraint to farmers in the semi-arid areas of Zimbabwe. But studies in similar environments in West Africa have shown that potential production from any given rainfall is limited mainly by nutrient availability. In other words, *poor soil fertility may be the most limiting natural factor in drought-prone areas.*

Mineral fertilisers are not much used in these areas. Recent surveys by ICRISAT indicate that only 0-25% of households use fertilisers. Only 20% of farmers in Gwanda and 50% of farmers in Tsholotsho have ever used mineral fertilisers, and mostly when it was distributed free under drought relief programs. Otherwise, farmers do not normally apply mineral fertilisers, and have limited knowledge about their use. In the 1998/99 cropping season, less than 3% of farmers applied basal mineral fertiliser and less than 4% used any top dress fertiliser. In the same districts, where most farm households own livestock, less than 25% use animal manure on their crops. More than 60% of cattle owners do not use the manure that is available from their animals. Maybe the returns to manuring are too low to justify the effort.

#### **Rule of thumb**

One cow can produce approximately 1 kg dried manure per kg of body weight per year in the kraal

Current extension messages promote the application of 100kg of nitrogen fertiliser (ammonium nitrate) to each hectare of maize in these highly risky environments. This recommendation is not helping the 95% of farmers who fail to apply mineral fertilisers. Recommended levels of manure, at 15 to 30 tons per hectare, are equally impractical given that only 10% of households have enough animals to get this much manure. The other 15% of farmers who apply manure to maize average only about 2 tons per hectare.

It is difficult to build up soil organic matter over time in sandy soils under semi-arid conditions. Current strategies for supply of N to crops are promoting smaller doses of mineral fertiliser (especially N) and manure combinations at critical growth stages, as well as adjusting fertiliser application to address specific nutrient deficiencies in a field. These approaches take into account how much fertiliser a farmer can afford, and how best this small quantity should be used. These offer much higher returns per unit of investment, compared with official recommendations, and are also less risky.

Small farmers in semi-arid environments do have many opportunities to raise crop productivity. This manual will help them explore, study and understand some of the options available to them.

# Module 1. What Is Soil?

Soil is the upper part of the earth in which plants grow. All soils are different. They are derived from different rocks, containing different types of minerals. When the rocks and minerals break down they create very different types of soils. What a soil is like depends on many factors – what rock it is made from, the shape of the land, climate, how long it has taken to form, and how it has been used or changed by human activity. Soil varies in thickness from a few millimetres to several metres. It is vital for agriculture and life on earth. Many things happen in the soil. Animals and plants interact with each other and with the weathered rocks to form soil. Micro-organisms in the soil carry out recycling programs which release nutrients for plants to absorb. Plants rely on soil as a source of water and nutrients. Soil is a short word that has many meanings. Soil has character and it is not just ‘dirt’. Soil is a complex medium and needs to be protected for future generations, just like air and water.

Each soil has different layers, also called *horizons*. These layers differ from each other in depth, colour, hardness, texture, pores, and stoniness and can be seen in deep gullies, roadside ‘cutaways’ or soil pits. The most important horizons are shown in Fig 1.1. An outline for a soil profile study is given in Field Study 1.2.

In a soil profile, not all the horizons shown in Fig 1.1 may be present. For example, if the soil has been eroded, the topsoil (A horizon) may have been removed and the soil may start with a B horizon. Shallow soils on steep slopes may go from an A to a C horizon with no B horizon. Also, the soil in a particular field may have been altered by human activity at some time in the past.

It is important for farmers to know their soils. That will improve their understanding of what crops to grow and how best to cultivate and manage the land. Water and nutrient availability, rooting

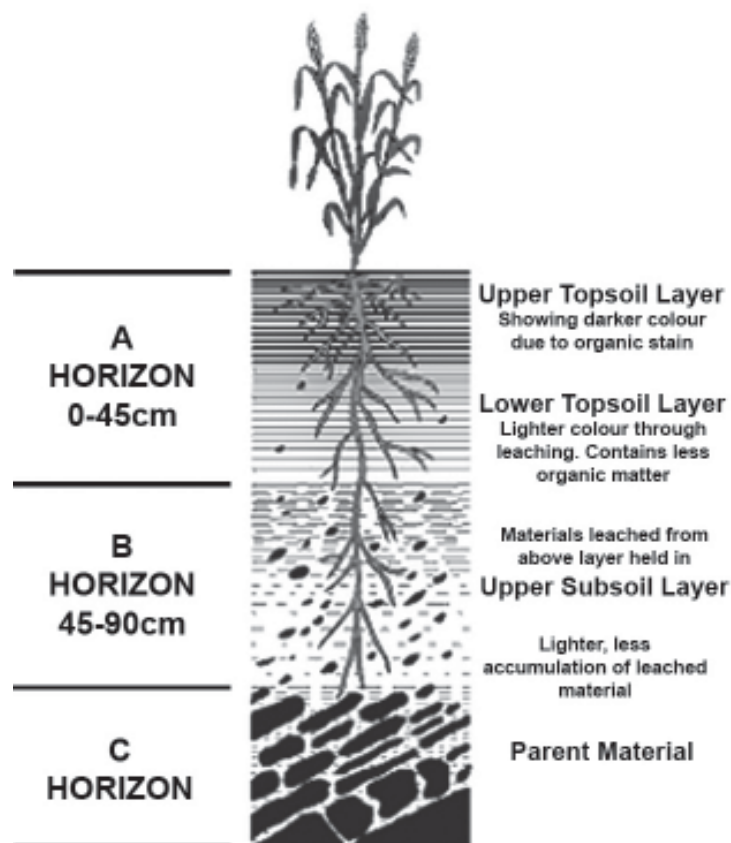


Figure 1.1. Soil horizons (from ABSA 1997)

conditions, biological activity and how easy it is to work the soil... these are some of the things that can be interpreted by examining the different soil layers.

## Giving the Soil Names (Soil Classification)

Soils vary from place to place and differ in properties such as colour, texture, structure, drainage, depth, stoniness, slope and erosion. Farmers have developed their own systems for describing local soils and their relative fertility status, by using indicator plants and other local methods.

### Exercise

As part of Field Study 1.1 farmers are encouraged to describe and name the main soils in their area and their position in the landscape. The main soils distinguished will form the basis for further studies.

For example, small-scale farmers in Zimbabwe use local knowledge to classify soils on the basis of colour, texture and physical structure, especially as they relate to their fertility status and water-holding capacity (see Table 1.1). They understand how soils and crops are inter-linked. Local classification systems are generally consistent with scientific systems. For example, sandy soils are associated with poor crop growth caused by low soil fertility and poor water-holding capacity. Red or reddish brown soils are normally perceived as more fertile with good structure and good water-holding capacity. Dark gray and black soils, though considered fertile, are known for high incidence of waterlogging and for their poor workability. Strong associations between natural vegetation and soil types are also reflected in the indigenous classification system. For instance, farmers use such terms as *ivhu ramapfuti*, meaning soils dominated by *Brachystegia boehmii*. Table 1.1 gives an example of an indigenous classification system developed by farmers in Zimbabwe.

## Soil Quality

In every region of the world, it is necessary to find or develop good techniques for agriculture. This means working with soils. Soil is an important part of our life, but how often do we look at it carefully? The important thing about any soil is its quality. Soil quality indicates whether a type of soil is able to function well, support plant and animal productivity, maintain or enhance water and air quality, and support humans and their quality of life; all without leading to soil degradation or otherwise harming the environment. It means a soil's ability to support crop, range and woodland production and to sustain water supplies. Good soil quality can reduce the onsite and offsite effects of erosion, and improve nutrient use efficiency. Good soil quality is also essential to maintain the quality of other resources that depend on the soil, such as water, air and wildlife. The quality of a soil can suffer badly if it is not cared for properly. Land use and farming practices can change soil quality either for the better or for the worse.

**Table 1.1. Soil classification system developed by smallholder farmers in Zimbabwe in relation to soil fertility and cropping potential**

Soil type			
Farmer description	Common description or textural class	Perceived fertility status and potential for cropping	Comments
<i>Ihlabati</i> sands water holding	Kalahari poor fertility, low Matebelel and Province	Very low potential; western Zimbabwe in capacity; structureless	Kalahari sands in (e.g. Lupane, Nkayi) and parts of Gokwe District in Midlands Province (WRB: Arenosols)*
<i>Jecha / tshhebetshebe</i>	Sand	Very low potential; poor fertility, low water holding capacity	Include some of the most depleted soils. Made up of soils derived from granitic parent material and Kalahari sandstone (WRB: Arenosols, Regosols)
<i>Shapa / musapa</i>	Sandy loam to loamy sand	Slightly better than <i>jecha</i> in the short term dambos (WRB: Luvisols, Arenosols, Cambisols)	Include most of the less depleted granitic soils, and grey soils on sandveld
<i>Nhurubvuka / ramapfuti</i>	Sandy clay loam	'Strong' soil (good structure), very productive	Comprises pockets of soils derived from intrusive dolerite and those derived from a mixture of mafic and felsic parent materials.
<i>Mhukutu / isibomvu</i>	Red clays	Highly productive, strong and 'un-ageing' soils (do not seem to lose structure with cultivation)	Typically productive Zimbabwean red clays derived from mafic rocks (WRB: Nitisols, Lixisols)
<i>Barebare / gan'a/ dhakimunyama/ isidaka</i>	Dark grey or black clays	Highly productive but difficult to work	Soils exhibiting vertic properties. Prone to waterlogging when they occur on bottomlands or dambos (WRB: Vertisols)
<i>Rukangarabwe / mujinga</i>	Gravelly soils	Generally unproductive	Often associated with shallow granitic soils (occur within various soil classes)

\* WRB = World Reference Base for Soil Resources  
Source: Mapfumo and Giller 2001

Good quality soils give clean air and water, generous crops and trees, productive rangelands, diverse wildlife, and beautiful landscapes. Soil does all this by performing five essential functions:

- Regulating water: soil helps control where rain and irrigation water go. Water flows over the land or into and through the soil
- Sustaining plant and animal life: the diversity and productivity of living things depends on soil
- Filtering pollutants and toxic materials: the minerals and microbes in soil are responsible for filtering, buffering, degrading, immobilizing and detoxifying organic and inorganic materials, including industrial and urban wastes
- Cycling nutrients: carbon, nitrogen, phosphorus, and many other nutrients are stored, transformed and cycled through soil
- A stable soil supports man-made structures like buildings, dams, roads, etc.

## Soil Physical Properties

A soil's physical properties and chemical composition largely determine how suitable it is for growing crops, and the sort of management required to keep it productive.

### Soil colour

Farmers use soil colour as a main indicator for the fertility of a soil. When soil is examined, colour is one of the first things noticed. The colour is determined by how much organic matter it contains, its drainage conditions, and how much it has been changed by climate (extent of weathering). Light colours are a sign that the soil is low in organic matter. Light or pale colours in the surface soil are often associated with coarse texture, highly leached conditions, and high annual temperatures. Dark colours might indicate poor drainage, low annual temperatures, and high organic matter content. Subsoil colours, in general, are indications of air, water and soil relationships and the extent of mineral decay during breakdown of the soil's parent material. A rough indication of the meaning of soil colour is given in Table 1.2.

### Soil texture

Texture refers to the relative amount of *sand*, *silt* and *clay* present in the soil. Texture measures the size of the mineral soil particles only, not organic matter.

**Table 1.2. What does soil colour tell us?**

Dark colours	Dark topsoil indicates high organic matter content, which is linked to better drainage, good soil structure and nutrient levels
Red-brown and orange	Good drainage, well aerated, free movement of air and water. With enough water these soils are generally fertile. Acidity may be a problem
Dull yellow and wet blue mottles	Some seasonal drainage problems (waterlogging) where air is lacking in the soil, especially in the season
Grey	Poor drainage, too much water and not enough air

Source: ABSA 1997

### **Categories of soil texture**

Soils made up of mostly sand are called *sandy* or *coarse textured*

Soils with a mixture of sand, silt and clay are called *loamy* or *medium textured*

Soils with mainly clay are called *clayey* or *fine textured*

### **Importance of soil texture**

In general, the finer the texture, the more difficult a soil is to work or till, the greater its water holding capacity, the slower water will enter and move through the soil profile. Such soils are richer in nutrients, but plant root penetration is more difficult, and the surface will crust more readily.

- **Sand** is relatively coarse, varying in size from 0.05 to 2 mm. Most sand particles can be seen with the naked eye. Sand particles feel gritty when rubbed between the thumb and fingers.
- **Silt** particles are much finer than sand and feel smooth and floury. When wet, silt feels smooth but is not sticky. When dry it is smooth, and if it is pressed between thumb and finger, it will show the mark of the pressed thumb or fingers.
- **Clay** refers to the finest soil particles, which cannot be seen without a microscope. They feel very smooth when dry, and become sticky when wet. Even a small proportion of clay in a sandy soil can have a big influence on soil properties. In clay soils the particles are tiny, so there is very little room for water and air to move between them. So when clay becomes wet it swells and sticks together. As wet clay dries, it shrinks and cracks.

The texture of a soil varies from one place to another. Sand, silt and clay are mixed together in various combinations to give different textures. The actual amount of sand, silt and clay size particles in a soil can be measured in the laboratory, classroom or in the field. Simple field and classroom exercises are described in Field Studies 1.3 and 1.4.

Soil texture is important because it affects and is related to several soil properties such as soil structure, aeration, water-holding capacity, nutrient storage, water movement, and root development. Knowing soil texture will tell us something about how fertile a soil is and how suitable it is for different uses. Texture also influences a soil's susceptibility to degradation.

For example, sandy soils have large particles with large spaces – called pore spaces – between them. They hold water and nutrients very badly and drain easily. Coarse-textured or sandy soils allow water to enter at a fast rate and to move more freely in the soil. Sandy soils are also easy to till. In contrast, loamy soils with a higher proportion of silt and clay have the ability to trap water and retain nutrients for plant use. Loamy soils are very good for growing crops. Clay soils have more nutrient and water storage than sandy soils, but it is harder for water to move through such soils.

### **Soil structure**

A close look at soil will reveal that the individual grains of soil – sand, silt and clay – do not occur as loose particles. Chemical cements and organic glues made by soil animals and decaying plant materials help 'glue' soil particles together.

### **Look under the soil surface**

It is important to look at what goes on under the soil surface, especially plant root systems and soil porosity. Although not easy to see, natural processes occurring under the soil surface are very important in relation to soil productivity. Many field workers and farmers have little knowledge about how a normal root system looks, for the most common crops or weeds, and they are not familiar with the various factors affecting crop root growth. Farmers can make simple observations on root development and soil compaction. This will improve their understanding of soil productivity constraints and contribute to finding solutions in the field. An exercise to examine plant roots is given in Field Study 1.7.

For example, clay particles and organic matter in the soil stick together naturally. This means they have a tendency to hold water and other particles to their surfaces, in the same way as dust settles on furniture.

Soil structure determines the size and shape of 'open' spaces in the soil through which roots, air, and water can move. Thus good structure allows good root development.

Clumps of soil are called *aggregates* or *peds* and give the soil its structure. Two main characteristics of a soil ped are its **shape** and its **stability**.

The stability of soil aggregates or peds is important because it affects erosion, movement of water, and growth of plant roots. Aggregates that break down in water or fall apart when struck by raindrops, release individual soil particles that can seal the soil surface and clog pores. This breakdown creates crusts that close pores, preventing water and air from entering the soil and also restricts emergence of seedlings from the soil.

Unlike texture, soil structure can be easily changed, or destroyed altogether, by farming practices such as tillage and water management. With mechanized farming, soil structure is affected by the weight of heavy equipment. Excessive tillage may break down aggregates and reduce water infiltration. Compacted soils are those in which the air spaces (pores) between the grains of soil and between aggregates are too few and too small; they have been compressed. This creates ideal conditions for water runoff and erosion. If the soil is compact and very hard, roots find it difficult to penetrate and water will not easily go down into the soil. Therefore, soil structure greatly influences the growth performance of crops. A soil with poor structure will need more nutrients and water to support a healthy plant, than a soil with good structure. Therefore, it is essential to maintain a favourable soil structure.

Field Study 1.5 shows a simple way to determine soil structure.

### **Soil air and roots**

A very important component of soils is the air space (pores, voids and cracks) between the soil particles and between the aggregates. It is in these air spaces where all the action, such as water and air movement, takes place. It is where soil organisms live and work. It is where plant roots grow. Roots need air to breathe and the air spaces make it possible for the roots to spread out in search of food. Even if your soil has enough nutrients, plants will grow poorly if they

cannot reach the nutrients or get enough air or water. A high pore volume will also assist water infiltration into the soil, increasing moisture for crop growth and reducing surface runoff.

The sizes and numbers of pores depends on the types of solid particles in a soil, the size of soil aggregates, and how the aggregates are held together. The pore spaces will vary according to the type of soil and how it has been managed by the farmer. An experiment to measure the amount of air in the soil is described in Field Study 1.6.



## Field Study 1.1. Local Knowledge of the Land

**Objective:** To record and use indigenous knowledge among farmers, on various aspects.

**Procedure:** For each topic, discuss with the group, and record their conclusions and answers to each question. This will enable farmers to clarify their ideas, and also help the facilitator during future modules of the FFS. Record all the findings, for future use.

### *Watershed management*

- Do farmers see any cause-effect relationships between uplands and lowlands? For example, do they find that activities in the uplands affect the lowlands or vice versa? How? If farmers have observed ill-effects, do they do anything to prevent or control them?
- How do farmers mark the boundaries of their community? Are water sources (rivers, streams, dams) used to mark boundaries? How are water resources shared and/or conserved?
- Do farmers conserve any part of their community's territory? Which part and why? Any specific measures used, e.g. tree cutting prohibited, protecting plant and animal species, replanting, etc.
- Do farmers manage their environment? What are their cropping practices? What are the reasons behind specific practices? Do farmers recognise soil erosion or soil fertility decline?

### *Types of soil*

- What kinds of soil do farmers recognise on their farm?
- Which criteria do farmers use to classify soil types? What are the local names?

### *Soil properties*

- What is the colour of the soil? What is its texture? How deep is it? Does it contain many stones? Is it alive with small animals? Any special characteristics of the soil?
- How quickly (or slowly) is water absorbed in the soil? How long will the soil hold water? When does it develop cracks? Does the soil develop a white coating immediately after rains?
- Do farmers use any local species as indicator plants for soil health?

### *Cultivation*

- Is the soil easy to cultivate? What crops grow best on which soils? Why?
- How deep does the plough normally cut into the soil?
- Are crops arranged in a special manner (e.g. intercropped) to control weeds, pests and diseases?
- What crop combinations or rotations are used to reduce weeds and pests?
- What additional methods or strategies do farmers use to control weeds, pests and diseases? For example, encouraging build-up of pest predator species, growing plants to repel insects.

### *Soil fertility management*

- Do farmers improve their soils? What indicators do farmers use to assess whether soil quality is improving, deteriorating or being maintained?

- What inputs (animal manure, termite mounds, legume cover crops, tree leaves, etc) do farmers use? Why? Are inputs recycled from the farm or brought in from another place?
- How are inputs prepared? How, when, and in what amounts are they applied?
- What are the views of community members regarding the use of common resources such as forests and waterbodies? How are conflicts resolved? Can outsiders access these resources? What are the terms and conditions?

#### *Use of trees*

- What tree or other plant species are valued by the local farmers? Where are these found? Are they planted? What criteria do farmers use when selecting trees and crops to grow together?
- Are they allowed to grow in the fields? What types are planted and why? What products do they provide to the farm or household?
- What are the linkages between crop, livestock and tree activities? For example crop residues as mulch for fruit trees, tree fruit as livestock feed in the dry season, tree leaves as organic manures for crops.

#### *Integration of livestock*

- Why do farmers keep different livestock species (e.g. for meat, milk, draft power, manure, other reasons)?
- Are there linkages between crop and livestock activities? How are they linked (incorporation of manure in the field, use of crop residues as fodder, etc)?

## **Field Study 1.2. Soil Profile Study**

**Objectives:** To describe different soil profiles (preferably in different landscape positions and linked to local soil classification) in order to recognise and understand the differences between soils from different layers (horizons) of the profile.

**Time required:** 2 hours

#### **Materials**

- digging tools (pick-axe, hoe, shovel and/or spade)
- machetes, knives
- bottles of water
- measuring tape
- data sheets, pens
- bags for soil samples, string, labels
- Magnifying glass

#### **Procedure**

1. Explain the objectives of the study.
2. Form groups of 5-6 people. Each group digs a soil pit about 1m deep and 1m wide, or as big around as necessary to easily see all the soil layers. Preferably, groups should choose different sites so that the pits can be compared during group presentations. For example, one pit can be in the middle of the field and another in nearby grassland. Where crops or grasses are present, it is important to dig down adjacent to the crop so that roots in the profile can be studied.
3. As soil is removed from the pit, look for changes in appearance or character. If different layers are noticed, keep each type of soil separate by putting it in different piles.

4. Look at the soil face, especially when the sun is shining on it directly. Starting at the soil surface and working down, look to see where there are changes in appearance of the soil face. For example, look for different soil colours. If the soil is dry, squirt it with water to help pick out the different soil colours. Also look at the size and number of stones and the shapes of particles. Look for the presence of plant roots and worms and other small creatures.
5. A change in appearance may be a sign of a different soil layer or horizon. Use a stick to mark any boundary between the different layers. Draw a sketch of the profile and mark the horizons. Measure the depth of each layer. Which layer is the shallowest? The deepest?
6. Each group in turn will explain their findings to the others in their own terminology. After each presentation, the entire group discusses how the soil characteristics (the different characteristics seen in the different soil profiles) influence crop production.
7. Take samples of the different soil layers for further study later. Label the samples.
8. After observations at the pit have been made, return the soil into the pit in the OPPOSITE order in which it was removed.

**Conclusions** (*farmers should use simple terminology or their own terminology*)

1. What is the difference between soils in the A and B horizons?
2. What is the difference between soils in the B and C horizons?
3. What evidence, if any, is there of weathered parent rock in the deepest horizon?
4. Scientists believe that it takes between 200 and 300 years for one centimetre of soil to form from parent rock. About how long did it take for the topsoil to form?
5. In the topsoil, separate out the small particles of soil from the decaying plant and animal matter (if any). Examine them using a magnifying glass. What types of particles do you see?
6. Along with the soil particles, what evidence is there of plant and animal activity?
7. Which characteristic about the soil site has the greatest influence on the formation of the soil profile and why? For example, what environmental conditions could have led to decomposition of the topsoil?
8. How do the different properties of the soil profile affect its moisture supply, soil fertility and the supply of nutrients? Are there drainage problems?
9. How well developed is the plant root system? Do the roots extend into the deeper horizons? If not, why not?

**Data sheets:** Use the following data sheets for this field study.

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**Soil profile site**

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Location	Landscape: topography, slope gradient	Recent land use, vegetation, soil cover	Climate	Evidence of drainage, erosion

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Soil horizon characteristics				
Horizons	Depth (cm)	Colour	Texture	Additional observations
O				Organic materials?
A				Biological activity? Pores and cracks?
B				Stoniness? Hard pans? Drainage problems?
C				

### Field Study 1.3. Soil Particle Size Experiment (Settling Technique)

Soils contain a mixture of clay, silt and sand. Since these particles have different qualities for crop production, it is important to know the specific soil mixture of a field and to know the dominant soil type.

**Objective:** To use settling technique to find out the proportions of sand, silt and clay in the soil

**Time required:** experiment over 2 days (2 hours on first day, 1 hour next day)

#### Materials

- large glass jars with screw tops
- drinking cup and scoop to collect soil samples
- a bit of salt (used to help break apart any clay)
- marker, measuring tape

#### Procedure

1. Explain the objectives of the study.
2. On the side of the jar, mark off one third of its height and record the height on a separate piece of paper.
3. Fill the jar with dry soil to just above the mark. Press the soil down lightly, and remove any soil that is above the mark.
4. Add water until the jar is almost full. If the soil is high in clay, add a pinch of salt and mix the soil, water and salt together.
5. Close the jar tightly and shake vigorously until the soil particles are mixed up (suspended) in the water. Leave the jar undisturbed for one hour.
6. Shake the jar again, let it stand and wait one minute. What do you notice? Mark on the side of the jar, without moving it, how much soil has settled at the bottom.
7. After about 2 hours, you may see distinct layers forming at the bottom of the jar. Again, mark how much soil has settled at the bottom.
8. After 24 hours, mark again how much soil has settled at the bottom. Is the water clear, or are some soil particles still suspended in the water?
9. If definite layers appear in the jar, measure the depth of the layers. Are some layers thicker than others? Describe the particles that make up these layers.
10. A layer of material may be seen floating on the surface of the water. This may be organic matter, which will eventually fall slowly to the bottom as it soaks up water.

11. Repeat this activity with different soil samples taken from different parts of the field. Compare the layers in each soil sample.

### Questions for group discussion

- Why is the thickness of a particular layer (sand, silt, clay) different in different samples?
- Do different soil particles settle at different rates? What determines how quickly or how slowly they settle?
- Is this experiment a good way to find out soil texture? Why or why not?
- Which of the soils (which sample) is the best for growing a crop?

## Field Study 1.4. Feeling Soil Texture

**Objectives:** To understand and practice a simple method of finding out the texture of a soil.

**Time required:** 1-2 hours

### Materials

- water bottle
- soil from different soil types and soil layers
- smooth hard surface such as plywood or metal, or a piece of cardboard

**Procedure** (Source: FAO 2000b)

In order to determine soil texture by feeling, the soil must be moist. Add a small amount of water until the soil is like 'putty'. Move the soil about between your thumb and forefinger. Break down hard particles and remove any stones or roots. You will be able to get the 'feel' characteristics of the soil: sand particles feel gritty, clay feels sticky, while silt feels smooth. After the soil is worked into a soft mass, squeeze the soil between your thumb and forefinger to make a 'ribbon'. The longer the ribbon, the more clay there is in the soil sample. Soils with a lot of sand will fall apart, while those with more clay can be worked into a very good ribbon which is over 5 cm long. Silty soils feel very smooth. Loam soil is smooth but slightly sticky and has just a little feel of grit. Eventually, after much practice, you will be able to accurately assess the type of soil using this method.

1. If the soil feels gritty and lacks cohesion (i.e. does not hold together)  
*the soil texture is .....very light*
2. Form the moist soil into a round ball, and then press your thumb into the ball to form a cup shape.  
If a round ball cannot be formed, or if the cup crumbles  
*the soil texture is .....very light*  
If a round ball can be formed, and the cup retains its shape, proceed to step 3.
3. Roll the ball of soil between your palms and then on a hard smooth surface to form a ribbon as thick as a pencil, up to about 20-25 cm long  
If no ribbon or only a short ribbon can be formed  
*the soil texture is .....light*  
If a long ribbon can be formed, proceed to 4.
4. Form the ribbon into a circle.  
If a circle is formed with cracks  
*the soil texture is .....medium*

If a circle is formed with no cracks, and the soil is very sticky  
the soil texture is .....**heavy**

## Field Study 1.5. Examining Soil Structure

**Objective:** To examine the structure of different soils and relate findings to soil functions and crop growth

**Time required:** 2 hours

### Materials

- shovel
- newspaper or piece of plastic

**Procedure:** work in groups of 4-6 people.

1. Explain the objectives of the study.
2. Walk around a field and choose several sites from which to take soil samples. Different sites could represent a cultivated field, a home garden, grazing land, a kraal, or a woodland area.
3. At each site, spread a newspaper on the ground. Carefully place a shovel full of soil onto the newspaper. Try not to break the block of soil. Does the soil form aggregates or clumps? Look for channels in the soil where water and air can pass through. Aggregates give soil its structure. A soil without structure is either *single-grained* (i.e. *granular*) or *massive*. Granular is like sand, when individual particles do not stick together. Massive is when the soil sticks together in a large mass, and does not break into any pattern. This often occurs lower down in a soil profile where the parent rock has not been weathered much.
4. If the soil forms clumps, look closely at their shape. Do the shapes match any of the shapes in the picture? If the soil sample contains several types of structure, which shape is the most common?
5. What happens if the soil is gently touched? Can a single clump (i.e. ped or aggregate) be picked up? Does the soil structure fall apart when handled? Soils that have a barely observable structure, which easily break apart when disturbed, are said to have a *loose*, or *weak*, structure. Because the material becomes loose, it is sometimes hard to distinguish between soils with no structure and weak-structured soils.
6. Hold a ped between your thumb and forefinger. Gently squeeze until it falls apart.
  - Does the ped break with only a small amount of pressure? If so, the structure is *friable*.
  - If the ped breaks only after applying a good amount of pressure, and the finger dents before the ped breaks, then the structure is considered *firm*.
  - If a ped cannot be crushed between the fingers, the soil structure is *extremely firm*.

### Questions for group discussion

- Each group should describe the structure of different soils examined. Explain differences or similarities and try to relate this to what happens at each site.
- Which type of soil is most likely to be physically damaged by rainfall or by wind, or by tillage? Why?

- Considering the soil structure of the different locations, on which site would roots find it easy to grow? How does root development differ at the different sites?
- How would soil structure at the different sites affect infiltration of water?

## Field Study 1.6. How Much Air Does the Soil Contain?

**Objective:** To find out the amount of air in different kinds of soils

**Time required:** 1-2 hours

### Materials

- 2 small tins
- 1 large bowl
- tool for stirring
- water
- knife, nail
- soil samples

### Procedure

1. Explain the objectives of the study.
2. Get two empty cylinders (coffee or margarine tins will do). Perforate one tin with a nail, making 5-6 holes at the bottom.
3. Turn the perforated tin upside down and press the open end firmly into the ground until the tin is completely filled with soil. Turn the tin upright and level the soil at the brim of the tin with a knife. The soil in the tin is now arranged in the same way as it was, in the ground. Fill the other tin with water (see figure A).
4. Mix all the soil and water from the two tins in a bowl and stir the mixture until no bubbles of air are seen to escape. Let the mixture in the bowl rest for a few minutes (figure B).
5. Carefully pour the mixture back into the two tins. First fill one tin and then continue pouring into the second tin (figure C).
6. You will see that the second tin is not completely full – although it was full earlier. Mark the height of the water level. The remaining empty space in the tin is equal to the volume of air that was contained in the soil sample.
7. Repeat the experiment with other soil types (clay, loam, sand).
8. Discuss the results and compare the amount of air in different types of soils.



**Figure A**

**Figure B**

**Figure C**

Source: Secondary Agriculture. Kenya Institute of Education, 1999

## Field Study 1.7. Root Doctor

**Objectives:** To investigate the general health of a soil by the condition of plant roots.

**Time required:** 2 hours

### Materials

- digging tool
- paper and pencil
- magnifying glass

### Procedure

1. Explain the objectives of the study.
2. Select a soil to study. Soil from a home garden is ideal. Carefully dig up some healthy looking weeds. (The group can also dig up a crop plant to examine its roots.) What do the roots look like? Be careful to cut off as little of the root mass as possible.
3. Make a chart similar to the one below, to record your findings.

Date of study	Description of plant	Volume of soil where roots grow	No. of fine root hairs	Direction that plants grow
Plant 1				
Plant 2				

4. Do the roots seem vigorous and well balanced? One way to tell is by estimating how far the plant roots grow into the soil. The deeper and wider the roots spread out (i.e. they grow in a large volume of soil), the more likely the plant can obtain what it needs from the soil. Record your results.
5. Use a magnifying glass to study the fine root hairs. Do the roots have many or few root hairs? If there are only a few fine feeder roots, it may mean that the roots have too little air in the root zone.
6. Examine the directions in which the roots grow. Do they grow in every direction, or do they grow sideways at a certain depth? If they suddenly grow sideways, there are probably obstacles in the soil, such as stones or a hard layer of soil.
7. Observe and record the condition of plant roots growing in this location over time.

### Conclusions

- From the group findings, do they think the soil is fertile or infertile?
- Do they think the condition of the soil changes over time?



## Module 2. Soil Water

### Learning objectives

- Understand the water cycle
- Make a simple rain gauge and record daily rainfall
- Understand why plants need water and how water is stored in the soil
- Explain the importance of water soaking (infiltrating) into the ground
- Observe the movement of water in soil
- Compare the water-holding capacity and drainage of different soils
- Understand that different plants have different water requirements; and that an individual plant or crop has varying water requirements during its life cycle
- Understand how infiltration can be improved and evaporation reduced by cultivation practices

When rain falls to the ground, some of it flows over the land and finds its way into rivers, dams and lakes, and eventually to the sea. This water is called runoff. The rest of the rain soaks into the ground, moving into the soil through cracks and other spaces. This is the soil water on which plants survive. The circulation of water from the earth's surface to the atmosphere and back again is called the **hydrological cycle**. Figure 2.1 shows a simple model of the hydrological cycle in a rural community. Field Study 2.2 describes a simple classroom experiment, demonstrating parts of the water cycle.

### Where is Water Found?

Farmers should sum up and discuss all water resources in their community. Field school groups can study several sites to discover the relationships between

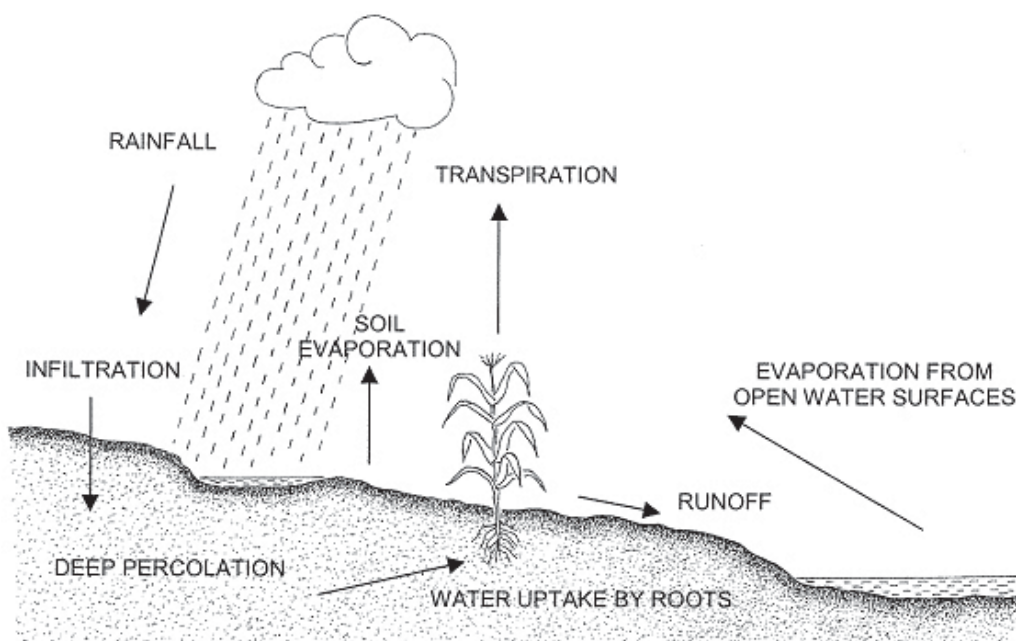


Figure 2.1. The hydrological cycle (Source: FARMESA 2003)

the various supplies of water in the community, and the impact these may have on the different users of water.

It is important for farmers to understand what actually happens in their community during seasonal rains, both above and below the ground. Water supply and demand is very important to a farmer. A farmer must know how to observe and measure rainfall, and to calculate the amount of soil water. Field Study 2.1 describes a simple method of measuring and recording rainfall.

A good knowledge of soil water balance will enable a farmer to answer the following questions:

- In rainfed farming, what crops can be successfully cultivated, taking soil moisture conditions into account?
- What are the risks of crop failure if there is a shortage of soil water? The question may be asked for the season as a whole, but especially for critical periods in the growth cycle of a crop that commonly coincide with mid-season droughts.
- At what times during the season would the plants benefit from additional watering (e.g. in home gardens)?

Soil water is one of the best indicators of how well plants can grow in a soil. Understanding how water moves and behaves in different soils is very important because farmers want to make sure their crops receive enough water. Plants wilt if the soil becomes too dry. If the soil is too wet, plant roots do not get enough air. Some plants grow best if their soil stays moist, most of the time. Other plants grow well if the soil is well drained, and does not hold a lot of water for too long.

## **Soil Water Concepts**

How well does a soil hold water? How quickly does water flow through a soil? These are two very important characteristics of soil, especially in areas with low and unpredictable rainfall. The amount of water in a soil will depend on how much of the rainwater remains in the soil after losses by runoff, evaporation, and deep drainage. Good water management will maximise the amount of water that enters the soil, and make best use of it while it is available. Farmers can investigate some of the water properties in their local soils using Field Study 2.3.

### **Water infiltration rate**

The term infiltration refers to the rate at which water moves *into* a soil. The water infiltration rate indirectly measures the quantity of large pores in the soil, because it is these large pores which allow the easy movement of air and water. Infiltration rate is affected by texture, structure, compaction, and organic matter content of the surface layers of the soil.

If water infiltration into the soil is restricted or blocked, less water soaks down to the subsoil for use by crop roots. Poor infiltration means more run-off; and water running over the surface may remove soil particles (erosion) and valuable fertilisers from the field. Soil particles and chemicals may thus end up in streams and lakes or in other places where they are not wanted. Excess run-off can also cause local flooding of fields, streams and rivers.

### Field test

To test soil drainage, dig a hole in the ground the size of a 20 liter bucket. Fill the hole with water. Let the soil absorb the water for one hour. Then fill it again with water. The hole should drain completely within 24 hours. If not, the soil is poorly drained and not suitable for most crops.

### Soil permeability and drainage

When water enters the soil, it moves downwards by gravity. It flows through air spaces (i.e. pores) between the soil particles and between soil aggregates (peds). The ability of a soil to let water pass through it is known as *permeability*.

How well water passes through the soil depends on many factors, such as the size of the soil particles (texture), how the particles are arranged (structure), how tightly they are packed together, and the attraction between soil particles and the water.

Sandy soil contains larger-sized particles and larger pore spaces, so water will drain (percolate) quickly through it. Sandy soil is said to be highly permeable. A soil that prevents water passing through it quickly is called slowly permeable or, in the extreme case, impermeable. Soils high in clay have small pore spaces, so water passes through only slowly.

### Remember

Infiltration refers to the rate at which water *enters* the soil  
Soil permeability refers to the rate at which water moves *through* the soil

The rate of water movement into the soil (infiltration), the degree of water movement over the surface (run-off), and the rate of water movement downward through the soil (permeability). These three movements, together, are called drainage. Slope is a very important factor in soil drainage. One good indicator of drainage conditions is the colour of the soil. Clear, bright colours indicate well-drained soils. Mixed, dull, and mostly grey colours indicate poor drainage. Both, too much and too little water in the soil are undesirable. With too much water, most plant roots cannot breathe from lack of oxygen. Where there is too little water, plants will wilt and eventually die. The best situation is when about half the pore space in the soil is filled with water.

### Evaporation from the ground

*Evaporation* describes the movement of water from the soil surface to the atmosphere. If the ground contains a lot of water, evaporation may be high, but if the ground is dry, the amount of water evaporated will be low.

The air above the ground surface continuously sucks up moisture from the soil. This is water found in the soil pores. That is why the soil surface dries out quicker than the sub-surface soil layers. The rate of evaporation depends on exposure of the surface to the sun, ground cover, air and ground temperatures, soil type and wind speed.

When the soil is bare, large amounts of water can be lost by evaporation. Strong sun and winds increase evaporation. During the early stages of crop

**Important principle**

Water that is transpired corresponds to a certain amount of plant growth  
Water that evaporates without passing through a plant is simply wasted

growth, the soil surface is bare and evaporation rates are very high. Therefore, a lot of soil moisture is lost, which can cause severe stress to young plants during their most vulnerable growth stage. Quick drying of a seedbed can damage an entire crop from the start. Weeds also pump water out of the soil and increase the rate of soil drying. This is why good weed control is vital in dry areas.

In areas with low rainfall, it is important to minimise evaporation as much as possible. This can be done by good management (see also Field Study 2.4).

**Water uptake and transfer by plants**

Plants depend mainly on roots to supply them with water and nutrients from the soil. Strong forces draw water from the soil into the roots and plant tissues, and then out again through the plant leaves. These forces are very similar to sucking up water through a straw. As water is given out from leaves, more water is drawn from the soil. This water evaporates from the leaves through small pores called stomata. The loss of water through a plant's stomata is called *transpiration*. Its importance is directly linked to plant growth. Field Study 2.5 demonstrates the process of transpiration in plants.

Since the plant gets its nutrients through water uptake, the rate of transpiration is closely related to crop growth. The more water that passes through the plant, the faster the plant will grow.

**Definition of crop water use efficiency**

The efficiency of crop water use is usually expressed as the amount of dry matter produced for each millilitre of water lost from the soil surface by crop transpiration and evaporation

For a plant to grow successfully, it has to achieve a balance between the amount of water it gives out to the atmosphere through its leaves (transpiration) and the amount of water available to its roots (moisture availability). The problem is that rainfall – and hence moisture supply – are irregular, while the demand by the atmosphere for water is more or less constant.

To survive during dry spells, the plant must rely on the reserves of water in the pores of the soil. When the plant does not get enough water from the soil it starts releasing water from its tissues and the plant begins to wilt.

The rate of transpiration from a field covered with vegetation varies in time. For example, imagine sorghum seeds sown on a tilled plot free of weeds. Before the seeds germinate, there will be no transpiration. From emergence to full maturity of the leafy stems, the transpiration capacity of seedlings increases in proportion to root and leaf development. If the ground dries up for a short time, plants stop transpiring – but they still keep their ability to transpire as long as the leaves and roots are healthy. When the plants reach the end of their life cycle, the leaves and roots dry up and stop transpiring.

Do not forget that plants also compete with weeds for water and nutrients. Some weeds can extract scarce soil water (and nutrients) so well that they are able to ‘rob’ the water that is needed by crop plants.

## Plant-Available Water

A very important characteristic of a soil is its ability to hold water. Plant-available water (PAW) is the amount of water that a soil can store. It is the water held between *field capacity* (FC) and the *wilting point* (WP). This water can be extracted by roots and used for crop growth.

### Mathematical definition of plant-available water

$$PAW = FC - WP$$

**Field capacity** is a measure of how much water a freely drained soil can hold about 1-2 days after thorough wetting by good rainfall or irrigation. After reaching field capacity, air will have re-entered the larger soil pores. At field capacity, plant growth is at its maximum and the soil feels very moist when you touch it. Soil holds and releases water like a sponge. When you take a sponge out of a bucket of water, it is fully saturated. If you hold it gently, the sponge drips water. It is losing water because the sponge is unable to hold the water against gravity. After some time the sponge stops dripping. It still contains a lot of water because it is able to hold the water in its air pockets. This water is like the field capacity of a soil after rapid drainage.

**Wilting point** is reached when all available soil water has been used or when a plant can no longer remove soil water (i.e. only non-available water remains). At this point the plant is thirsty and its leaves droop; the soil feels nearly dry or only very slightly moist. In practice, the wilting point is the water content at which seedlings wilt irreversibly and die. Wilting is a direct indicator that a plant is suffering from water stress.

The amount of plant-available water depends on various factors – texture, soil structure, organic matter content and the plant’s rooting depth. Soil organic matter is especially important because it can hold up to 20 times its weight of water. Field Study 2.6 demonstrates the effect of soil organic matter and texture on soil moisture-holding capacity.

The quantity of available water can be expressed as millimetres (mm) of water per meter (m) of soil depth. It varies from 40 mm/m in coarse sandy soils to more than 180 mm/m in clay soils. Higher values occur in soils which are very rich in organic matter. A rough guide is given in Table 2.1.

The amount of water available to plants also depends on the depth of soil that can be exploited by the crop, especially by its underground root system. All soil-plant interactions occur in the space near the roots. Plant condition and planting density determine the volume of soil that must be saturated to its field capacity to give adequate water to a plant. Deep rooting crops will have access to more water as compared to shallow rooting crops.

**Table 2.1. Water-holding capacity of some soil texture groups**

Texture	Field capacity (mm/m)	Wilting point (mm/m)	Available water (mm/m)
Coarse sand	60	20	40
Fine sand	100	40	60
Loamy sand	140	60	80
Sandy loam	200	80	120
Light sandy clay loam	230	100	130
Loam	270	120	150
Clay	350	170	180

Figures are averages and will vary depending on structure and organic matter content  
Source: ABSA 1997

### **Making water available to plants**

There are three components of successful rainfed farming in drier areas:

- retaining rainfall on the land and in the soil
- reducing evaporation
- using crops that have drought tolerance and that match rainfall patterns.

Some of rain falling on the land is of little use to crops. In semi-arid areas with summer rains, crops sometimes use only 30% of total rainfall. The remainder may be lost by weed transpiration, evaporation (can be very high, up to 50% of total rainfall), surface runoff (about 10-25%) and deep drainage into the groundwater table (10-30%). This is inefficient use of water, which is often caused by poor crop management. The effect is low productivity. In these environments, farmers must carefully manage the little water that is available. Farmers can use various techniques to obtain this water, conserve it, and use it efficiently. In this way, good land management can also prevent any damage or loss of soil.

For example, water harvesting and soil moisture retention practices will reduce runoff and evaporation. And if this water enters the soil, more water will be available for the crop. The timeliness of operations (tilling, planting, weeding) is also important.

Another technique is to correctly match land use to soil type, i.e. within the farm, grow each crop in the soil type most suited for it. This can increase the efficiency with which the soil water available in the different soil types is utilized for crop production. For example, a soil suitable for maize in semi-arid areas must be able to store enough water and should be of sufficient depth so that the maize can tolerate a dry period of up to four weeks.

Farmers can also take advantage of variations in available water capacity by planting moisture-sensitive crops and crops with longer growing periods on soils with high available water, and drought-tolerant and early-maturing crops on soils with low available water. The growth period of common field crops and their susceptibility to drought are given in Tables 2.2 and 2.3.

#### **Rule of thumb**

Improve soil properties to improve plant-available water. Every 50 mm of stored water (plant-available water) in the soil can increase yield potential by 1 ton per hectare, if the water is stored for plant growth. Therefore, yield and income are directly linked to the amount of water the soil can capture and hold for a crop.

**Table 2.2. Growth period (days) of common field crops**

Crop	Establishment	Vegetative	Flowering	Yield formation	Ripening	Total
Beans (fresh)	10-15	20-25	15-25	15-20	0-5	60-90
Cotton	15-25	25-35	60-70	30-40	15-20	150-180
Cowpea	10-15	10-20	15-40	10-30	0-15	45-120
Groundnut	10-20	25-35	30-40	30-35	10-20	90-140
Maize	15-25	25-40	15-20	35-45	10-15	100-140+
Millet	10-20	25-40	10-20	30-40	10-15	85-135
Onion	30-35 (nursery)	25-30	–	30-80	25-30	100-140
Sorghum	15-25	25-40	15-20	35-40	10-15	95-125
Soybean	10	30-40	25-35	30-40	10-15	100-130
Sunflower	20	25-30	30	25	15	90-130
Tomatoes	25-35 (nursery)	20-25	20-30	20-30	15-20	100-140
Water melon	10-15	20-25	15-20	20-30	15-20	80-110

Adapted from FAO 1986

**Table 2.3 Crop susceptibility to drought**

	Growth cycle (days)	Sensitivity to drought	Critical periods for soil water stress
Bananas	300-365	Low - medium	Throughout, especially early vegetative growth, flowering and up to bunch formation
Beans	Fresh: 60-90 Dry: 90-120	Medium - high	Flowering, pod setting, ripening period
Cabbages	100-150+	Medium - high	Head formation & enlargement
Citrus	240-365	Low - medium	Flowering and fruit set. Flowering can be induced by not watering just before flowering stage
Cotton	150-180	Low	Flowering & boll formation
Cowpea	45-120	Low	
Groundnut	90-140	Low - medium	Flowering (root activity reduced) & seed development
Maize	100-140+	Medium - high	Pollination period from tasselling to blister kernel stage. Less acute at grain filling
Peas	Fresh: 65-100 Dry: 85-120	Medium - high	Start of flowering & when pods are swelling
Pigeonpea	130-190	Low	
Potatoes	100-150	High	From flowering to harvesting (during tuberisation)
Sorghum, Millet*	85-140+	Low	Very sensitive during emergence, flowering & seed formation
Sweet potato	115-155	Low - medium	Forming and swelling of tubers
Sugarcane	270-365	High	Period of max vegetative growth
Sunflower	90-130	Low - medium	Germination, flowering & grain development
Tomatoes	90-140	Medium - high	When flowers are formed & fruits are rapidly enlarging

\* Sorghum is tolerant to water stress early in growth cycle, unlike maize

Adapted from *Yield response to water*. FAO Irrigation and Drainage Paper 33, Rome, 1986

## Crop growth and water

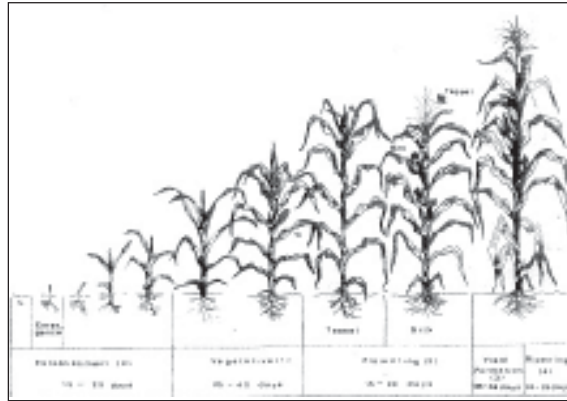
The amount of water that goes through the plant is directly linked to yield levels. It is therefore very important to capture as much as possible of the total water available for transpiration by plants. This means that soil must be moistened deeply.

Before a farmer can plan how to use his/her land, the life cycles of the main crops should

be understood in terms of their water requirements, because:

- plants are not thirsty all the time – their water requirements depend on the phase of their life cycle
- the volume of soil from which plants extract moisture varies with root growth and soil conditions.

Plants adapt to semi-arid conditions in different ways. Some plants have a short life cycle: they germinate, grow, and produce a crop during a very short period of available soil moisture. Plants with short life cycles such as millet and sorghum can satisfy their water needs by taking infiltrating water from the superficial soil layers, when available. Then, there are plants with deep or extensive root systems which can draw water from a greater volume of soil. Field Study 2.7 will help you discuss crop water requirements.



**Figure 2.2. Growth stages of maize**  
(Source: FAO 1986)

### Principle

To ensure satisfactory yields, the periods when water is available in the soil must coincide with the periods when crop plants need water

## How does water stress affect crop growth and yield?

Scarcity of water hinders the growth, development and yield formation of crops. In rainfed farming, insufficient rainfall (i.e. the lack of soil water) is one of the main reasons for uncertain production and low yields. Many semi-arid areas have not only low total rainfall but also poor and unpredictable rainfall distribution. Mid-season droughts are common and can cause extensive damage to a standing crop.

The effect of water stress on yield depends very much on the crop, the stage of crop growth at which the stress occurs, and even on the crop variety. In general, crops are more sensitive to water stress during flowering and yield formation than during vegetative and ripening stages. If water stress occurs outside the critical growth stages, foliage/straw production may be affected more than grain yield.

In cereals, even slight water stress at flower initiation can markedly reduce the potential number of grains per ear. Stress during flowering can inhibit fertilisation of the flowers and grain set. Moreover, root growth of many cereal crops is very much reduced and may even stop altogether when the flowers start to develop.



When root activity slows down during this critical period, water absorption by the plant can be severely reduced. For example, maize is the most sensitive of the cereals to water stress, and even short periods of wilting at flowering and grain filling can reduce yield by 50%. The critical growth stages, when maize is most sensitive to water stress, are shown in Figure 2.2.

Many areas with low and erratic rainfall, where crop water stress is common, also have soils that are deficient in nutrients. Farmers may apply fertilisers. But whether or not the crop will respond to fertiliser, and how much fertiliser should be applied, will depend on water availability. This is particularly important with Nitrogen fertiliser.

Water shortages may take many forms and affect the plant in different ways:

- The total amount of water absorbed by the soil was not enough during the growing season. For example, a total of only 200mm entered the soil instead of a minimum of 400mm needed for a particular crop.
- Total amount of rainfall during the season may have been enough, but too little water was available at a crucial time, e.g. at emergence or at flowering. Suppose there is a mid-season drought during the flowering phase of maize (or any other cereal crop). Yield will be severely reduced. Some farmers may even lose the entire harvest.
- The risk of crop failure depends on the *duration* of the period of water deficit. The longer the deficit lasts, the greater the risk.
- The risk of crop failure also depends on the *suddenness* of the water deficit. If the deficit occurs suddenly, plants may not be able to adapt sufficiently to the new growth conditions.
- If there are several periods of insufficient rainfall, the effects are cumulative. For example, if a sunflower plant suffers from severe moisture stress at the shooting phase, the plants and flowers will be stunted. Later, if there is mid-season drought during bud emergence, seed set can be severely affected because the plant's root system is too weak to feed the flowers, or the bud is badly formed or not formed at all.

## Indicators of Crop Water Stress

Direct indicators of water stress are wilting, leaf roll, high leaf temperatures, stunted growth and leaf drop. The most useful and visible sign is that of crop wilting in the early morning. Crops frequently wilt at midday or during the hot afternoon, but this is often temporary water stress and crops will recover during evening or night when it is cooler. Temporary water stress rarely affects growth or yield seriously. In contrast, wilting that has persisted overnight into the morning, and is not relieved during the next day, usually indicates severe water stress from which the crop may not recover. Leaf drop indicates prolonged periods of very severe water stress.

### Questions for farmers

What indicators do farmers use as evidence of crop water stress?  
What strategies do farmers use to overcome crop water stress?

## Field Study 2.1. Making a Rain Gauge and Measuring Rainfall

**Objectives:** Farmers to measure daily rainfall in their own fields

**Time required:** 45 minutes for making and installing rain gauge; a few minutes every day during growing season to measure and record daily rainfall

### Materials

- plastic transparent bottle with regular cylindrical shape
- plastic ruler
- knife
- pole, 1.5m long
- piece of string, or soft wire (2 pieces of 50 cm)

### Procedure

1. Explain the objectives of the study.
2. Cut top of bottle.
3. Put pole upright in open terrain (away from buildings and trees). Height of the pole above ground should be about 1.2m.
4. Tie bottle to upper part of pole. Make sure it is easy to tie and untie the bottle.
5. Every morning, measure depth of water in bottle with ruler.
6. The depth (in mm) is the amount of rainfall (in mm).
7. Empty the bottle after recording the rainfall for that day.
8. Re-tie the bottle to the pole.
9. Repeat steps 4-7 every morning after rainfall the previous day and/or night.

## Field Study 2.2. Understanding the Water Cycle

**Objectives:** This simple experiment poses questions that are not widely understood. For example, how does the water cycle function on the land? What causes floods and droughts?

**Time required:** initially 1 hour; more observations the next day(s)

### Materials

- 4 two-litre plastic bottles, of which at least two should have a handle
- 4 plastic drinking cups
- a sharp knife
- some 'Sticky Stuff' or putty

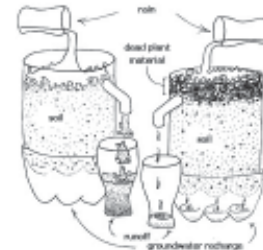
### Procedure

1. Explain the objectives of the study.
2. Take the two plastic bottles with handles. Cut off the top of each bottle, and also make small holes in the bottom. Cut the handle halfway. Leave the top half attached to the bottle. Remove the bottom half of the handle and seal the hole where it joined the bottle. The top half of the handle thus becomes a 'spout'.
3. Fill both bottles with soil to the level of the spouts. In one bottle, add a layer of dead plant material (litter) on top of the soil, as shown in Figure A.
4. Cut the base from the two other plastic bottles. Fix the bases under the two bottles containing soil. Place drinking cups under the spouts, and pour a

- cupful of water into each bottle (Figure B). Do it where people can see what happens over the next few minutes.
5. Pour a second and third cupful of water into each bottle and observe what happens. Over time, the rates of evaporation from covered and bare soils can be observed.



**Figure A**



**Figure B**

### **Field Study 2.3. Comparing Water Infiltration Rates for Different Soils**

The surfaces of some soils are more dense and compacted than others. Some soils have a surface crust. What causes soil to compact and crusts to be formed? Are they trampled by feet, machinery, raindrops or cattle? What in nature keeps soils from becoming compacted: earthworms, insects, roots, organic matter, wetting and drying? Is compacted or non-compacted soil more porous? This exercise should help answer some of these questions.

#### **Objectives**

- Understand how water moves into soil
- Understand relationship between particle size of the surface horizon and rate of water flow into the soil
- Test the infiltration rate of soils having different colours
- Demonstrate differences in the infiltration rate of soils having different cropping histories and soil cover.

**Time required:** 2-3 hours

#### **Materials**

- 30-35 cm length of 20 cm diameter PVC drainage pipes
- watch
- water source
- one 5-liter bucket to carry water
- permanent marking pen
- paper and pens for report

#### **Procedure**

1. Explain the objectives of the study.
2. Visit three sites in a field where soil samples were taken for the previous exercise.
3. At the first location, carefully push the pipe into the ground (using a screwing motion) a few centimetres. Try not to disturb the soil inside the pipe.

4. Make a prediction about the rate of water absorbed by each soil type and discuss reasons why differences might occur.
5. Fill the PVC cylinder with water to a few centimetres below the top. Record the time taken for 5 litres of the water to enter the soil. Note any changes in the soil's behaviour and record these observations.
6. Repeat steps 2-4 at the second and third locations.
7. Each group should present their results and findings at their location. Thus, all the three sites will be studied, and the results discussed.

### Conclusions

1. Which soil sample had the highest infiltration rate?
2. Discuss the reasons for differences observed in time taken for water to infiltrate into the three types of soil. Relate these differences to the texture, porosity, colour and surface cover (if any) of soil in each case.
3. How does the texture and porosity of each soil compare to its infiltration rate? Does soil cover make any difference to infiltration rate? How important is it for us to know this?
4. Discuss the impact that these differences will have on soil erosion and loss of rainwater, nutrients and fertilisers by runoff and by drainage.
5. Which soil type is suited for which crops? How does this correlate with the cropping history observed in the field?
6. Are livestock kept in the area? If so, what kind of livestock?
7. How could farmers use this knowledge? For example, will the results of this experiment change the criteria used by farmers in future to better match crop needs with the different soil types on their fields? Why or why not?

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**Data table:** Record data using the following table.

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Soil type	Soil texture and colour	Cropping history (minutes)	Time for water to enter soil
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## Field Study 2.4. Soil Cover to Reduce Evaporation

**Objectives:** To see how evaporation takes place, and how soil cover can reduce evaporation

**Time required:** 45 minutes at the beginning and 20 minutes 4 hours later. The exercise should be carried out in the middle of a hot sunny day

### Materials

- mulch (dry grass or crop residues) cut into small pieces
- 2 big transparent plastic bags
- watering can, water
- nails
- sticks

**Procedure** (Source: FARMESA 2003)

1. Explain the objectives of the study.
2. Locate a flat area of bare soil and mark out two squares 50cm x 50 cm. Cover one of the squares with a 1 cm layer of mulch.
3. Water the two plots with about 10 litres of water.
4. Place the plastic bags over the soil so that the open end of the bags covers as much as possible of the plot. The bags should be full of air and take up as much volume as possible. Place sticks inside the bags to keep them upright. Finally, use nails to fix the opening of the bags into the ground.
5. Leave the plots in the sunshine for four hours. After 4 hours return to the plot and study the amount of water that has evaporated from the soil and now hangs on the inside of the plastic bags.
6. Discuss the outcome of the experiment and the benefits of soil cover.

### **Field Study 2.5. Demonstrate the Process of Transpiration in Plants**

**Objective:** To demonstrate the process of transpiration and the variation in transpiration rate with temperature and exposure to the sun

**Time required:** 1 hour; could be repeated during different times of the day

**Materials**

- clean, dry transparent plastic bags of approximately 30 x 40 cm
- string

**Procedure**

1. Explain the objectives of the study.
2. Select a field where the soil is moist, and where tall leafy plants are growing
3. Select a tall plant or clump of plants in the shade. Tie the plastic bag over the upper stems to enclose as many of the leaves as possible. At the same time, repeat for plants growing in the sun.
4. Wait 10-15 minutes, then remove the plastic bag. Observe and measure the quantity of water droplets inside the bag that were formed as a result of leaves transpiring.
5. Repeat steps 1-3 for large common weeds in the field. It is also useful to investigate water loss from plants during different hours of the day (early morning, noon, late afternoon, evening).
6. Compare the differences and discuss conclusions.

### **Field Study 2.6. Effect of Soil Organic Matter and Texture on Moisture-Holding Capacity**

**Objectives:** To appreciate the role of soil organic matter, texture and organic matter management in soil moisture retention

**Time required:** 1-2 hours

**Materials**

- paper and pens
- small scale (5 kg max)

- container to use for weighing
- 4 small cotton bags (or stockings)
- small buckets
- water

**Procedure** (Source: FARMESA 2003)

1. Explain the objectives of the study.
2. Collect four soil samples: two soils of similar texture but different in organic matter content, and two soils of different texture
3. For each soil sample, weigh 500grams in a container and put soil into a bag. Close the bag to make sure no soil can escape (all the bags should be made of the same material).
4. Immerse the bag in a small bucket of water and leave for about 5 minutes to make sure the soil is completely wetted.
5. Take the bag out of the bucket and hang it up for about 10 minutes to allow the free water to drain out.
6. Weigh each bag and its contents and record the weight.
7. Calculate (by subtraction), the difference between the initial and final weight for each soil. This difference is due to the amount of water held by the soil.
8. Compare the figures for the different soils.
9. Go back to the original four soil samples. For each sample, put 250grams in a container, add water to cover the soil, and stir vigorously for 30 seconds. Now observe the materials that float on top, versus materials that settle at the bottom.

**Questions for group discussion**

- Why do different soils hold different amounts of water?
- What can we do to increase the amount of water held?
- What are the materials floating on water in each container?

**Comments**

You can also ask farmers to collect their own soils, do the same exercise, and rank the soils with respect to water holding capacity. You could also use the soils collected during transect walks.

## **Field Study 2.7. Crop Water Requirements**

**Objectives:** To understand how much water different crops need, and what affects a plant's water needs.

**Time required:** 45 minutes

**Materials:** paper, pens

**Procedure** (Source: FARMESA 2003)

1. Explain the objectives of the study.
2. Form groups of about 4-5 persons.
3. In each group, compare the water requirement for each of the crops grown in the area. List the crops in order of drought tolerance, i.e. from highly drought-tolerant crops, to crops that need most water.

4. In each group select 2-3 crops and analyse their water requirement. Consider each growing stage of the crop and try to determine which stages are crucial, i.e. stages when water is critically important for the crop, and stages when it is less important.
5. Discuss the physical factors that affect crop water requirement: soils, weather conditions etc.
6. Summarize the findings of your group and present it to the other groups.

## Module 3. Soil Life

### Learning objectives

- Identify various forms of soil life
- Appreciate the role of soil organisms in maintaining soil fertility
- Understand how tillage and other farm management practices affect soil life

Farmers walk over their fields, till the soil, apply manure and fertiliser and harvest crops with little thought to life underneath the soil surface. When you look at the soil, it may seem like lifeless sand and rocks. In fact, healthy soil is crowded with life. A teaspoon of soil may contain billions of living things that are so tiny they are invisible to the naked eye. These microscopic organisms include nematodes (tiny worms), bacteria, fungi and many larger soil creatures (earthworms, dung beetles, cutworms, termites, spiders, ants, etc). This mix of living things under the ground is called *soil biodiversity*. Without these soil organisms the soil is dead and is unable to sustain plant growth. Together, these creatures perform tasks that are vital to all life on earth. Field Study 3.1 gives some ideas how farmers can examine their soils for living organisms.



**Figure 3.1. Various soil creatures (not to scale)**

### Where do soil organisms live?

The majority of soil organisms (biota) live in the top 10 cm of soil. Farming practices that change the environment in this top 10 cm layer will have an effect on the type and number of biota that live in this layer. For example, if topsoil is lost by erosion, soil organisms are also lost.

### What do soil organisms do?

The action of breaking down organic materials in the soil is called *decomposition*, and the many creatures which break down the materials are called *decomposers*. Soil creatures such as mites, millipedes, *chongololos*, insects (including termites) and earthworms *physically* break down once-living

### Rule of thumb

Under favourable conditions, 10% of the organic matter in soil is made up of soil animals. Thus, a layer of soil covering one hectare to a depth of 10 cm with 1% of organic matter contains roughly 1500 kg of soil creatures. This equals the weight of 3 to 4 cows!







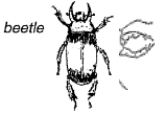

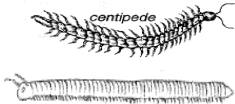
organic materials. Other decomposers such as fungi, algae and microscopic bacteria and protozoa *chemically* break down organic matter.

As these organisms break down organic material, nutrients locked up in dead plants and animals are released into the soil. When the nutrients are dissolved in soil water, they can be taken in by plants through their roots. Over time, the organic matter will become humus. Humus is the name for highly decomposed plant and animal remains. Soil with a lot of humus is very fertile. Most soil organisms help plants in many ways:

- break down dead leaves and other plant debris, converting them into organic matter, and making their nutrients available for crop roots
- burrow in the soil to make small tunnels that increase air space and water movement
- increase nutrient availability, storing nitrogen and other mineral compounds
- fix nitrogen from the air
- cause tiny soil particles to stick together (aggregate), opening up spaces that allow water and air to enter the soil more easily
- protect plant roots from harmful organisms
- serve as food for predators such as beetles.

Plants will either grow well or suffer, depending on the organisms that live around their roots. Some organisms such as fungi that surround plant roots, not only provide nutrients to the roots but also shelter large numbers of other soil organisms (mainly bacteria) which protect the plant from disease-causing organisms.

This close relationship between a plant and a soil organism is called *symbiosis*. Some farming practices are harmful to soil organisms. It is easy to

Soil organisms	Count
Plant roots	nil, few, or many
Moulds, fungi	
 <i>earthworm</i> Different kinds of worms (e.g. earthworms, roundworms, flatworms, snails and night-crawlers, which have no legs)	
Different kinds of grubs (thick worm-like creatures that are larvae of insects)	 <i>larva</i>
 <i>springtails</i> Different kinds of insects (animals with 3 pairs of jointed legs), such as ants, termites, springtails, beetles, crickets, etc	 <i>beetle</i>
 <i>spider</i> Different kinds of spiders, mites and ticks (animals with 4 pairs of legs)	
Different kinds of animals with more than 4 pairs of legs (e.g. centipedes, millipedes, chongololos)	 <i>centipede</i>

**Figure 3.2. Soil life chart**

see how inappropriate management practices can upset the balance between, for example, a fungus and a plant. If the soil is grazed or cropped too long without rest, plant roots are retarded and the large soil organisms are killed (due to lack of organic matter and extremes of temperature). Next, the fungi are killed. Pores between soil particles become smaller, air and water infiltration is restricted.

The level of soil biota activity helps the soil's ability to recover from stresses like compaction, waterlogging, and tillage.

### **Termites and ants**

Termites play an important role in African soils. Although they are best known for their habit of eating and destroying crops and wooden structures, they also have a beneficial role. Like many other soil creatures they play a prominent part in recycling nutrients, particularly nitrogen, through disintegration and decomposition of dead wood and plant debris. By building mounds, termites bring different soil materials to the surface. These soil materials are often rich in clay and minerals. When the mounds erode, the soil particles and nutrients are washed into the surrounding soil and become available for plant growth. The channels ('galleries') built by termites in the mounds improve structure, permeability and water-holding capacity of the soil.

## Field Study 3.1. How Alive is the Soil?

**Objective:** This study will enable farmers to recognise that soil contains living things. Group members will probably recognise some of the larger soil creatures, but identification is not as important as understanding that there are billions of soil organisms and micro-organisms, of many different species. Farmers will of course have local names for many creatures seen in this exercise.

**Time required:** 1 hour

### Materials

- 3 big paper bags
- ruler
- small spade
- 6 or more small jars with lids (with small holes punched into the lid)
- magnifying glass
- sheets of newspaper
- a copy of the “Soil Life Chart” (Figure 3.2 in)

### Procedure

1. Explain the objectives of the study.
2. Select four different locations: (a) kitchen garden, especially near plant roots, (b) sorghum field, (c) badly eroded field where the subsoil is exposed, (d) below the surface or dead grass layer in a pasture or ungrazed plot.
3. Form four groups, each with about five farmers. Each group is assigned a different location.
4. At each location, mark off an area of land approximately 30 X 30 cm.
5. Gently sift through the leaf litter, and collect any creatures that are found. Look on the soil surface for evidence of holes. Record what is found, using the Soil Life Chart.
6. Dig the soil to a depth of about 4-6 cm. Observe and record the presence of plant roots.
7. As the soil is dug and removed, watch for worms and other animals. You may find other signs of animal life such as burrows or eggs of insects which may be single or in masses or pods.
8. Spread the soil onto a sheet of newspaper.
9. Carefully sort the soil, watching closely for small living things. Place the different kinds of animal life in separate jars. Count the animal life belonging to each of the groups shown on the Soil Life Chart.
10. Examine these creatures with a magnifying glass, and make drawings of them. Return the creatures to the soil after observations and drawings are completed.

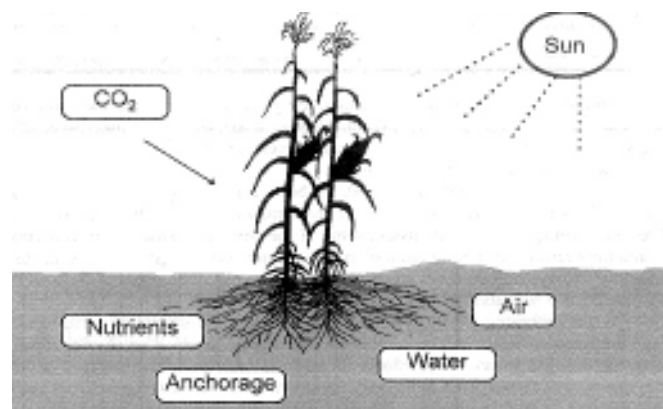
## Module 4. Soil Fertility and Plant Nutrition

### Learning objectives

- Explain why plants need nutrients and where nutrients come from
- Realise that different plants need different nutrients and that the same plant/crop has different nutrient requirements at different stages of its growth cycle
- Consider the factors that make a soil fertile or infertile
- Identify major nutrients limiting crop production in that area
- Identify some nutrient deficiencies from seeing how the crop looks
- Understand how crop nutrients can be lost or gained
- Appreciate the importance of applying external nutrient inputs to the field
- Apply knowledge of crop nutrient demand to improve plant nutrition

All crops need nutrients to produce healthy roots, leaves and seed (grain). To grow, plants get food by taking up water and mineral substances from the soil, carbon dioxide from the air, and energy from the sun. Like humans, plants need a balanced diet containing a mixture of different nutrients. Good soil fertility management means that farmers know the crops' nutrient needs: the kinds and amounts required, and when they should be applied to coincide with the crop's growth phases.

If a soil cannot meet the basic needs of plants, then the soil is unproductive, or infertile, and the plant will not grow well. The ability of the soil to supply enough nutrients for plant growth is called soil fertility. How plants take up nutrients and use them in their metabolism is called plant nutrition.



**Figure 4.1. Basic plant requirements for growth (from Raussen 1997)**

But a nutrient-rich soil is not always productive. To be productive, soil must also provide a healthy environment for plant growth; and the nutrients it contains must be available for use by the plants. Productive soils are characterized by:

- good rooting conditions (soils deep enough to provide anchorage for plants)
- good moisture conditions (enough rainfall and good water-holding capacity)
- good drainage (enough air for roots to breathe)
- absence of toxic (poisonous) substances
- absence of hazards, such as floods
- good workability: easy to carry out planting and other operations

**Box 4.1. The role of N, P and K in plant growth (after Raussen 1997)**

- Nitrogen: affects the growth of leaves and the whole plant. Plants well fed with nitrogen are large and dark green. Nitrogen is generally the most deficient nutrient in the soils of Zimbabwe
- Phosphorus: is an important substance in growing parts of a plant. It encourages growth of roots and development of flowers and seeds. Phosphorus deficiency is common in Zimbabwean soils
- Potassium: strengthens plant stems against lodging and increases disease resistance. It is required for sugar/energy manufacturing in the plant. Plants with adequate potassium can better withstand drought conditions. Potassium is generally not deficient in the soils of Zimbabwe.

## Nutrients Needed for Plant Growth

There are 17 nutrients which are essential for plant growth (Table 4.1). These nutrients are obtained from the air and the soil. Different plants need different quantities of each of the 17 nutrients. **Macronutrients** are nutrients which are needed in relatively large amounts, like carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca) and magnesium (Mg). **Micronutrients** or trace elements are nutrients which are needed in small amounts, like boron (B), chlorine (Cl) and zinc (Zn).

Each nutrient, whether required in large or small amounts, fulfils a specific role in plant growth. One nutrient cannot substitute for another. The importance of the major nutrients N, P and K is described in Box 4.1.

Some nutrients like hydrogen, oxygen and carbon are usually plentiful, but others may be present only in small quantities. Deficiency of any nutrient, regardless of the amount needed, will reduce the growth and yield potential of a plant or crop. The major nutrients (N, P, K) are needed in the largest amounts, therefore they are often the first ones to become deficient in the soil. If plants lack any of these elements, they will show signs of nutrient deficiencies.

### Toxicity

Nutrients may be in limited supply, but they can also be excessive. An excessive supply of any one nutrient may be *toxic* (poisonous) to plant growth or may cause an imbalance. Such conditions may result in abnormal and reduced growth patterns and usually reduce crop yields (see also Table 4.1).

### Most limiting nutrient

Plant growth and crop yields depend on the availability of many nutrients (and many other factors). If one of these nutrients is lacking plants will not grow well, even though the other nutrients may be plentiful. Plant growth and crop yields are determined by the most limiting factor, and only when this factor has been overcome will yields increase until they become limited by the second most

limiting factor, and so on. This is known as the *Law of the Minimum*.<sup>1</sup> Field Study 4.2 will help farmers to identify nutrient deficiencies in their own crops.

### Law of the minimum

With respect to soil fertility the *Law of the Minimum* states that if nutrient shortages exist, plant growth will be limited by the nutrient that is in shortest supply. If the deficient nutrient is supplied, growth will increase. If more of the deficient nutrient is supplied, growth will increase further – until the point where the nutrient is no longer deficient. Now, lack of the nutrient is no longer a limiting factor. Providing additional nutrient is not helpful, as some other nutrient, being the one in shortest supply, has become the limiting factor.

## Removal and Replacement of Nutrients (Nutrient Flow)

Nutrients do not stay in one place. They move from soil to plants and from plants to animals when animals eat the plants. When nutrients move from one place to another, it is called *nutrient flow*. Some nutrients flow into a farm, others flow off the farm. When a farmer buys fertiliser or applies kraal manure to the field, nutrients flow into the farm. When a farmer takes vegetables to the market, or sells grain at the depot, nutrients flow off the farm. Both these activities are planned flows, i.e. the farmer takes these actions deliberately. But some nutrient flows are not planned. When nutrients are washed further down into the soil by heavy rainfall, this is unplanned flow. The most important nutrient flows on a mixed crop/livestock farm are shown in Figure 4.2.



**Figure 4.2. Nutrient flow within mixed farm (from Giller 2002)**

1. The Law of the Minimum also applies to other factors limiting crop yields, such as moisture availability (rainfall), weeds, pests and diseases, soil rooting conditions (drainage, stoniness, compaction) and cultivation practices (e.g. time of planting). For example, nutrient conditions may be good for maize, but if the crop is eaten by baboons then there is still no production. In this example the presence of baboons is the 'minimum' that has to be overcome.

In most Communal Areas in Zimbabwe the major nutrient pathways are:

- crop harvests from the fields to the home, and to the market
- crop residues from the field to the kraal (feeding livestock)
- burnt crop residues (N and S lost to the atmosphere)
- crop residues eaten by the neighbour's livestock
- manure lost to (i.e. deposited in) the veld or grazing area
- manure from the kraal to the field
- mineral fertilisers from the market to the field
- tree leaf litter from the woodlands to the field
- grazed plant materials from the grazing area to the kraal

With the nutrient flow mapping exercise (Field Study 4.1) farmers will be able to identify the dominant nutrient pathways on their farms, and determine whether nutrient cycling on their farms is properly balanced.

### **Role of livestock in soil fertility management**

Cattle are one of the main agents of nutrient transfer in the Communal Areas of Zimbabwe. Access to livestock generally correlates well with crop production. Besides giving manure, cattle are used for tillage and transport, so that cattle owners can more easily collect nutrients from off-farm sources (e.g. leaf litter and soil from termite mounds and anthills) or from market places (buying and transporting mineral fertilisers).

The traditional (free-range) livestock management system results in a complex re-distribution of nutrients within a community, mainly to the advantage of the livestock owners. Livestock are allowed to graze on communally owned grazing land and on all crop residues left in the field after harvest. In the process, most of the nutrients are transferred to the kraals of the livestock owners, although some manure will be left behind throughout the grazing area during day-time grazing. In the long run this is not a satisfactory and sustainable form of nutrient transfer for the community.

Because of the strong crop-livestock interactions in terms of nutrient flows, soil fertility depletion affects grazing land as well as crop fields.

### **Symptoms of nutrient deficiency**

One way to find out the nutrient status of soil is to take soil samples from the field to be planted, and send the samples to a laboratory for testing. Soil testing helps farmers to determine the nutrient need of the crop before it is planted. However, laboratory tests are expensive and not all small farmers can afford to pay for the tests or afford the levels of nutrients recommended by the laboratory.

Another method is visual examination. The farmer studies his/her crop in the field and looks for signs of nutrient deficiencies on the plants. If a nutrient is lacking in the plant, i.e. that there is not enough to feed the plant for healthy growth, then the plant will show some signs, e.g. changing the colours of its leaves, or parts of leaves, or it may show signs of abnormal growth. Different nutrients have their particular signs showing nutrient hunger (i.e. deficiency symptoms) on plants (Table 4.1).

### **What quantities of nutrients are removed in crop harvests?**

When land is brought into cultivation, nutrients will be lost from the soil-plant system in a number of ways. When the crop is harvested, a large amount of nutrients are removed in the harvested products (straw, grain). That is because nutrients are

**Table 4.1. Essential plant nutrients, visual deficiency symptoms, and effect of toxicity**

Name, chemical symbol	Visual deficiency symptoms	Effect of toxicity
Primary macro-nutrients		
Carbon C,	Death	
Hydrogen H,		
Oxygen O,		
Nitrogen N,	Leaves become light green or yellow; especially older leaves; stunted growth	Dark green foliage which may be susceptible to lodging, drought, disease and insect invasion. Fruit and seed crops may fail to yield
Phosphorus, P	Leaves may develop purple colouration; stunted plant growth and delay in development	May cause micronutrient deficiencies, especially iron or zinc
Potassium, K	Older leaves turn yellow initially around margins and die; irregular fruit development	May cause deficiencies in magnesium and possibly calcium
Secondary macro-nutrients		
Calcium, Ca	Reduced growth or death of growing tips; blossom-end rot of tomato; poor fruit development and appearance	May cause deficiency in either magnesium or potassium
Magnesium, Mg	Initial yellowing of older leaves between leaf veins spreading to younger leaves	Imbalance with calcium and potassium may reduce growth
Sulphur, S	Initial yellowing of young leaves spreading to whole plant	Premature dropping of young leaves
Micro-nutrients		
Iron, Fe	Initial distinct yellow or white areas between veins of young leaves leading to spots of dead leaf tissue	Possible bronzing of leaves with tiny brown spots
Copper, Cu	Interveneal yellowing or mottling of young leaves	Older leaves have brown spots surrounded by a chlorotic circle or zone
Manganese, Mn	Interveneal yellowing of young leaves; reduced leaf size	May cause iron deficiency in some plants
Zinc, Zn	Death of growing points and deformation of leaves with areas of discolouration	Leaf tips become yellow followed by necrosis. Leaves get a scorched appearance and fall off
Boron, B		
Molybdenum		
Mo Chlorine		
Cl Cobalt Co		



stored in all plant parts. The amount removed depends on the type of crop and the yield. Think of other ways in which farmers may deplete the soil of nutrients.

If the crops are fed to farm animals and the manure is returned to the land, then some of the nutrients return to the land from which they came. But most crops are taken to the farmer's homestead, sometimes a long way from the field where they are grown. When this happens, very few nutrients return to the soils that grew the crops. This is one way soils lose their nutrients. When the soil loses too many nutrients, it becomes over-exploited and 'exhausted'. If the soil cannot provide plants with all the nutrients they need to grow well, the soil is infertile.

Therefore, to even keep the nutrient status of a soil at its existing level you need to apply nutrients to make up for these losses. Fertilisers and organic manure must be applied in order to maintain soil fertility and thereby ensure good plant growth and high yields. The type and amount of fertiliser to be applied depends on what crop will be planted, and on the nutrient 'bank' in the soil.

Table 4.2 shows the average mineral composition of three crops. It also shows the quantity of macro-nutrients removed by crops at harvest. For example, if 1000kg of maize grain was harvested from a field measuring 1 ha, and all the residue was burnt or removed, the total amount of nutrients removed from the field would be 25kg N, 4kg P and 20kg K. To make up for these losses, approximately 150kg fertiliser is needed in the form of AN (73kg), SSP (46kg) and MOP (40kg).

#### Topics for discussion

Farmers should be encouraged to discuss, from their own experiences, which soil types can be cropped for several years without applying nutrients (e.g. clayey soils with high organic matter), and which soil types cannot be cropped for more than one or two years without applying any fertiliser or manure (e.g. sandy soils with low organic matter). Farmer groups should discuss the management practices that would favour nutrient cycling and those that would prevent nutrient cycling. Farmers should consider what would be the fate of the nutrients in crop residues

- if they are cut and carried to livestock for fodder
- or if fields are grazed by livestock, or if residues are burned in the field (N and S are lost)
- or if residues are left on the soil surface?

See also Field Study 4.1.

**Table 4.2. Average mineral composition of crop products and residues (assuming grain yield of 1000 kg/ha)**

		Yield (kg/ha)	N (kg)	P (kg)	K (kg)
Maize	grain	1000	16	3	4
	straw	1400	9	1	16
	total grain + straw	2400	25	4	20
Pearl millet	grain	1000	19	3	5
	straw	3500	25	3	74
	total grain + straw	4500	44	6	79
Sorghum	grain	1000	17	3	3
	straw	4000	26	3	41
	total grain + straw	5000	43	6	44

after Defoer et al 2000

## Soil pH

It is important to know whether the soil is *acid* or *alkaline*. Whether plants can take up the nutrients in a soil through their roots depends partly on the acidity (meaning sour) or alkalinity (meaning sweet) of soil. The measure of a soil's acidity or alkalinity is called its pH (*potential Hydrogen*).

pH is a very important chemical property of the soil. It is measured on a scale containing 14 divisions known as pH units. The centre of the scale is pH 7, which is neutral. If pH is below 7 the soil is acidic. If pH is above 7 the soil is alkaline (see Table 4.3).

<b>ACIDIC</b>	0	
	1	Battery acid
	2	Lemon juice, stomach acid
	3	Coca cola, vinegar
	4	Beer, tomatoes
	5	Orange juice, carrots, cabbage
<b>NEUTRAL</b>	6	Rain water, potatoes, cow milk
	7	Distilled water, blood
<b>ALKALINE</b>	8	Baking soda, sea, water, eggs
	9	Borax
	10	
	11	Ammonia
	12	Lime
	13	Bleach
	14	

**Table 4.3. The pH scale**

The pH of a soil affects the solubility of nutrients. Thus, it affects whether plants can take up nutrients in the soil through their roots. Most nutrients that plants need are available when the pH of a soil is between 6 and 7.5. So, most plants grow better on neutral or slightly acidic soil.

When pH is below 6, some nutrients like nitrogen, phosphorus and potassium, are less available to plants. Strongly acid soils cause rapid loss of soil nutrients. If the soil is too acidic other soil nutrients, especially metals (aluminium, iron, manganese, copper, zinc), get dissolved in soil water. They become more available to plants – in fact they may even reach toxic or poisonous levels in the soil, which can kill plants.

When pH is above 7.5 (too alkaline), then not enough of the main nutrients are found in soil water, so plants become undernourished. Also, phosphorus makes some micronutrients (iron, zinc, copper, manganese, boron) get chemically tied up, so that they are less available to plants.

### How can soil pH be changed?

The pH of a soil should always be tested before making management decisions that depend on the soil pH. A pH of more than 8 is too high for most crops. This can be rectified by treatment with acid, but this is generally uneconomic for soils containing more than 5% calcium carbonate. Because phosphorus, iron, copper and zinc are less available to plants growing in calcareous soils, nutrient deficiencies are often seen. Instead of trying to reduce pH of the soil, it is more efficient to apply these deficient nutrients.

A soil pH below about 5.6 is too low (too acidic) for most crops. Liming is a common method to rectify the problem.

#### **Why apply lime?**

- helps nutrients become available to plants
- improves soil structure
- provides nutrients for plant growth (calcium, magnesium)
- promotes growth of good soil organisms
- overcomes acidifying effects of some fertilisers (N)
- reduces metal toxicity to plants

**Caution:** sandy and highly weathered soils in southern Zimbabwe contain little organic matter. On such soils, be careful not to over-lime. As a general rule, very few soils in Zimbabwe should be limed unless pH is below 4.3 (sandy soils) or below 4.8 (heavier soils), and yields of more than 3 t/ha are expected.

## **Nutrient Availability**

Apart from the *quantity* of nutrients in the soil, what is also important is whether the nutrients are *available* to plants. This depends on the soil characteristics. There are many factors that affect a plant's access to nutrients in the soil. For example:

- whether the soil is moist
- what kinds of compounds contain the nutrients
- how deep is the soil
- whether there is enough organic matter
- whether roots can penetrate into the soil
- how acidic is the soil
- what kinds of plants and animals live in the soil

This list is only a very brief summary of the factors that influence soil fertility. The list includes physical, biological and chemical aspects of soil, some of which are discussed in the following modules.

## Field Study 4.1. Nutrient Flow Mapping

**Objectives:** To identify nutrient flow pathways, estimate the amounts of nutrients moved through these pathways, and discuss how to regulate these flows

**Time required:** 1-2 hours

**Materials:** Flip chart and stand, markers of different colours, calculator

### Procedure

1. Explain the objectives of the study.
2. Form at least 3 groups. Each group should have flip charts and markers.
3. Farmers in each group list all the major resource components of their farming system, such as grazing lands, crop fields, gardens, markets, kraals, woodlands, etc.
4. Take one group member's farm as an example. Draw all the components of this farm in relation to the farming environment.
5. List the various forms of nutrients (e.g. grain, wood, manure, fertilisers from markets, etc) that are found on this 'example' farm. Discuss where these nutrients are found, and how they move from one component to another. On the drawing of the farm, mark arrows showing the flow of nutrients between components. Use a different colour for each nutrient.
6. The owner of the 'example' farm should give estimates of the quantities of resources associated with each arrow. Use whatever units are convenient and easily understood, e.g. 3 bags of AN fertiliser, 1 wheelbarrow of manure, etc.
7. Each group then presents their findings to the whole group. This will be followed by a discussion to improve the maps. While discussing each map, members from other groups should be encouraged to ask questions about the nutrient flows shown.
8. Collect all the maps for safe-keeping and future reference.
9. Every farmers should later try to produce a similar map for his/her own farm as an assignment – after discussing with other family members at home.

### Questions for group discussion

- What goods do you get from grazing and woodland areas?
- What goods do you get from the market in town?
- In what form do you lose or gain nutrients to your neighbours?
- Based on your map, which losses can be reduced and how?
- How to increase nutrient flow from cattle kraal to the field?

**Comments:** This Field Study is more than just mapping the direction of nutrient flows. Farmers should be able to identify which management factors can influence the nutrient flow pathways. Groups may choose to concentrate on selected arrows (e.g. farmers in Gwanda may be concerned about increasing nutrient flows from grazing areas to crop fields, while in Zvishavane they may concentrate on increasing inflows of fertiliser purchased from the market). Make sure farmers revisit the maps regularly during the cropping cycle.

## Field Study 4.2. Identifying Nutrient Deficiencies in the Crop

**Objectives:** To learn how to identify common nutrient disorders in crops, and understand how management practices can influence crop nutrition. At the end of the Study farmers should also be able to understand that different crops have different nutrient demands. (*This exercise is best done as part of transect walks during the season*)

**Time required:** 2 hours on first day, 2-3 hours on second day

**Materials:** paper and markers

### Procedure

1. The facilitator should make a reconnaissance trip to identify suitable sorghum fields before the day of the study.
2. Explain the objective of the study to farmers the day before the transect walk. At this session, ask farmers to discuss and list common crop disorders (deficiency symptoms) they may observe in their fields. List the deficiency symptoms on a chart and ask the participants to rank them in order of frequency of occurrence. Ask farmers to list and explain any criteria that they themselves may use to diagnose crop nutrient disorders.
3. Identify farmers whose sorghum fields show the disorders appearing on the list. Select the fields to visit. *The facilitator can use his experience (reconnaissance trip) to guide the discussion.*
4. On the day of the study, form groups of 4-5 farmers. The groups walk in different directions and reconvene later at an agreed time. Each group should have a copy of the list of common nutrient disorders of sorghum. Are these nutrient disorders recognised in the local language?
5. Each group describes and records any nutrient deficiency symptoms observed on the cereal crop, and the conditions under which they occurred (e.g. soil type, type of fertiliser or organic amendment used, cropping history etc).
6. Farmers should also record details of the topography (e.g. are deficiency symptoms more common on sloping or on flat land?) and other land use activities.
7. After the transect walk, groups present their findings. Participants then discuss the possible causes of the disorders observed, and construct a chart of disorders/symptoms and their probable causes. *The facilitator should use his/her knowledge and experience to help identify the limiting nutrients by names.*
8. Farmers discuss ways of correcting these disorders or nutrient deficiencies.
9. Keep all the written materials presented by the farmers for future reference and use.

### Questions for group discussion

- Which of these symptoms are common during mid-season?
- Which of these symptoms are associated with low yield?
- How do these symptoms relate to the different planting dates used by farmers?
- What organic or mineral fertilisers do you think you need to apply in these fields?

### **Comments**

This exercise can be done over different sessions, and can be combined with other exercises. There may be need for follow-up visits to some outstanding sites; this can be done during exchange visits or some special FFS field days.

Books and pamphlets are available, showing keys to nutritional disorders of specific crops. FFS facilitators should try and obtain these keys for the main crops grown in that area.

After the study, farmers will begin to recognise that nitrogen deficiency is generally widespread on infertile, sandy soils. This is because these soils are very low in organic matter, and because farmers add very little manure and almost no mineral (inorganic) fertiliser.

## Module 5. Mineral Fertilisers

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### Learning objectives

- Understand the importance of using mineral fertiliser to add to the nutrients that may be available in the soil
- Realise that the amount of fertiliser needed, depends on soil fertility of the field and the nutrient requirements of the crop
- Know the types of available fertilisers and understand the meaning of labels placed on fertiliser bags
- Understand how to calculate the nutrient content of mineral fertilisers
- Understand that the cost of fertiliser should be compared with the expected yield benefits
- Realise that fertiliser application will only be effective if there is enough soil moisture
- Learn how to decide how and where to apply fertilisers, particularly when financial resources are very limited

Some farmers buy and apply fertilisers to their crops, with the expectation of higher yield. They do this when they think there are not enough nutrients in the soil to sustain a healthy and productive crop. But before using mineral fertilisers, it is important to understand the benefits of proper use, as well as the ill effects of improper use. Using fertilisers is not a simple procedure. The first step in proper usage is to understand the technical terms.

Farmers and extension officers must work out the best type and amount of fertiliser to apply, and the best time to apply it, in order to produce the best crop. If a farmer uses too much fertiliser it may end up in underground water or rivers (not on the crop). Or it may just get wasted because it was not applied properly. Fertiliser is expensive. Farmers can use experiments to work out how much fertiliser to apply. They can:

- keep records of the amount of fertiliser they applied every season, and the crops produced
- test the soil to find out how much NPK the soil contains, and calculate how much more NPK should be applied
- experiment with using more fertiliser or less fertiliser on small pieces of land (see Field Studies 5.3, 5.4 and 5.5)

FFS participants will learn about the differences between compound fertilisers versus single-nutrient fertilisers and how to compare the price of different fertilisers by calculating the amount of nutrients in each fertiliser. The participants can test different amounts of mineral fertiliser and ways to apply it. They can also compare the costs and benefits of inorganic versus organic fertilisers and combinations of the two.

### What is mineral fertiliser?

Commercial fertilisers contain plant nutrients that are manufactured industrially from non-living materials. Therefore they are called *mineral fertilisers* or *inorganic fertilisers*. Farmers can use these fertilisers to meet plant nutrient

requirements or to correct soil deficiencies. Note that plant nutrients such as nitrogen, potassium etc are *elements*. The fertiliser that farmers apply contains these elements, e.g. nitrate fertilisers contain the element nitrogen.

The fertilisers commonly available in Zimbabwe contain nitrogen, phosphorus, potassium and sulphur because Zimbabwean soils are naturally deficient in these nutrients. Unfortunately, very few small-scale farmers in semi-arid Zimbabwe use mineral fertilisers. In any given year, 75-90% of fields receive no fertiliser from any source. This is because poor farmers will not take the risk of using expensive fertiliser in areas where rainfall is low and unpredictable, and also because fertiliser is often scarce in communal areas.

Many different brands of mineral fertilisers are sold. But many farmers do not fully understand which type is best for their needs. The main concerns about the use of mineral fertilisers in these areas are farmer education and whether fertilisers are available and accessible. For example, farmers in parts of Chiredzi and Gwanda generally believe that fertilisers will burn crops and will destroy soil health. While farmers may speak from experience, in many cases they do not know the best way of applying mineral fertiliser.<sup>1</sup> There is a critical lack of information on fertilisers and soil-moisture interactions in semi-arid areas. Also, some farmers think that N, P, K is all that a plant needs. Field Study 5.1 will help understand various types of fertiliser.

### **Fertiliser quality**

The quality of a fertiliser depends on its nutrient content, the chemical form of these nutrients, moisture level of the fertiliser, dust content, and the hardness and size of the fertiliser particles. Proper packaging is important to maintain the quality of fertiliser.

### **Fertiliser labels**

There are strict regulations on the type of bags (or containers) for mineral fertilisers, and how they should be labeled. The label should contain the names of all the main nutrients, the contents of the fertiliser (in most cases also the nutrient forms) and the analysis or grade of the fertiliser.

The main nutrients are usually expressed as percent N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O (sometimes with the addition of trace elements Ca and S). They are always given in this sequence. For example, 7-14-7 (e.g. Compound D) means that the fertiliser contains 7% of N, 14% of P<sub>2</sub>O<sub>5</sub> and 7% of K<sub>2</sub>O.

The label also indicates the weight of the bag, and the name of the company making the fertiliser. Often it contains instructions on handling and storage. Most fertilisers have a brand name, which is printed on the bag; e.g. *Compound D* or now called *Maize Fertiliser* (or *Maizefert*).

### **Types of mineral fertilisers**

Fertilisers come in many forms. Mineral fertilisers sold in Zimbabwe can be divided into two types: straight fertilisers and compound fertilisers. The latter are also known as multi-nutrient, mixed, or blended fertilisers.

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1. Fertilisers are salts, much like table salt, except that they contain various plant nutrients. When a fertiliser is applied to soil, any nearby water begins to move very gradually towards the area where the fertiliser has been applied. Salts in the fertiliser begin to dissolve and move away from the place where they had been applied. This action dilutes the fertiliser and distributes the nutrients over a large area. If young plant roots are close to the area where the fertiliser was placed, the roots will burn, especially if soil moisture is very low.



**Straight fertilisers** contain one main plant nutrient, but they may also contain some minor nutrients such as sulphur and calcium. Examples are given in Table 5.1. The three main nutrients are nitrogen (provided in the form of nitrates), phosphorus (provided in the form of phosphates), and potassium.

- Calcium nitrate is a common straight fertiliser, and is preferable because it does not make the soil acidic (like ammonium nitrate does). However, calcium nitrate is more expensive.
- Phosphate fertilisers are sold as either granules or powder form. Both types are chemically identical. Farmers generally prefer to use the powder form because it is easier to apply, and also cheaper. However, the granular form is believed to deliver nutrients more effectively to plants.
- Of the potassium fertilisers used in Zimbabwe, Muriate of Potash (MOP) is usually preferred for its low cost. However, in cases where sulphur is also deficient in soils, then potash sulphate should be used. MOP should not be used on crops that are sensitive to chlorine such as cotton, tobacco and potatoes.

**Compound fertilisers** contain at least two of the main plant nutrients. In Zimbabwe, the three main nutrients (N, P and K) are mixed in different ratios to make up the different types of fertiliser sold on the market. The nutrient composition of various compound fertilisers have been developed in response to the most common nutrient deficiencies in soils across Zimbabwe. Most compounds contain sulphur and other micronutrients.

### Storage and handling of mineral fertilisers

Poor storage can result in deterioration of fertiliser quality both chemically and physically. Fertiliser should be stored in well ventilated rooms with good air circulation, and protected from sunlight and rain. Do not store or mix different fertiliser products together – put each type of fertiliser in a separate stack. If fertiliser bags are placed outside, they should be protected with a cover (e.g. tarpaulin, canvas, large plastic sheet). In a storage shed, fertiliser should be stacked with bags placed in neat criss-crossed layers (maximum 2-3 meters high), on top of wooden pallets above a concrete floor. Do not throw bags in a

loose pile as they can break open. Stacking bags on wooden pallets or planks allows air to circulate under the bags. It keeps fertilisers dry and prevents them from becoming lumpy and hard (this is particularly true for urea). Also, poor ventilation can cause ammonia gas to build up, which can explode and cause fire.

**PLANTS OBTAIN NUTRITION THROUGH ROOTS**  
**DEVELOP STRONG ROOTS WITH SSP DIVISI**

**BENEFITS OF SSP DIVISI BASAL FERTILIZER**

- ✓ Promotes root development
- ✓ Accelerates energy supply
- ✓ Increases oil content
- ✓ Improves nodule formation

Mfd by: [Logo]    Marketed by: [Logo]    Promoted by: [Logo]

SSP DIVISI  
50kg  
ZPC LIMITED

**Figure 5.1. Promotion of single superphosphate by a fertiliser company**

**Table 5.1. Composition of fertilisers made and sold in Zimbabwe**

Fertiliser type	Main use	Composition in percentage						
		N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	S	CaO	B	Zn
<b>STRAIGHT</b>								
Ammonium nitrate	All crops (top dress)	34.5						
Calcium nitrate	Tobacco, paprika (top dress)	15.5						
Urea		46						
Single superphosphate (SSP)	Groundnut		20		12	20 +		
Potassium chloride (MOP)	Paprika (top dress)			60				
Potassium sulphate				50	18			
Gypsum (calcium sulphate)	Groundnut (top dress)				17.5	23		
<b>COMPOUND</b>								
MaizeFert (compound D)	Maize, sorghum, millet	7	14	7	8.5			
SandMaizeFert (compoundZ)	Maize on sandy soils, sorghum, beans	7	14	5	7.5			1
CottonFert (compound L)	Cotton, groundnut, sunflower	5	17	10	8		0.25	
VegeFert / SeedbedFert	Tobacco seedbeds, potatoes, vegetables	7	20	7	8		0.04	

Food should be kept away from fertiliser storage areas, to prevent food contamination and possible poisoning. Empty bags should be destroyed immediately or washed if they are going to be re-used.

## Crop Demand and Fertiliser Requirement

How much of each nutrient should be applied to the soil as fertiliser? This depends on two factors:

- the difference between the amount of that nutrient the crop needs, and the amount already available in the soil
- the amount of fertiliser nutrient lost, e.g. as a result of *leaching* beyond the rooting zone, or conversion to chemical forms that are unavailable to plants.

In general, the greater the yield per hectare that the farmer wants to achieve, the more nutrients the crop requires; and so the greater the amount of fertiliser needed. However, one should not apply more fertiliser than necessary, because:

- it is a waste of money
- it may reduce yields instead of increasing them
- any excess nutrient may leach down to the groundwater and pollute it.

## Crop establishment and management

To obtain maximum benefit from the fertiliser applied, the land should be correctly prepared, seed sown at the correct rate and spacing, and weeds and pests should be well controlled (see Modules 7 and 8). Using extra fertiliser will not compensate for poor crop husbandry. Indeed, the optimum amount of fertiliser to apply will tend to be less if crop growth is reduced by factors other than the supply of mineral nutrients.

## Making soil-plant nutrient decisions

The fertility of a soil depends on the quantities of nutrients the soil contains. If all the nutrients that plants need are present in the soil in large, well-balanced quantities, then the crops will grow well. If a farmer applies enough mineral fertilisers, and the soil can store the nutrients it contains, then the soil is fertile. It acts like a bank....a *nutrient bank*. When the farmer adds fertiliser (organic or inorganic) to the soil, it is like depositing money in the bank. When crops are grown and produce removed from the field, nutrients are 'withdrawn' from this 'soil bank'.

## Timing of fertiliser applications

**Basal application:** fertiliser is applied before planting, or shortly after planting but before crop emergence. Compound fertilisers are generally used for basal applications. Basal application gives plants the initial boost needed to achieve the crop's yield potential. Nutrients such as phosphorus are important for rapid root development and must be available during early plant growth. Therefore basal fertiliser should be rich in phosphorus.

**Top dressing:** fertiliser is applied after seed emergence and establishment of a crop. Top dressing may be applied as late as the flowering stage of an annual crop. It should provide nutrients that can easily be lost from the soil before roots are well developed, e.g. nitrogen. Ammonium nitrate (AN) is widely used for top dressing cereals, field beans and paprika in communal areas of Zimbabwe. It is commonly known as "TOP".

**Split applications:** top-dressing can be done in several stages to reduce nutrient losses. This will also depend on soil type. Sandy soils require more frequent applications of nitrogen and some other nutrients, compared to clay-type soils. For example, nitrogen fertiliser is easily lost from freely-draining soils by leaching, as water moves downwards through the soil. These losses can reduce the effectiveness of the fertiliser and can cause pollution of groundwater. Losses can be high if most of the N is applied at planting time, because initially, there is no network of plant roots to gather up the N supplied. Therefore, it is usually best to divide the total fertiliser N into a series of applications, called *split applications*. Split application allows a farmer to apply nutrients as and when needed. This increases the efficiency with which nutrients are absorbed by the crop. When there is good, evenly distributed rainfall, AN can be applied three times during the season:

- about 30% of the total fertiliser needed is applied 2-3 weeks after crop emergence
- 40% is applied at 5-6 weeks (or mid-vegetative stage)
- the last 30% is applied at flowering.

A farmer can delay or withhold fertiliser application if the season is very dry or if there is waterlogging, in order to avoid N losses. Unlike N, which moves very readily in moist soil, P does not move much away from the point of application. Hence there is no advantage in using split applications with P fertiliser. In fact, all the P should be applied at planting. Potassium is in-between N and P as regards its movement within the soil. There is no advantage in split applications of K.

### **Placement of fertiliser**

Fertiliser can be applied in various ways, depending on its formulation and the needs of the crop. The choice of one method of application instead of another, usually depends on the nutrient's potential for movement in the soil. For example, nitrogen is quite mobile, so it will come in contact with plant roots more easily than potassium or phosphorus, which are less mobile. There are many ways to get the fertiliser in contact with the plant roots, and there are advantages and disadvantages for each method of application.

**Banding:** the most effective way of overcoming problems associated with broadcasting fertiliser is to limit the contact between fertiliser and soil by concentrating the fertiliser into a narrow band below the planting row, closer to plant roots. With this method, plants take up nutrients at a higher rate. It also requires less fertiliser compared to broadcasting. However, if you carelessly place the fertiliser band too close to the seeds, it will burn the roots of the seedlings. Banding is one way to satisfy the needs of many plants for phosphorus as the first roots develop.

**Side-dressing:** in this method, dry fertiliser is applied as a side dressing after plants are up and growing. Fertiliser is scattered on both sides of the row, 6-8 inches (15-20 cm) from the plants, and then mixed into the soil.

### **Calculating fertiliser application rates**

How much fertiliser to apply? This depends on many factors – not only soil fertility but also weather and rainfall. In low-rainfall areas, soil moisture is very low, therefore fertiliser nutrients may not reach the plant effectively. Under such

conditions, applying large quantities of fertiliser will not have the desired effect. Farmers should apply only small quantities, and apply only when the soil is moist (e.g. after a rain shower). Fertiliser rates are generally determined by:

- type of fertiliser
- amount and distribution of rainfall in the area
- soil type: for the same rainfall, clay soils can hold more nutrients than sandy soils
- type of crop and variety
- target yield: the higher the target yield, the higher the levels of nutrients needed (up to a threshold)

The soils in semi-arid parts of Zimbabwe (e.g. Natural Regions IV and V) are naturally poor in phosphorus, and receive very little additional phosphorus from natural sources. Every season phosphorus is removed by the crop, so the amount of soil phosphorus gradually declines. This loss must be replaced by fertilisers. It is important to continually build up soil phosphorus levels to raise productivity. Rates vary but about 15 kg P/ha is needed after each cropping season to build up soil P stocks, since only 10-20% of applied phosphorus becomes available to a crop – the rest is converted into insoluble compounds in the soil. Note that phosphorus is not lost in the soil through leaching.

The specific fertiliser type that a farmer will need depends on the soil nutrient level – it is not possible nor wise to make blanket recommendations because different plants use different nutrients at different rates, most farmers do not know the amount of nutrient reserves in their soil, and because levels change with every soil type and location. Sometimes soil tests are used to determine soil nutrient levels and calculate how much of each *element* (N, P or K) should be added per hectare. The farmer can then calculate the actual weight of *fertiliser product* that should be applied to achieve the nutrient levels recommended by the soil tests. Table 5.2 shows what quantity of nitrogen fertiliser is needed to obtain various rates of pure nitrogen nutrient.

To calculate, you need to know how much of the nutrient element is needed by the crop, as well as the nutrient content of the fertiliser. For example, if 50 kg of nitrogen is needed per hectare, and you are using AN which contains 34% nitrogen, then you must apply 147 kg of ammonium nitrate per hectare:

$$(50 \times 100) / 34 = 147\text{kg}$$

#### **Formula to calculate amount of fertiliser needed**

$$\text{KFN} = \text{KNN} \div \text{PNIF}$$

KFN = kg of fertiliser needed, KNN = kg of nutrient needed, PNIF = % of nutrient in the fertiliser

Calculating the amount of fertiliser needed for a given area is difficult at first, but after some practice, it becomes very easy.

#### **Calculate amount of nutrient fertiliser needed (example)**

Suppose a 3 ton/ha maize crop needs 50kg N/ha, and the unfertilised soil can provide 20kg N/ha. Thus the crop needs a further 50–20 = 30 kg/ha. If no fertiliser N will be lost, you need to apply only 30 kg/ha. However, if, for example, half of the N applied was lost by leaching or other means, you need to add 60kg N/ha

### Fertiliser composition: mineral nutrient versus oxide-basis

The concentration of each nutrient element in fertiliser is given in percentage terms, i.e. weight of the nutrient as a percentage of the weight of fertiliser. However, in Zimbabwe the concentrations of P and K are expressed instead as the weight of the corresponding oxide (not the element itself) as a percentage of the weight of fertiliser. The oxide-basis is sometimes used also for Ca and Mg. The use of the oxide basis makes fertilisers appear to contain more of the nutrient than they really do. Thus single super-phosphate (SSP), which contains 9.6% P, would be labeled as containing 20% P on the oxide ( $P_2O_5$ ) basis. Similarly muriate of potash (MOP), which contains 50% K, would be labeled as containing 60% K on the oxide ( $K_2O$ ) basis. This terminology can cause confusion. When discussing fertiliser application rates, or when conducting fertiliser trials, you must be absolutely clear whether you are using weight percentage or oxide basis.

You can easily convert from nutrient basis to oxide basis as follows:

to convert % P to %  $P_2O_5$  ..... multiply by 2.3  
 to convert %  $P_2O_5$  to % P ..... multiply by 0.44  
 to convert % K to %  $K_2O$  ..... multiply by 1.2  
 to convert %  $K_2O$  to % K ..... multiply by 0.83

**Table 5.2. Nitrogen (N) content of the main nitrogen fertilisers**

Rate of N (kg of N per ha or per acre)	Amount of N fertiliser (bags of 50 kg)		
	Ammonium nitrate (AN)(34% N)	Calcium nitrate (15.5% N)	Urea (46% N)
5 kg	1 bag	½ bag	¼ bag
10 kg	½ bag	1 bag	½ bag
25 kg	1½ bag	3 bags	1 bag
50 kg	3 bags	6½ bags	2 bags

Example: If the recommended rate is 50 kg of N per hectare, apply 3 bags of Ammonium nitrate, or 6½ bags of Calcium nitrate, or 2 bags of Urea per hectare

### What is the Optimum Level of Fertiliser?

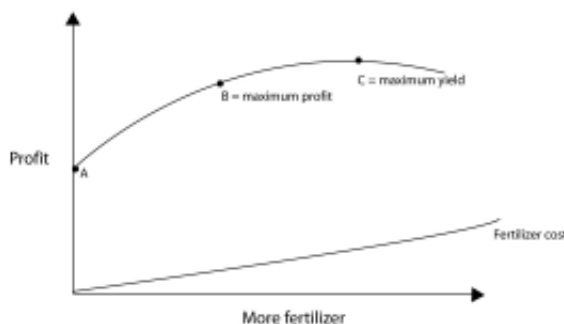
Economically, the optimum rate of fertiliser use is the rate which provides maximum profit. Applying fertiliser will increase the harvest. The amount of increase will depend on various factors, especially inherent soil fertility, rainfall and weather conditions (unknown), plant nutrients supplied from other sources, and the farmer's skill. Under any given set of conditions the economic optimum depends on the relationship between the price of the crop (usually unknown) and the cost of fertiliser.

To determine the economic optimum it is necessary to carry out a series of field experiments. These experiments may be too expensive. However, we can draw important conclusions from experiments which have been done elsewhere. Figure 5.2 shows a typical 'response curve' for cereals. It shows how yield (and total fertiliser cost) changes as we apply more and more fertiliser. The shape of

this response curve may be slightly different for other crops, but the principle is the same.

Figure 5.2 illustrates that:

- There is some yield even without fertiliser (point A), depending on the fertility of the soil and the growing conditions, particularly soil moisture



**Figure 5.2 Optimum level of fertiliser application**

- During the steepest part of the curve (between points A and B), the extra quantity of crop obtained per unit of fertiliser applied, is the greatest.
- The economic optimum is at point B. This gives maximum profit from fertiliser – even though yield will be less than the yield at point C.
- Point C represents the maximum yield. Beyond this point, the response curve goes slightly downwards, i.e. yield and profits become lower, due to over-fertilisation.

Farmers have a choice. They may decide one of the following:

1. Not to apply fertilisers – but unless other sources of nutrients are applied, yield will be low and the soil will become progressively impoverished, through loss of nutrients removed in the crop
2. If farmers cannot afford fertiliser or if they are afraid of risk (e.g. due to drought) they can apply a small amount of fertiliser. If applied correctly and timeously it will give good returns. However, there is still a risk that more nutrients are removed by the crop, compared to the quantity applied as fertiliser – hence nutrient status will deteriorate over the years.
3. At the economic optimum (point B) the farmer's profit and productivity are optimal for the nutrient in question. Farmers can continue to improve yield further (to point C) with by good crop management and use of other inputs. It is in the farmer's interest to progress towards point C as they gain experience.
4. Over-fertilisation (i.e. going beyond point C) should be avoided, but this will rarely happen in practice.

### **Net profit from fertiliser use**

The benefits of fertiliser use can best be demonstrated by simple economic analysis, e.g. calculating *net profit*. The net profit can be calculated from data collected during Field School trials, provided they are monitored closely throughout the season by the group members. Data on growth development, rainfall, weed and disease control, and any other indicators used by farmers, should be written down in a notebook. All costs incurred must be recorded. A sample plot can be harvested and weighed during a field day.

The net profit of fertiliser use can be calculated easily, provided all the necessary information is available – fertiliser costs, crop prices, and yield data from fertilised and unfertilised plots. Net profit indicates the increase in income, e.g. the farmer's income increased by so many dollars, because of using fertiliser. To calculate it:

- first calculate the value of the extra crop produced by using fertiliser (due to higher yield)
- deduct the cost of fertiliser (purchase cost, transport, etc)

### Net profit from fertiliser

Net profit (\$) = Value of extra grain produced minus Cost of fertiliser

#### Example:

Assume:      Unfertilised plot yielded 200 kg of maize (grain)  
                  Fertilised plot yielded 320 kg of maize (grain)  
                  Sale price of maize at harvest time is \$ 1000 per kg

Total cost of fertiliser applied was \$ 50 000

Fertiliser application resulted in a yield increase of 120 kg, valued at \$ 120 000

The net profit in this example is 120 000 – 50 000 = \$ 70 000

In some cases, the farmer can also make a loss, i.e. the value of the additional grain is less than the cost of fertiliser.

### Low input soil fertility management

Few farmers in Zimbabwe's semi-arid areas use mineral fertiliser, partly because it is not easily available at affordable prices. But it also because of perceptions that mineral fertiliser is too expensive and risky. As a result, despite the adoption of new seed varieties, average grain yields remain less than one ton per hectare. Yields will not increase without improvements in soil fertility management.

ICRISAT (Dimes et al 2003) has been conducting on-farm trials of small doses of ammonium nitrate (AN). Grain yield can be increased by 25-50% by applying as little as 10 kg of nitrogen (N) per ha, i.e. approximately 30 kg AN per ha, or 12 kg per acre. This also increases the probability of achieving a minimum harvest in drought years. At such small levels of AN, farmers reduce

the risks of application, and even poorer farmers can afford the quantities needed (Table 5.3).

The yield gains achieved from these small doses depend on good management of crops, soil and water. In particular, the fertiliser must be applied on a timely basis (at the 5 to 6 leaf stage) and the field must be well weeded. If weeding is late, tillage is poor, or the fertiliser is washed away by rains, the yield gains will not be so large.

One concern is, whether it is sustainable or desirable to promote such low levels of fertiliser (much lower than



**Figure 5.3. Apply ammonium nitrate in small doses at the 5 to 6 leaf stage**



**Table 5.3. Grain yield responses to low input N in Hwange and Matobo Districts in 2003-04**

District		Yield (bags per acre, 50 kg bags)	
		No fertiliser	With fertiliser
Hwange	Maize	4	6
	Millet	4	5
	Sorghum	4	5
Matobo	Maize	6.5	11
	Millet	6	9
	Sorghum	7	10

officially recommended rates) and to concentrate on a single nutrient (nitrogen). The answer is: higher levels and more nutrients would be ideal. But the reality on the ground is that small-scale farmers are simply not applying fertiliser – low levels at least provide a good starting point.

Field Study 5.2 lets farmers experiment with low levels of Nitrogen fertiliser. Field Study 5.3 gives guidelines on how a farmer field school can undertake fertiliser response trials.

## Field Study 5.1. Types of Mineral Fertiliser and their Uses

**Objectives:** To appreciate the importance of mineral fertilisers in crop production, understand why certain fertilisers are suitable for particular crops, and understand the advantages and limitations of mineral fertilisers.

**Time required:** preparation 1 hour; actual study (next day) 1 hour

### Materials

- samples of different fertiliser types (straights and compounds) in their original packaging
- flip charts, markers
- transparent plastic pockets

### Procedure

1. Before the day of the field study, purchase different types of fertiliser from a local agri-dealer and put a sample of each type into a small plastic pocket. Put the samples on top of (or next to) to the respective fertiliser bags.
2. Explain the objective of the experiment.
3. Form groups according to farmers' experience in fertiliser use. For example, make three groups: non-users, moderately experienced users, and experienced users.
4. Examine the fertiliser samples and discuss the perceived advantages and disadvantages of each fertiliser type. Each group should list these attributes on a paper and present the list to others.
5. The facilitator explains the suitability of different fertilisers to crops commonly grown by the farmers. This can be done separately for each group.
6. With the assistance of experienced fertiliser users, explain and demonstrate the different methods of fertiliser placement (e.g. broadcast, banding, station placement)

### Questions for group discussion

- Which of these fertilisers do you usually use and on which crops?
- Why do you use the fertiliser you are using?
- From the list of fertilisers just described, which one would you prefer to use?
- What is the advantage of broadcasting fertiliser?
- What assistance would you require to increase your fertiliser use?

**Comment:** Some parts of this Field Study may be too simple for farmers in areas where fertilisers are commonly used, but may be useful in other areas.

## Field Study 5.2. Response to Low Rates of Ammonium Nitrate Fertiliser

**Objectives:** In this experiment, farmers will use AN as a top dressing on either maize, sorghum or millet. At the end of the Field Study, farmers will appreciate the advantage of using low application rates, and learn appropriate methods of application.

**Time required:** experiment lasts throughout the cropping season, and can be repeated the following season

### Materials

- farmer's field of 0.5 acres (0.2 ha)
- 5 kg Ammonium Nitrate
- seed: 5 kg maize seed, or 2 kg sorghum or 1 kg millet
- hoes, planting line
- small No. 5 fertiliser cups or beer bottle caps (clear beer like Castle etc)

### Procedure

1. Explain the objective of the experiment.
2. Let the farmers compare a fertilised crop versus a non-fertilised crop.
3. Use a simple paired plot design, 0.25 acres receives 5 kg AN and the other 0.25 acres receives no fertiliser (0.25 acres = 0.1 ha = 25x40m).
4. Farmers plant according to their normal practice. The entire half-acre should be planted on one day. Plant maize, sorghum or pearl millet.
5. Apply AN at 5-6 leaf stage (3-4 weeks after emergence) at the rate of 1 beer bottle cap per 3 plants. AN should be applied only to half the field (0.25 acres)
6. Keep plots weed free, with at least 2 hand weedings at 2 and 6 weeks. Weeding of the entire plot should be completed in 1 or 2 days.
7. Farmers should make all other management decisions. They should also make regular observations.

### Questions for group discussion:

- Do you think you used the right amount of fertiliser?
- What lessons did you learn from this exercise?

## Field Study 5.3. Fertiliser Response Trial

**Objectives:** To use ammonium nitrate as a top dressing and thereby understand fertiliser response for the particular area, i.e. what is the maximum amount of AN which they can apply to a crop in their area.

**Time required:** experiment lasts throughout the growing season, and can be repeated in the following season with same crop or different crop.

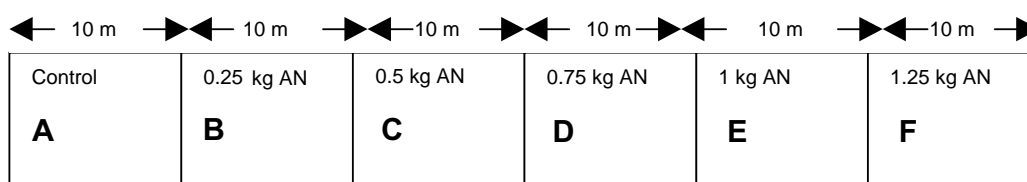
### Materials

- a homestead plot or main field that has been manured or fertilised regularly
- 6 plots of 10m x 10m
- 4 kg AN
- seed: 1.5 kg of maize, or 600 grams of sorghum, or 420 grams of millet
- hoes
- planting line
- weighing balance

### Rates of AN applied at 5-6 leaf stage

Plot A: zero

Plot B: 0.25 kg AN (equivalent of ½ bag per ha = 8.5kg N per ha)



Plot C: 0.5 kg AN (equivalent of 1 bag per ha = 17kg N per ha)

Plot D: 0.75 kg AN (equivalent of 1½ bags per ha = 25.5kg N per ha)

Plot E: 1 kg AN (equivalent of 2 bags per ha = 34kg N per ha). Apply half at 5-6 leaf stage, apply the other half at 6-8 weeks after emergence at stem elongation

Plot F: 1.25 kg AN (equivalent of 2½ bags per ha = 42kg N per ha). Apply half at 5-6 leaf stage, apply the other half 6-8 weeks after emergence, at stem elongation

### **Procedure**

1. Explain the objective of the experiment.
2. Let the farmers decide which cereal grain crop they want to experiment with.
3. Select a fairly representative area and lay out six plots as follows. Each plot measures 10x10m:
4. Farmers plant according to their normal practice. The entire plot should be planted on one day. Plant maize, sorghum or pearl millet.
5. Apply first top dressing of AN at 5-6 leaf stage (3-4 weeks after emergence).
6. Apply the split dressing on plots E and F between 6 to 8 weeks after planting.
7. **If the soil is very dry, delay applying the top dressing.**
8. Keep plots weed free: two weedings by hand at 2 and 6 weeks after planting. Weeding of all 6 plots should be completed in 1 or 2 days.
9. Farmers should make all other management decisions. They should also make regular observations.

### **Questions for group discussion**

- Do you think you used the right amount of fertiliser?
- What lessons did you learn from this exercise?

**Comment:** The facilitator should make sure that the fertiliser on plots E and F is split in two applications.

## **Field Study 5.4. Soil Nutrient Evaluation and Fertiliser Recommendations**

Every season, farmers have to make decisions on what type and amount of fertiliser to use. Their decisions are based upon: advice from the extension officer, fertiliser traders and/or other farmers; common practices in the area; experience gained in previous seasons; available money, and/or availability of (types of) fertilisers. Very rarely do farmers evaluate the nutrient status of their soil in order to make decisions on fertiliser.

**Objectives:** To enable farmers to obtain information for correct fertiliser use

**Time required:** 1-2 hours

**Materials:** large sheet of paper, marker

### **Procedure**

1. Explain the objectives and procedure of this exercise.
2. Ask the farmers how they decide on what amount and type(s) of fertiliser to use. List the answers on a large sheet of paper.
3. Discuss how they evaluate the nutrient status of their soils in making their fertiliser decisions.

4. List and explain the different methods which can be used to evaluate soil nutrient status. Ask farmers if they know about any other methods.
5. Farmers discuss (in small groups) the feasibility of each listed method for their own use.
6. Ask the farmers if they know what are the official fertiliser recommendations made by the extension office. Do they follow the recommendations?
7. Inform farmers that the recommendations are based on fertiliser trials at research stations and farmers' fields.
8. Discuss with farmers how these recommendations can be used in making their fertiliser management decisions.

#### **Questions for group discussion**

- Where do you obtain information for making your fertiliser use decisions?
- Do you think it is important to evaluate the nutrient status of your soil?
- Do you think it is possible to evaluate the nutrient status of your soil?
- Are the methods listed feasible for you?
- Would you like to learn more? Would you like to try out one of these methods to evaluate nutrient status of your soil?
- Fertiliser recommendations are based on on-farm trials. Will farmers be able to conduct such trials themselves on their own farms?

### **Field Study 5.5. Nutrient Deficiency Trial**

Nitrogen (N), Phosphorus (P) and Potassium (K) are the major nutrient elements that all crops need. The main mineral fertilisers used in agriculture are meant to supply these nutrients. When levels of N, P or K are too low in a soil, crops will show visible symptoms of the nutrient deficiency.

**Objectives:** To understand how a balanced supply of major nutrients is needed for plant growth and crop production

**Time required:** experiment continues throughout the crop season

#### **Materials**

- fertilisers: Single Superphosphate (SSP), Ammonium nitrate (AN), Muriate of potash (MOP)
- hoes
- weighing scale
- calculator
- recording sheets

#### **Procedure**

1. Explain the objectives and expected outcome of the experiment.
2. Initiate a discussion and let the farmers agree on: a) sites to be used, b) cropping and fertility history at each site, c) size of plots and rates of fertiliser application. Note: if application rates are too low you may not be able to induce desired deficiency symptoms for the missing nutrient (*see comment below*).
3. Ask the farmers to gather at the FFS field site. The experimental plot should have soil of poor fertility.
4. Lay out eight plots of about 10m x 10m. The eight treatments are:

NPK all added	N only
N and P only	P only
N and K only	K only
P and K only	no fertiliser added

5. Weigh each fertiliser in a separate plastic bag. The facilitator should ensure that correct amounts are weighed, but the farmers should apply the fertilisers. Farmers should calculate the nutrient equivalent of the fertilisers applied.
6. Nitrogen should be applied in splits, starting at 2 weeks after crop emergence. P is applied basally at planting, and can be banded along planting furrows a few centimetres below the seeding depth. K can be applied basally or as topdressing just after crop emergence.
7. Farmers should visit the experiment during each FFS session and observe the symptoms at different stages of crop growth. They should keep careful records of a) symptoms as they develop on the plant, b) pest and disease problems in each plot, c) any differences in susceptibility to pests and diseases. During each visit, farmers should discuss their observations.
8. Leave the crop to mature and record the yields. Compare the differences.

#### **Questions for group discussion**

- What nutrient element is most associated with yield response?
- Under what management conditions do you normally see these symptoms in your fields?
- Can you relate the observed symptoms to the situations in your own fields?

**Comments:** Suggested application rates are 15kg N/ha, 15kg P/ha and 15kg K/ha. Deficiency symptoms are easy to observe on cereals such as maize and sorghum. However, farmers should be allowed to use a legume as a test crop if they want.

In addition to NPK, crops also need other nutrients such as magnesium (Mg), calcium (Ca) and sulphur (S). Their deficiency symptoms can also be observed during the cropping season.

# Module 6. Soil Organic Matter and Organic Fertilisers

## Learning objectives

- Understand what is soil organic matter and how it can contribute to soil fertility
- Understand how soil organic matter can be increased by various farming practices
- Identify and use organic nutrient sources like crop residues, compost and leaf litter
- Know how organic materials can be improved by composting and/or adding mineral fertilisers
- Learn how to manage manure

## Soil organic matter

Soil organic matter is any material in the soil that was originally produced by living organisms. It is made up of root systems and above-ground plant residues, microbes and other organisms living in the soil (e.g. fungi, earthworms, beetles, bacteria); dead and decomposed plant and animal residues; ‘glues’ and substances produced by plant roots and microbes. All these soil creatures (*tupukanana*) are nature’s recyclers. They convert plant residues and animal manure into usable nutrients and soil organic matter for both plants and all the organisms living in the soil (see also Module 3).

The average organic matter content of different soil types<sup>1</sup> is given in Table 6.1.

**Table 6.1. Average organic matter content (%) of different soil types**

Texture	Low	Moderate	High
Sand	<0.8	0.8-1.6	>1.6
Sandy loam	<1.1	1.1-2.2	>2.2
Loam	<1.5	1.5-2.9	>2.9
Clay loam, clay	<1.9	1.9-3.2	>3.2

Adapted from ABSA 1997

## What does organic matter do?

Organic matter provides plant nutrients and improves the condition of the soil. It increases infiltration of air and water and promotes water retention, thereby erosion. Soil organic matter is perhaps the single most important indicator of soil quality and productivity. It is important for the following reasons:

- *Increases nutrient storage:* organic matter has the capacity to store (hold on to) nutrients. The greater the amount of organic matter in a soil, the more nutrients there will be for plant growth. Organic matter holds more than 90% of a soil’s nitrogen reserves. It can also hold around 90% of the soil’s sulphur and 15-50% of phosphorus supplies. The amount of phosphorus is variable because

1. A large part of Zimbabwe is covered with sandy soil derived from granite and Kalahari sand. These soils contain very little organic matter because of (a) low rainfall and low humidity, (b) high turnover rates caused by high temperatures, (c) extra aeration after tillage and cultivation, (d) because sandy soils do not provide good protection against attack by soil microbes. Organic matter content of these soils is usually less than 0.8%.

P easily binds to iron or calcium in the soil. The presence or absence of organic matter also influences other plant nutrients, because it acts as a food for soil organisms. These organisms hold on to nutrients and release them in forms available to plants.

- *Increases nutrient supply*: organic matter regulates the supply of plant nutrients because it binds with nutrients in the soil and chemically holds onto metals such as iron, copper, manganese and zinc. This prevents them from becoming insoluble and therefore unavailable to plants.
- *Improves soil structure and water holding capacity*: organic matter improves soil structure by binding soil particles together to form stable aggregates, which are better protected from the erosive action of rainfall impact, wind erosion and, to a limited extent, cultivation. It prevents compaction, reduces crusting (especially in fine-textured soils) and reduces evaporation from the soil surface.
- *Increases water holding capacity*: the formation of stable soil aggregates creates gaps and pores for better air and water movement into and through the soil. It also opens pathways for root growth. Organic matter is of greater structural importance in medium to light textured soils than in clay soils, because the clay itself helps to bind the soil.
- *Buffers the soil against rapid changes*: organic matter in the soil acts as a buffer against rapid changes in soil acidity, for example when acidifying fertilisers are added to the soil. Organic matter gives the soil a darker colour and buffers the soil against rapid changes in soil temperature – if day to night temperature variation is large, rapid changes in soil temperature can occur in light-coloured soils. Organic matter is also a strong absorber of pollutants such as pesticides, organic wastes and heavy metals. This stops the pollutants from moving into water supplies and also prevents their contact with the target organism.

In sandy soils, organic matter acts like a sponge, holding water and nutrients in place so plant roots can get to them. In clay soils, organic matter helps to clump clay particles together, allowing water to sink through and air to more easily circulate.

### **Organic fertilisers**

Soil fertility can be improved by increasing the organic matter content. This can be done by incorporating into the soil, various sources of organic matter such as crop residues, weed residues, leaf litter, manure, compost, household wastes, and soil from anthills and termite mounds. Field Study 6.1 will help farmers learn to identify organic nutrient resources in their own area.

Manure and crop residues are the best long-lasting nutrient sources currently used by farmers. However, manure is readily available to only about 50% of small-scale farmers (i.e. those who own cattle) and is generally applied to maize only, while other crops must rely on residual fertility after the maize crop.<sup>2</sup> The amount of organic fertilisers applied by small farmers depends mainly on availability and accessibility of nutrient sources during the crop season, rather than crop requirements or recommendations by extension. The use of green manures in crop sequences and mulching is rarely practiced, although some farmers grow legumes in the cropping sequence. In any given season, 75-90% of cropped lands in Zimbabwe receive no fertiliser from any source.

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2. Even if sources of organic matter are available, many farmers lack labor and transport (wheelbarrows, scotch carts, draft animals) to make use of them.



The scarcity of nutrient sources is further worsened by their poor quality. Almost all nutrient resources used by small-scale farmers are of poor quality. Fertiliser resource quality may be defined in terms of quantity of nutrients contained, and how readily these nutrients are released under given soil conditions to benefit the plants. Local organic fertilisers are often poor and highly variable in quality or nutrient content, particularly nitrogen (Table 6.2).

**Table 6.2. Nutrient quality (range in brackets) of organic fertilisers used by small farmers in Zimbabwe**

Fertiliser type	N (%)	P (%)	K (%)
Cattle manure	1.50 (0.5-1.4)	0.15 (0.10-0.16)	0.78 (0.70-0.96)
Leaf litter	1.40 (0.5-3.1)	-	-
Soil from termite/anthills	0.23 (0.07-0.8)	0.05 (0.02-0.11)	-
Compost	0.34 (0.19-0.28)	0.12 (0.06-0.16)	-
Crop residues (cereals)	0.45 (0.25-0.7)	0.06 (0.02-0.22)	-
Legumes	1.50 (1.21-1.90)	0.08 (0.04-0.16)	-

Source: Mapfumo and Giller 2001

## Managing Soil Organic Matter

In semi-arid (sub) tropical environments the organic matter content of most soils is naturally low. Thus, good crop management is essential in order to maintain soil organic matter. Management practices which influence organic matter are given in Table 6.3.

**Table 6.3. Management practices which influence levels of organic matter in the soil**

Practices which reduce organic matter	Practices which increase organic matter
<ul style="list-style-type: none"> <li>• <i>Decrease the production of plant materials by:</i> <ul style="list-style-type: none"> <li>- increasing the use of bare fallows</li> <li>- replacing perennial vegetation with short-season vegetation</li> <li>- replacing mixed vegetation with monoculture crops</li> <li>- introducing more aggressive but less grasslands</li> <li>- using cultivars with a high harvest index</li> </ul> </li> <li>• <i>Decrease the supply of organic materials by:</i> <ul style="list-style-type: none"> <li>- burning woodlands, rangelands, or crop residues</li> <li>- grazing in excess of carrying capacity</li> <li>harvesting</li> <li>- removing plant products</li> </ul> </li> <li>• <i>Increase decomposition of organic materials by:</i> <ul style="list-style-type: none"> <li>- tillage</li> <li>- drainage</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• <i>Increase the production of plant materials by:</i> <ul style="list-style-type: none"> <li>- fertilisation to increase plant biomass production</li> <li>- better management of soil water</li> <li>- use of cover crops</li> <li>- improved vegetative stands</li> <li>- introduction of plants that produce more productive species</li> </ul> </li> <li>• <i>increase supply of organic materials by:</i> <ul style="list-style-type: none"> <li>protection from fire</li> <li>- using forage by grazing rather than by</li> <li>- controlling insects and rats</li> <li>- applying animal manure</li> <li>- applying plant materials from other areas (e.g. mulching)</li> </ul> </li> <li>• <i>Decrease decomposition of organic materials by:</i> <ul style="list-style-type: none"> <li>- reducing or eliminating tillage</li> <li>- keeping the soil cool with vegetative cover</li> </ul> </li> </ul>

### **Exercise**

Can farmers add to the list given in Table 6.3?

### **Don't forget the roots**

Crop residues on the soil surface is only one part of how plants build up soil organic matter. Roots also produce large amounts of material. One quarter of the organic matter produced by maize or sorghum is made by the roots. In grasslands about half of plant production is underground. How does that translate into weight? Maize can produce half to two tons of root organic matter in each acre. A grassland makes over two tons. In no-till conditions, where surface residue is not tilled into the soil, roots become especially important as a source of organic matter to the crops.

### **Incorporating crop residues / stover into the soil**

In most farms, roots and above-ground plant growth are the most important sources of organic matter. When choosing what crops to plant, think about how much residue can be left behind, even if the farmer needs most of it to feed livestock. Burning crop residues leads to a decline in soil organic matter and eventually fertility levels. Crop residues can be incorporated into the soil either by ploughing under conventional tillage or by leaving it as a mulch on the soil surface under minimum or reduced tillage.

### **Applying manure to crop fields**

Livestock manure, particularly from cattle and goats, can be a valuable source of plant nutrients for farmers in the communal areas of Zimbabwe.

#### *Benefits of using good quality manure*

- increased soil organic matter
- increased soil aggregation and hence reduced erosion
- better water infiltration and aeration
- higher soil biological activity as the manure decomposes in soil
- increased yields after the year of application due to good residual effects
- reduced effects of soil acidity
- recovery of nutrients lost to the grazing areas

#### Disadvantages of using manure:

- if not properly composted, manure may spread weed seeds in the field
- requires a lot of labour for collection, handling and application
- if not properly composted, manure may harbour crop pests and diseases

Under practical situations, the benefits of using manure far outweigh the disadvantages. The challenge for FFS in semi-arid areas of Zimbabwe is to create this awareness and to demonstrate its benefits to farmers (see also Field Studies 6.1 to 6.5).

### **Quality of kraal manure**

The quality of kraal manure is highly variable and depends on the quality of the grazing resource, on kraal management, and on how the manure is stored and

applied. If manure is exposed to wind and rain for long periods, it will lose nutrients, especially N. The moisture content of manure will also vary depending on time and method of storage. As a general rule, the N in manure breaks down rapidly: about half is available in the first year, but little or no residual N is available after three years of cropping. Also, you cannot improve manure quality if cattle continue to rely on poor quality grazing and crop residues, especially those from cereals. Manure quality is normally reported in terms of its N content and in terms of how effective it is for crop growth. Manure is generally low in P and N, but the amounts will vary considerably. Table 6.4 gives some nutrient contents for manures collected in Tsholotsho from two groups of farmers, i.e. better endowed farmers with 5 or more cattle, and poorly endowed farmers with only 2-3 cattle. This shows that manure from the communal lands is often very poor in nutrients (Giller 2001).

**Table 6.4. Typical nutrient contents of kraal manure in Tsholotsho**

	kg nutrient in 1000 kg of kraal manure		
	Organic matter	Total P <sub>2</sub> O <sub>5</sub>	Total N
poorly endowed farmers	132	2	4
well endowed farmers	146	3	4

Source: Giller 2001

### Improving the quality of manure

There are several methods of improving manure quality:

- Apply bedding in the kraal. Locate the livestock kraal where there is no chance of runoff water, which will wash (i.e. leach) nutrients away. Apply bedding such as grass, leaf litter or cereal stover into the kraal area to absorb nutrients (including the nutrients dissolved in urine). Then cure the manure to enhance N availability.
- Store manure in a pit. Dig a pit near the kraal to collect any slurry that may flow out of the kraaled area. Add bedding into the pit and cover it to prevent loss of nutrients into the atmosphere. Covering will also allow the bedding to decompose (see also Field Study 6.2).
- Plough in the manure soon after spreading it on the field. This will reduce the loss of N into the air.
- Combine manure and mineral fertiliser. Apply manure at planting (basal application). The N fertiliser should be split-applied, first at planting and later as top-dressing. If properly cured manure (e.g. pit-stored) and AN are applied together as basal, the application rate should not exceed 5 kg of AN (equivalent to 1.6 kg of nitrogen) per ton of manure.
- Improved animal feeds. Well-fed cattle produce better quality manure. Where possible, cattle should be given protein-rich supplementary feeds, e.g. legume residues and cuttings from multipurpose legume shrubs and trees.

### Method and rate of manure application

Farmers living in semi-arid areas like Gwanda do not use much manure because they think it burns crops. If crop burning is a problem, then the manure should be used together with methods of soil moisture conservation to prevent burning.

Below are some hints on manure management in the field, but it is always necessary to also draw on the local experience of farmers.

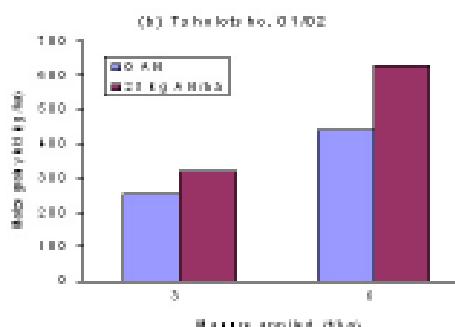
If there is plenty of labour, it is advisable to band manure along the planting furrows (but away from the seed), so as to cover a greater area.

Broadcasting the manure needs less labour, but it may be less effective in the first season, particularly if weeding is delayed (weeds take up some of the nutrients in the inter-row spaces).

Broadcasting helps to evenly cover the whole area with manure. Some farmers use spot application, i.e. placing manure in holes made near the planting station. With this method the available manure will cover a large area, but more labor is needed.

The recommended rate of manure application in semi-arid areas is 8-20 t/ha, but few farmers will be able to manage this. Rates of 5 t/ha may give good results, provided the manure is of good quality. See Field Studies 6.3 and 6.4 for experiments with methods and rates of manure application.

Manure can be applied either alone, or in combination with a small quantity of inorganic fertiliser. With ammonium nitrate, the quantity applied should not exceed 5kg AN (equivalent to 1.6 kg of nitrogen) per ton of manure. Maize yields from using manure-fertiliser combinations are illustrated in Figure 6.1. If the manure is not cured, combine it with small amounts of another fertiliser containing N (such as Compound D, S or L), to offset N immobilisation. Apply the compound fertiliser at rates not exceeding the equivalent of 4 kg N/ha. See Field Studies 6.3 and 6.4 for possible field experiments.



**Figure 6.1. Maize response to combining kraal manure with a low rate of N, measured on farmers' fields in Tsholotsho. Source: ICRISAT**

### Including legumes in crop rotation

Farmers should try to diversify the farming system to include nitrogen-fixing legumes, especially drought-tolerant multi-purpose legumes like cowpea, pigeonpea and bambaranut. These legumes are useful nutrient sources, they also have potential as grain and fodder crops.

### Applying soil from anthills and termite mounds

Soil from termite and anthills is a preferred organic fertiliser used by farmers, mainly on sandy soils. Its role is probably more as a soil conditioner than a source of nutrients. According to farmers, soil from termite hills enhances soil structure, reduces soil erodibility, improves water holding capacity, and has longer lasting residual effects than manure (4-5 years). These properties may be simply due to the influence of the clay it supplies. Sometimes the soil is only applied to sandy patches showing poor fertility.

### Growing nutrient-rich crops for incorporation into soil (green manure)

Green manuring normally refers to a practice where farmers grow legume cover crops to enrich or fertilise the soil, which are ploughed or tilled under at a later

date. In some parts of the world, such as in tropical climates, farmers plant legumes and let them take over. By the next season the legumes cover and protect the soil and add organic matter and fertility (especially N). Legume covers are also good for suppressing weed growth and are very good to cover fallow land for a year or more before ploughing under. It is not easy to find a cover crop adapted to a short season in semi-arid conditions, but a few options are available. For example, deep-rooted legume crops (e.g. pigeonpea) grown for one season on a problem soil can help break up a hard pan and greatly improve tilth.

### Use of leaf litter

Fresh and dead leaves of various trees and shrubs can be used to improve soil fertility. This material adds nutrients to the soil, increases water holding capacity and reduces erosion. Figures 6.2 and 6.3 will help farmers decide how best to utilise available leaf litter. Field Study 6.5 gives a practical exercise.

#### Rules of thumb for managing organic resources

- High quality organic materials are best utilised by incorporating them into the soil.
- Low quality organic materials, such as maize stover, can be used as such in perennial crops. Alternatively, compost them with high quality materials, or chop them into small pieces and mix with some mineral fertiliser before incorporating them into the soil.
- Some organic materials, such as woody stems and twigs, do not make good compost because they contain a lot of lignin. These should be left on the soil surface to conserve soil moisture and reduce erosion.
- If you have both high and low quality organic materials, mix them together before applying them to the field.
- Plant and animal wastes should be mixed to enrich poor quality manures.
- It is better to use a mixture of organic and mineral fertilisers than either separately. Reason: high quality organic materials contain enough nitrogen but not enough phosphorus. This can be rectified by adding fertilisers that contain phosphorus and potassium.

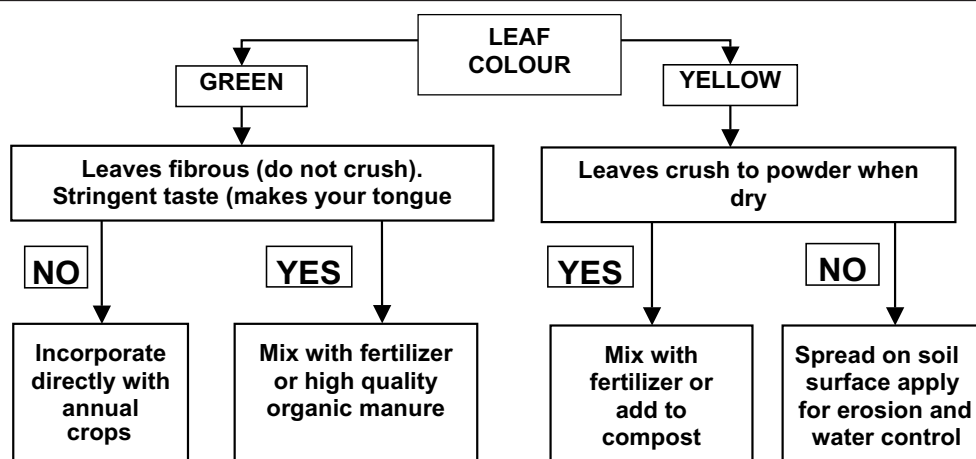


Figure 6.2. Decision tree to assist in managing organic resources (source: Mapfumo and Giller 2001)





Category	Examples	C: N ratio	Ease of decomposition	Best management option
Soft & green 	Weeds, tithonia, cabbages	25:1	Fast (2-3 weeks)	Green manure Animal fodder
Hard & green 	Tree leaves, banana leaves, mango trees	50:1	Moderate (6-8 weeks)	Manure Fodder
Soft & brown 	Dry grass & leaves	50:1 to 75:1	Slow (10-12 weeks)	Mulching Fodder
Hard & brown 	Stover of maize, sorghum and twigs	75:1 to 100:1	Very slow (12+ weeks)	Mulching

Figure 6.3. Quality of different materials and how they can be used

## Field Study 6.1. Organic Nutrient Resources and their Uses

**Objectives:** To identify organic nutrient resources found in the locality, and rank their preferred uses.

**Time required:** 1-2 hours

### Materials

- samples of different organic resources
- flip charts and markers

### Procedure

1. In a prior session, ask farmers to bring organic nutrient sources which they use in their fields and gardens (maize residues, groundnut residues, leaf litter, termitaria, etc).
2. Explain the objective of the Field Study
3. Form groups. Groups can be based on any criteria, e.g. based on geographical location of their villages, livestock ownership or affiliation to farmers' clubs. Farmers can suggest the criteria for making groups.
4. Each group should make a list of commonly used organic resources and indicate their sources. The list should also be ranked according to ease of availability.
5. For each resource on the list, farmers should discuss and indicate the preferred use among the following:
  - livestock feeding
  - add to manure in the kraal
  - mulching
  - burning
  - incorporation into soil
  - other uses
  - compost
6. Rank the preferred uses for each resource giving the perceived advantages and disadvantages. How do crops respond after application of each of these resources?
7. Each group should present its findings. The rankings should be kept for future reference.

### Questions for group discussion

- How would mulching improve your crop yields?
- How can the amount of leaf litter be made sufficient for application to your crops?
- Why do you prefer to burn your crop residues? Is this a good practice?
- After farmers have completed this module, they could again rank the different uses of resources, as described in procedure # 5-6. Having acquired more knowledge, is the new ranking different from the previous one?

## Field Study 6.2. Producing Pit-Stored Manure

**Objective:** To learn to produce high quality manure from pits, as well as appreciate its importance in improving yield

**Time required:** 3 hours initially; 1-2 hours 3 months later

### Materials

- digging tools, shovels
- kraal manure
- cereal residues, veld grass or leaf litter
- drum full of water

### **Procedure**

Pit-stored manure is of good quality, because the pit is designed to ensure optimal decay of manure and minimize losses of nutrients during the decay process.

1. Discuss the advantages and disadvantages of pitting manure. Let farmers share their experiences with each other.
2. Farmers select a suitable kraal site accessible to all group members. Dig a pit of 2 m x 2 m, located less than 3 m from the kraal on the downslope side. The pit should be no more than 1 m deep.
3. Make a trench about 30 cm deep, from the kraal to the pit. Thus, any manure slurry which forms in the kraal during rain showers, will collect in the pit.
4. Collect cereal residues (maize, sorghum etc) and/or veld grass. Place it in the pit so as to completely cover the bottom (a layer of about 20 cm). Steps 1-4 can be done in May or June.
5. Dig and remove the manure from the kraal and put it into the pit. The manure thus falls on top of the residues/grass bedding. This should be done no later than July since it takes about 3 months for the manure to 'cure'.
6. Fill the pit with manure up to about 15 cm below the top. Fill in these remaining 15 cm with cereal residues or veld grass.
7. If water is available, pour up to 200 litres (1 drum) of water into the pit. Cover the top of the pit with soil (you can use anthill soil) until the top layer of residues/grass is completely covered.
8. Leave the manure to cure for 3 months, after which the manure is dug out and applied to the field. Storage for longer than 4 months results in loss of quality.
9. Farmers should compare the performance of pit manure with traditionally-stored manure. This can be done by trials on field plots.

### **Questions for group discussion**

- What stages of this process are difficult?
- Does pit manure look the same as manure produced through traditional means? What are the differences?

**Comments:** In practice, the pit should be large enough to accommodate the amount of manure available to the farmer. If water is not available, omit the watering part in Step 7. More details are given in *Soil Fertility: Guide for farmers on good land husbandry* (Agritex/ZFU 1999).

## **Field Study 6.3. Methods and Rates of Manure Application**

**Objective:** To learn how to use manure appropriately, and better understand the benefits of good manure management

**Time required:** 1½ – 2 hours (for establishment)

### **Materials**

- manure
- hoes
- weighing scale
- recording charts, markers

### **Procedure**

1. Explain the purpose of the exercise to farmers, select suitable plots.



2. Farmers form two groups (e.g. men-women, or cattle owners and non-owners). Each group will manage its own set of treatments in the experiment.
3. One group will test two application rates of manure, namely zero and 5 t/ha using broadcast as the application method. The other group will test the same two application rates but use the banding method.
4. Based on the chosen plot sizes, weigh appropriate amounts of manure into suitable containers (e.g. a clean 20 litre bucket or an old grain bag). The land should have been prepared for planting prior to the meeting.
5. Broadcast manure should be incorporated before planting while banding should be done in furrows that will also be covered.
6. Each group should plant the same crop and on the same day. They should also use the same type of manure (either pit-stored or heap-stored).
7. Each group should take regular records on plant growth characteristics, e.g. plant height, leaf colour, and grain yields. Each group presents its findings at the end of the study.
8. At the end of the Field Study, have an overall discussion and record all the findings on a chart as farmers make their presentations (farmers should take a leading role in preparing these result charts).

**Comments:** Application rate of 5 t/ha cattle manure is optimal for semi-arid areas. For goat manure, which is not available in large quantities, use lower rates of about 3 t/ha.

## **Field Study 6.4. Combining Manure and Nitrogen Fertiliser**

**Objectives:** To understand the advantages of combining manure and fertiliser (gives better crop yields than applying either manure or mineral fertiliser alone)

**Time required:** one day at start of growing season; follow-up throughout the season

### **Materials**

- cattle manure of good quality (at least 40 kg)
- Ammonium nitrate (at least 200 grams)
- maize/sorghum seed
- hoes
- weighing scales

### **Procedure**

1. Explain the purpose of the study.
2. Get an appropriate piece of land prepared before the day of the Study. The land should be prepared and marked out into four plots measuring 10m x 10m each.
3. Treat the four plots as follows:
  - manure only, applied at 5 t/ha (50 kg for plot of 10m x 10m)
  - AN fertiliser only, applied at 10 kg N/ha (300 grams AN for plot 10 x 10m)
  - manure (5 t/ha) + N fertiliser (10 kg N/ha) combined
  - no treatment

Apply the manure at planting. N fertiliser should be split applied as top-dressing.

4. Plant either maize or sorghum.
5. Monitor the crop for growth performance and record grain yields. At the end of the season each group presents its findings to the other FFS members.

#### **Questions for group discussion**

- What are the advantages of using manure and mineral fertiliser in combination?
- Did you get any crop burn from your fertiliser or manure?

**Comments:** Allow farmers to choose a water harvesting technique. Tied-ridging is a good option. Allow for regular field observations and discussions between farmers belonging to different groups.

### **Field Study 6.5. Management of Organic Resources**

**Objectives:** On completion of this exercise farmers should be able to: (a) appreciate that different organic resources have different qualities, (b) choose the appropriate management method for various organic materials.

**Time required:** 1-2 hours

#### **Materials**

- small quantities of various organic resources, such as cowpea, sun hemp, groundnut (fresh leaves, at flowering), dry maize residues, fresh mopane leaves, mango tree leaves, miombo litter, etc.
- copies of Figure 6.2, “Decision tree for management of organic resources”

#### **Procedure**

1. Ask farmers to bring different organic materials as suggested in the ‘Materials’ list. Encourage them to add to this list, based on their local knowledge and experiences.
2. Farmers follow the steps given in the decision tree, and determine the best uses for the different organic materials.

#### **Questions for group discussion**

- How do you traditionally define the quality of nutrient resources? What criteria do you use?
- Which of the materials you started with would be suitable for addition to the kraal?
- What materials do you currently use for erosion control?

**Comments:** This exercise is can be linked to Field Study 6.1. It is important to compare the quality attributes traditionally used by farmers with the outcome obtained using a decision tree.

# Module 7. Crop Establishment <sup>1</sup>

## Learning objectives

- Select and plant seed of good quality
- Understand the importance of timely land preparation and early planting
- Plant under the right soil moisture conditions
- Place seeds at the right depth and correct spacing
- Understand the advantages of seed soaking
- Understand the advantages of planting basins

## General Principles for Good Crop Establishment

Poor crop establishment leads to poor yield. The key to good crop establishment is to ensure maximum emergence. If first planting fails, replanting or gap filling can be done 2 to 3 weeks after emergence. Crop management depends on many factors; the best practices will vary from farm to farm and field to field as soils change. However, it is important to understand the basic agronomic principles.

**Seed quality:** Always check your seed's ability to germinate. If you buy certified seed the quality is assured. If you grow your own seed you can test it.

### How to test your seed

Place 100 seeds on a plate and pour a little water on top. Keep the seeds moist for 5 days and observe how many of the 100 seeds germinate. If less than 70 seeds germinate you must increase the amount of seed used at planting.

**Timely planting:** Many farmers ask the question: "When is the best time to plant?" The answer is not simple and depends on where you live, as this determines the amount of rainfall, soil type and the crops grown. Farmers in the semi-arid areas of Zimbabwe can usually plant some time in November (see Table 7.1). Note that the dates and lengths of growing seasons given in Table 7.1 are averages only; each year is different and unpredictable. With respect to time of planting, note the following recommendations:

- make sure the land is prepared before November
- plant as early as possible after the first rains
- do not sow seeds during the hot time of day. It is better to plant during the morning or late afternoon. This will keep moisture in the soil.

**Table 7.1. Typical rainfall season in selected areas (long-term averages)**

Area	Start of season	End of season	Length of growing season
Zvishavane	16 Nov	30 March	134 days
Tsholotsho	24 Nov	28 Feb	96 days
Nyamandhlovu	25 Nov	23 March	118 days
West Nicholson	2 Dec	8 April	127 days

1. Large parts of this Module are adapted from Agritex/ZFU 1999

### **Advantages of early planting**

- It allows crops to make best use of available water
- Crops benefit from the extra nitrogen released from soil organic matter with first rains
- Crops have an advantage over weeds
- Farmers have the option of growing late-maturing crops
- Farmers have time to re-plant if needed, or to fill in bare patches

- never plant all your area at the same time. In dry areas it is best to spread the risk of drought by planting at different times.

**Soil moisture:** Seeds need moisture to germinate and emerge well. To make best use of moisture it helps to plant early with the first rains, when the soil is wet. Choose a crop production system which makes the best use of the whole length of the growing season. If the rains are late plant a crop or variety which has a short growing season. If the soil is wet enough to plant do not delay! Plant as quickly as possible for good crop establishment.

### **How do I know the soil is moist enough for planting?**

- Dig a small hole and look how wet or dry the soil is. A sandy soil should be moist from the surface to a depth of at least 20-25 cm. A clay soil should be moist from the surface to a depth of at least 10-15 cm
- If you have a rain gauge you can measure rainfall. In sandy soils plant after 20-30 mm of rain. In heavier soils plant after 30-50 mm of rain. See Field Study 2.1 for making your own rain gauge

**Seed planting depth:** Plant the seed at the correct depth. This depends on the crop and the soil type. If you plant seeds too deep, the seedling will die before it reaches the surface. If you plant too shallow the soil may become too dry and the seed may die before it emerges.

### **Rule of thumb**

Planting depth is equivalent to approximately 10 times the seed diameter

**Seed covering:** Ensure the seed has good contact with the soil around it so that it can take up water from the soil. This means you should cover the seed well and not wait too long after opening planting lines or planting holes, as the soil might dry out, inhibiting germination. Remove trash and stones from the planting lines, cover the seed with enough soil and close the furrow or planting hole as soon as possible. If you plough and leave the furrow open in the morning, by late afternoon the soil will be dry and the seed will not germinate or emerge well.

**Seed soaking:** If you cannot plant straight after a rainstorm, soak your seed in water overnight before planting. This will give the seed moisture and help it germinate and emerge quicker. Soaking (also called seed priming) is very good for sorghum and maize seed and helps young seedlings compete with weeds. Field Study 7.1 describes an experiment with seed soaking/ seed priming.



**Figure 7.1. Seed soaking**

keeping the soil covered with mulch, either by leaving crop and weed residues on the surface or by bringing in organic material from outside the field and spreading it over the surface.

**Plant population:** To obtain the best yields from your crops it is important to have the correct spacing and plant population. These will vary with rainfall and soil type. Very often some patches of your field are wetter or more fertile than other patches. In these patches more plants can be grown than in other parts of the field. Look for these patches and try planting more seed in them, if you don't already do so. Look for and plant more seed in wet areas, contour drains, anthills, depressions etc.

**Soil fertility:** The importance of soil fertility in crop production and the use of mineral and organic fertiliser have been explained in Modules 4 to 6. However, if you cannot get fertiliser, manure or compost, do not delay your planting! Plant first, and apply fertiliser, manure or compost when you can. Fertiliser can be applied after planting and before emergence. Or it can be applied as a top dressing once the seedlings have emerged. You can apply the fertiliser when the plants need it.

## **Permanent Planting Basins in Cropped Fields**

Many of the recommended agronomic practices which lead to good crop establishment can be combined – simply by making planting basins before the rainy season begins. The basins are dug with a hoe at regular intervals using a planting line (also called Teren rope). Basins are spaced at 60-70 cm intervals along the row. The rows are 90 cm apart, giving a total of 16 000 to 18 000 basins per ha (or 6400 to 7200 basins per acre). Place a handful of manure in each basin and cover it with a layer of soil. Leave the basins open until the first good rain. After the first soaking rain plant the seeds in the hole and cover them with soil. A small depression usually remains at the site of the basin, collecting more rainfall and reducing runoff. Apart from manure, mineral fertiliser can also be applied to the basins. With little effort, the same basins can be used the next season, provided the field is not ploughed.

Planting basins have the following advantages:

- land preparation is done before the rainy season, so you can plant early
- the basins collect rainwater and allow for early planting
- the basins break through plough pans and provide good rooting conditions
- using basins, you can have even and controlled plant population
- seeds, manure and mineral fertiliser can be correctly placed and thus used effectively

Field Study 7.2 describes an experiment with planting basins.

Planting basins are most effective if combined with conservation farming practices, such as minimum soil disturbance (except for the basins), maintenance of permanent ground cover, and crop rotation.

## **Field Study 7.1. Effects of Seed Priming (Seed Soaking) on Crop Establishment**

**Objectives:** To compare the effects of seed priming on germination rates and crop establishment.

**Time required:** experiment lasts throughout the season, and can be repeated in the following season

### **Materials**

- farmer's field: 2 plots of 10 m x 10 m (total 0.02 ha or 0.05 acre)
- maize seed 200 grams
- hoes
- planting line

### **Procedure**

1. Explain the objective of the experiment, i.e. to let farmers compare the effects of seed priming on crop establishment.
2. Use a simple paired plot design, one plot of 10 x 10 m with un-primed seed, and another plot of 10 x 10 m with primed seed.
3. Get an appropriate piece of land prepared before the study begins. The land should be prepared and marked out into 2 plots measuring 10 x 10 m each.
4. The day before the study take 100 grams of maize seed and place it in a bucket of water. Allow the seed to soak overnight.
5. In the morning remove the seed, place it on a piece of sacking or cloth and remove the excess water.
6. Farmers plant each plot according to their local practice.
7. Keep the plots weed free, at least 2 hand weedings at 2 and 6 weeks after emergence. Weeding of the entire plot should be completed in 1 or 2 days.
8. All other management decisions are to be made by the farmers. They should also make regular observations.

### **Questions for group discussion**

- What lessons did you learn from this exercise?
- Are you going to prime your seeds in future? Why or why not?

## **Field Study 7.2. Use of Planting Basins for Good Crop Establishment**

**Objectives:** To compare planting basins versus traditional planting practice, and see the effect on crop establishment

**Time required:** experiment lasts throughout the growing season, and can be repeated the following season. Planting basins should be prepared before the first rains.

### **Materials**

- farmers field, 0.2 ha (0.5 acre)
- 100 kg manure
- 10 kg Ammonium Nitrate (equivalent to one 50 kg bag per ha)
- seed: 5 kg of maize or 2 kg of sorghum or 1 kg of millet
- hoes

- planting line
- small No. 5 fertiliser cups or beer bottle caps (clear beer such as Castle)

### **Procedure**

1. Explain the objective of the experiment.
2. Get an appropriate piece of land prepared before the study begins. The land should be marked out into 2 plots measuring 20 x 50 m each: one plot for farmers' normal planting practice and one for planting in planting basins.
3. Planting basins should be prepared before the start of the rainy season.
4. The basins should be spaced at 90cm x 60cm giving a total of 1850 basins per 0.1 ha in unploughed land. The basins can be made with a hoe and should be about 20 cm deep and 20 cm long. Use the planting line to get the correct spacing.
5. Apply manure at land preparation, one handful per basin.
6. Cover the manure with a thin layer of soil. Leave the basins open until you receive the first effective rains.
7. Plant immediately after receiving a good planting rain that fills the basin.
8. Plant maize, sorghum or millet in the basins at rate of 3 seeds per basin and cover. To plant one plot of 0.1 ha (0.25 acre) you need 2.5 kg maize, or 1 kg sorghum, or 500 grams millet seed.
9. Farmers should manure and plant the control plot (without basins) according to their normal practice.
10. Apply Ammonium Nitrate at 5-6 leaf stage (3-4 weeks after emergence) in both plots at rate of 1 beer bottle cap per 3 plants.
11. Keep plots weed free, at least 2 hand weedings at 2 and 6 weeks after emergence. Weeding of the entire plot should be completed in 1 or 2 days.
12. All other management decisions should be made by farmers.

### **Questions for group discussion**

- Compare and record performance of both plots throughout the season.
- After both plots are harvested, discuss the experiment and draw conclusions.



## Module 8. Weed Management, particularly for Witchweed and Couch grass<sup>1</sup>

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### Learning objectives

- Realise that weeds compete with crops for nutrients, water and light
- Compare various types of weed management
- Select appropriate weed management practices
- Control Witchweed and Couch grass

### Introduction

Weeds compete with crops for food, water and light (smothering effect) or produce harmful chemicals (allelopathic effect). They can greatly reduce crop yield if not controlled. Small-scale farmers spend a lot of time and energy in weeding. In southern Zimbabwe, Witchweed (*Striga* species) and Couch grass (*Cynodon dactylon*) are particularly harmful and very difficult to control. In pastures weeds may be the least palatable species for livestock, whilst they compete with the more palatable species. Field Study 8.1 may help farmers to recognize weeds and to discuss weed management.

### Harmful effects of weeds

Most of the disadvantages of weeds, listed below, are well known:

- compete with crops (including fodder and pasture crops) for nutrients, water, light, carbon dioxide and space. They reduce the yield and quality of the crop
- may produce chemicals that harm the crop (this is called *allelopathic effect*)
- may carry diseases and pests which attack crops
- some weeds are poisonous to people and/or animals
- may pose a fire hazard when dry
- can impede irrigation and drainage systems
- weeds that are difficult to control may reduce the value of land
- water weeds affect fish, drinking water supplies, and recreation in lakes (e.g. water hyacinth). They also affect water flow along natural drainage lines

Although weeds mainly have disadvantages, they also have some positive side effects, which could be used for the farmer's benefit:

- weeds provide soil cover and root biomass, which can prevent soil erosion and reduce leaching of nutrients
- weed residues, if not removed, act as a mulch and conserve moisture. But be careful with some grasses and weeds that have produced seeds, as they can increase the 'seed bank'
- some weeds can be eaten by humans and animals (e.g. *Amaranthus*)
- some weeds act as insect repellents. Other weeds may harbor insects that destroy or eat crop pests
- weeds, especially those that are wild relatives of crop species, act as gene banks; i.e. they can be used to breed new crop varieties
- weeds are a source of plant nutrients

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1. Large parts of this module were developed in cooperation with the FAO Agricultural Department, notably AGLL and AGPP. See also Gacheru et al 2002.

## Yield losses caused by weeds

As it is almost impossible to completely eradicate weeds, it is essential to develop appropriate weed management practices. Different types of weeds require different control methods. Some have to be controlled at certain stages to avoid competition with crops, especially at crop germination and when the crop is still young and vulnerable. Some have very specific constraints. *Striga* is an indicator of low soil fertility and being a parasite on the host plant, it reduces productivity of the crop. Weeds such as couch grass reproduce through underground horizontal stems (called tillers or rhizomes), which are fast-growing, difficult to remove and will easily re-grow when cut.

Weeding is a major task for smallholder farmers. Some studies show that smallholder farmers in Zimbabwe spend more than 75% of their time battling to control weeds during the peak weeding period from December to February. This reduces the time and labour available for other duties, limits the area that a farmer can handle, and drastically reduces farm output.

Estimated yield losses caused by weeds vary considerably. Using a conservative estimate of 25% yield loss, a smallholder farmer planting 1 ha of maize, with an average yield of 800 kg/ha will lose 200 kg of maize. The results of a trial at Makoholi Research Station (Table 8.1) show the benefits of good weeding practices.

The experiment shows that timely weeding has a positive effect on yields and that weeding twice is better than weeding once. Whether the second weeding was really beneficial in economic terms is not discussed here.

**Table 8.1. Weeding practices and maize yield, Makoholi Research Station**

	Maize yield (kg/ha)
No weeding	350
Weeding 2 weeks after emergence	1200
Weeding 4 weeks after emergence	1350
Weeding 2 and 6 weeks after emergence	1600

## Weed Management

Farmers can choose from four types of weed management:

- *Preventative measures*: Use clean or uncontaminated crop seeds. Control weeds that grow in the borders of fields. Remove weeds before they reach the flowering and seed-setting stage.
- *Agronomic measures*: Crop residue management, manure management (2-3 months of composting kills 70% of weed seeds), crop rotation, cover crops, intercropping and mulching. More information on these topics is given in Module 6 (Soil organic matter and organic fertilizers).
- *Mechanical measures*: Physically pull weeds out of the soil or cut the weeds, either by hand or with draft animals or mechanization. Problem weeds such as *Striga* and couch grass should be collected and burned. Most other weed residues can be used as mulch, compost or fodder, provided they have not reached the flowering stage.
- *Chemical measures*: Use of herbicides, like glyphosate and pre- and post-emergence herbicides. Herbicides can be very effective, they are expensive

and may affect soil life and soil water quality. They may also damage useful plants which grow in or around a sprayed field. The use of herbicides needs special equipment and clothing, careful handling and storage, and good knowledge.

### Timeliness of weeding

...*One year seeding causes ten years weeding.*

Timing of weeding is as important as the actual weeding itself. There is a critical period for weed control during the life cycle of a crop. Weed control in the early stages of crop growth is usually more important than weed control in late stages of crop growth. For example, the critical period for controlling weeds in maize is during the first six weeks after planting, when maize is becoming established and its canopy has not yet fully developed. This means maize should remain weed-free from the 3-leaf stage to the 14-leaf stage. To avert significant yield loss, maize should be weeded twice during the season in low-rainfall areas. In high-rainfall areas, it should be weeded three times during the season.

Crops differ in their need for 'Weed-free periods' due to differences in crop size and leaf cover. Suggested weed-free periods for some crops are shown in Table 8.2. 'Weed-free' does not mean that there cannot be any weeds in the field – it only means that the existing weed population does not compete seriously with the crop for food, water and light. First weeding should be done as soon as the crop emerges and when a significant weed population is present. Depending on the vigor of weed growth, weeding should be continued for at least four weeks in maize and sorghum, and six weeks in groundnut and cotton.

**Table 8.2. Weed-free periods required to prevent yield losses in different crops**

Crop	Weed free period (weeks after sowing)
Sorghum, field beans	4-5
Maize, sunflower	4-6
Groundnut	6
Cotton	6-8
Onions	12

The method of weeding is also crucial. For example, a *Striga* plant produces thousands of seeds that can lie dormant for many years. Therefore, you must systematically remove and burn all *Striga* plants before they can germinate. Farmers should experiment with weeding at different times to see what effect it has on crop yields. See Field Study 8.2 for a hand-hoe weeding experiment.

### Economics of weeding

Farmers have to decide whether it is worth spending a lot of time and/or money on weeding, particularly when the weeds are many and the crop is at an advanced stage. Even if (unpaid) family labour is used, farmers should ask themselves whether they can do more profitable work elsewhere. If labour is hired for weeding, the likely benefits (higher yield) should be compared with the labor costs. In most cases, however, destruction of weeds before they set seed, is profitable in the long run, because this will substantially reduce weed growth and labour costs in future seasons.

### Remember

- Weeds compete with the crop for nutrients, water, light and space
- If weeds are not controlled crop yields will be reduced
- There are different types of weed management to choose from
- Control weeds before they flower and spread their seeds
- During the crop season, always weed when it is hot and dry. This promotes desiccation of the weeds and avoids re-growth
- Timing of weeding is very important

### Weeds that need special attention

Each Natural Region and each farming system in Zimbabwe has its own specific weed problems, but couch grass (*Cynodon dactylon*) and witchweed (*Striga*) are important in many areas. The biology and control of *Striga* is particularly complicated and is therefore described in detail.

### Couch Grass (*Cynodon dactylon*)

Couch grass occurs in many areas where farmers have practiced shallow ploughing at the beginning of the rainy season. This grass spreads very quickly through underground tillers or rhizomes.

### Management strategies

- *Weeding, hand pulling.* If possible, the weed should be pulled out completely and removed from the field together with its tillers. The tillers should not be put in a compost heap or fed to cattle, but should be burnt. In heavily infested fields, the only option may be to use herbicide.
- *Intensive cultivation,* such as repeated deep disc ploughing and harrowing during dry weather, can reduce couch grass infestations. The underground tillers (rhizomes) are dragged to the surface and become dried out in the sun. However, even if half the original moisture content is lost, some tillers are capable of sprouting again. Ploughing twice within six hours of dry weather before planting will significantly reduce couch grass growth in the coming season and for at least one more season afterwards. This method is effective, but requires a tractor or draft animals.
- *Herbicides.* Relatively few herbicides are effective against couch grass. Herbicides are often unaffordable, not easily accessible and may have negative side effects on soil life, soil water, and on useful plants which grow nearby. Therefore, hand weeding or mechanical control procedures, described above, can provide effective couch grass control with minimum use of herbicide.



### Striga or Witchweed (*Striga asiatica*)

*Striga* not only competes with crops, but also attacks them directly. *Striga* is a parasite (like a tick or a flea),

### Remember

- *Striga* only develops from seeds
- Most seeds are found in the upper 20 cm layer of the soil
- A single *Striga* plant can produce a huge number of seeds that make future control difficult
- The seeds can survive for many years in the soil

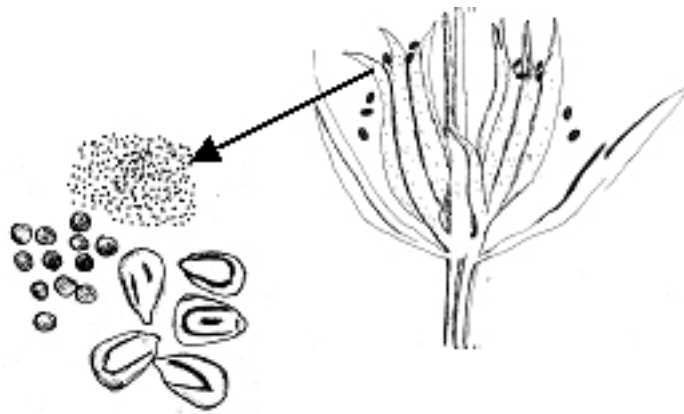
which means it cannot live and grow without a host. It lives at the expense of that host and damages its host more severely than any common non-parasitic weed.

### Appearance, distribution and host crops

*Striga asiatica* is an erect plant growing up to a height of 30 cm. It has red flowers arranged in spikes. The seeds develop in small capsules that split open to release their seeds. *Striga* affects many species of the grass family, such as maize, sorghum, finger millet and sugar cane.

### *Striga* seeds

One seed capsule contains between 250 to 500 minute seeds. One *Striga* plant can produce up to 50,000 seeds. The seeds can remain viable in the soil for many years in the absence of a host plant.



**Figure 8.1. *Striga* seed size in relation to sorghum and maize seeds**

### *Striga* germination and development

*Striga* seeds in the soil require moisture for one to two weeks before they are ready to germinate. They only germinate when the roots of host plants produce a chemical stimulant. A second chemical – produced only by cereal host crops – enables the germinated seedling to grow towards, and penetrate the roots of the host plant. *Striga* then attaches itself to the roots where it obtains water and nutrients for its growth.

After 3 to 6 weeks of development below the soil surface, the first *Striga* plants emerge above ground. Not all attached *Striga* seedlings emerge. Many will still remain underground.

About 3 to 4 weeks after emergence, the *Striga* plant flowers and within 14 days produces its first viable seeds. Once the seed has developed in the capsules it might mature and be viable even if the plant is uprooted.

The life cycle of *Striga* is illustrated in Figure 8.2.

### Effects of *Striga* on the host crop

The first symptoms of *Striga* damage on the host crop can be observed even before the parasite has emerged. Symptoms are similar to those caused by drought:

## Remember

- To germinate and attach to the host roots, *Striga* needs chemical stimulants, produced by the host itself
- *Striga* extracts water and nutrients directly from the host
- *Striga* also poisons its host
- Most damage to the host occurs before *Striga* emerges from the soil
- Some *Striga* attaches to roots but remains underground
- *Striga* needs 10-15 weeks from germination to full maturity
- *Striga* can produce viable seeds just 2 weeks after flowering

- stunted growth (e.g. short internodes)
- wilting or scorching, even where soil moisture is available
- yellowing of upper leaves
- barrenness, i.e. no setting of cobs or heads
- death of host plant before flowering, especially in highly infested fields.

Yield loss depends on the level of infestation and other stresses affecting the crop. Losses can be 30 to 100% for maize and 20 to 50% for sorghum.

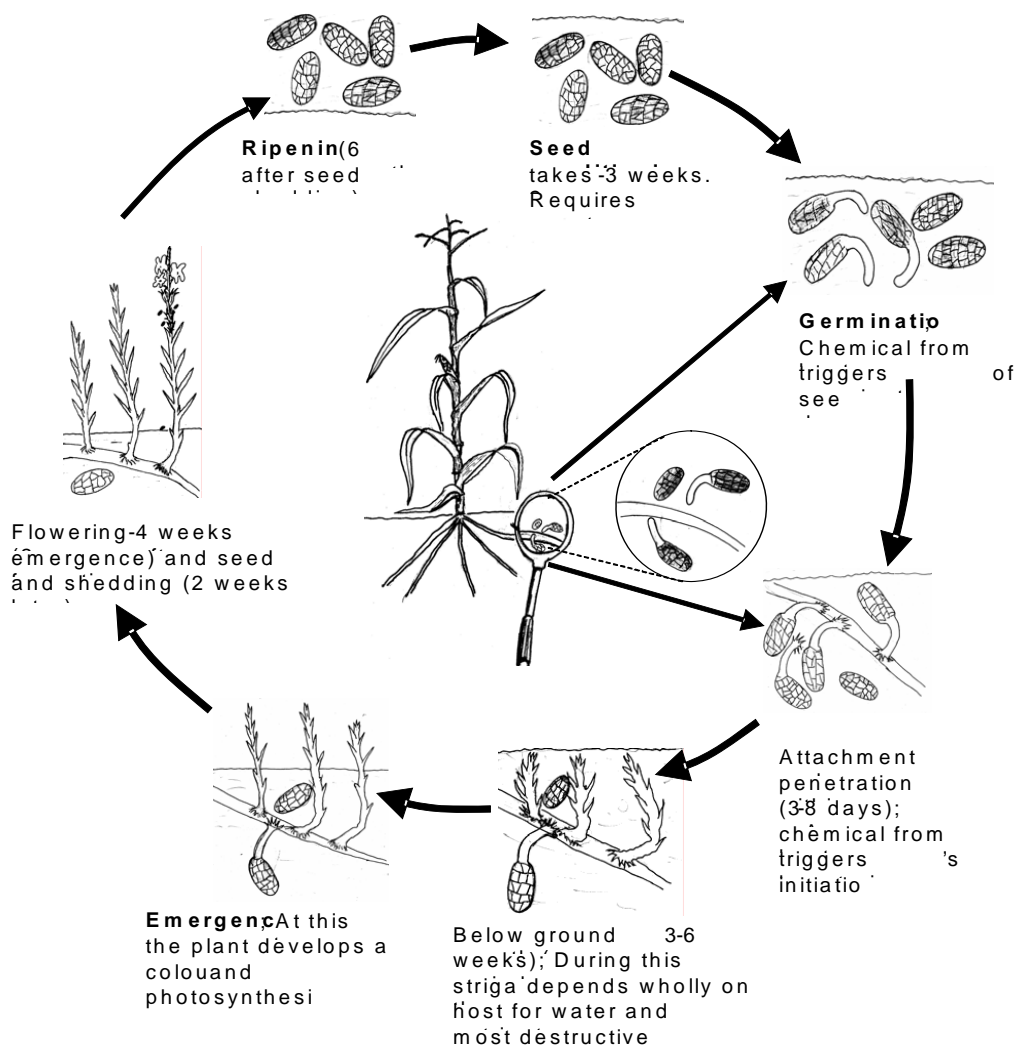


Figure 8.2. Life cycle of *Striga*

### Remember

- *Striga* damage symptoms: stunted growth, wilting, yellow leaves
- Yield reductions are most severe when *Striga* infestation occurs along with other stresses
- Early parasitism causes greater yield loss than late infestation
- A healthy crop has more resistance to *Striga* than a crop suffering from low soil fertility or diseases
- *Striga* is most serious where soil fertility (nutrient supply and organic matter) is low. This can be rectified by improving soil fertility

### How *Striga* is spread

*Striga* seeds can be spread to non-infested fields by crops, farm machinery, animals, man, wind and water.

- **Crops:** *Striga* seed lying on the soil can stick to harvested maize cobs or sorghum heads. If these seeds are used for planting, *Striga* will be carried to non-infested fields.
- **Farm machinery and tools:** Farm machinery or tools can carry soil containing *Striga* seeds, to other fields.
- **Animals:** *Striga* seeds can stick to the fur/hair of animals grazing in harvested fields and are thus carried to other fields. Also, seeds eaten by animals (cows, goats, sheep) pass undamaged through their digestive tract and can be spread with their droppings.
- **Man:** *Striga* seed can stick to shoes and clothes along with muddy soil.
- **Water:** Run-off water from infested fields spreads *Striga* seeds to adjacent fields or carries them to creeks and rivers, which can then deposit the seeds as they run past other fields.

### How to prevent *Striga* from spreading

To avoid contamination:

- collect the seeds for future planting directly from the plants in the field, e.g. maize cobs or sorghum heads, without dropping or threshing them in the field. Do the same for seeds of intercrops (beans, cowpea, etc)
- clean farm tools after working in infested fields
- do not graze livestock in infested fields
- burn all uprooted *Striga* in a deep hole to avoid further spread of seed. Do not throw them or place them on roadsides or footpaths
- remove all *Striga* plants before flowering to prevent any build-up.

### How to Control *Striga*

Control methods reduce the amount of *Striga* seeds in the soil and/or reduce the rate of infestation. The following points are important:

- Controlling *Striga* by agronomic practices in low-input systems is always a long-term approach, usually with an immediate increase of crop yields in the short-term. Good agronomic practices include timely land preparation, good seed selection, proper spacing and timely weeding.
- Whatever control strategy is used, it is essential to uproot flowering *Striga* plants to avoid seed shed.

- An integrated approach, i.e. combination of two or more methods, has the best chance of success.

### **Soil fertility improvement**

*Striga* is typically associated with low soil fertility. Its effect is most devastating on nutrient poor soils. Therefore, agronomic practices to improve soil fertility are an important aspect of control. Soils with a frequent supply of organic matter will produce healthy crops, which are less prone to *Striga* attacks. After few seasons *Striga* numbers will decrease tremendously. However, increasing soil fertility is a long-term process that cannot be achieved within a few seasons.

**Remember:** *Striga* only builds up and is most damaging on soils with low fertility

### **Select and plant varieties that are tolerant to *Striga***

Tolerant varieties allow *Striga* attachment but can withstand moderate pressure and still give reasonable yields. Some varieties are more tolerant to *Striga* damage than others. In general, sorghum is more tolerant than maize, i.e. if sorghum and maize are infested with the same number of *Striga* plants, yield loss will be more severe in maize.

### **Weeding/Hand pulling**

Weeding or hand pulling of *Striga* is still the most effective control method, because once no new *Striga* seeds are produced, infestation can be successfully reduced. It needs a continuous period of weeding at emergence or before flowering over many cropping seasons to get rid of the weed seed bank.

The *Striga* plants should be carried from the field and burned in a pit somewhere near the field to ensure that all viable seeds are destroyed. Putting the *Striga* plants at roadsides will make the *Striga* seeds spread further.

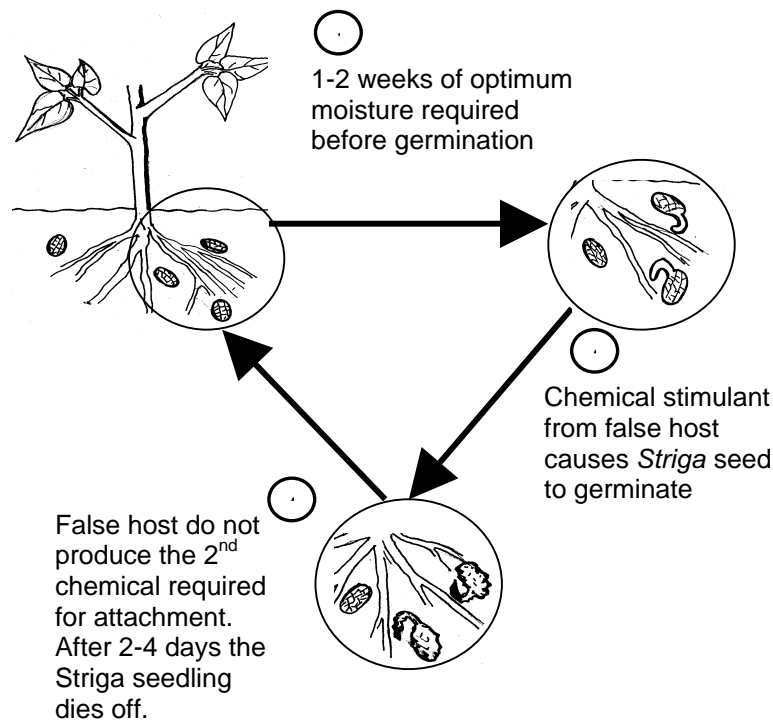
#### **Remember**

- Weeding of *Striga* is an essential component of every control method
- Weeding should be done when the first *Striga* plants are flowering
- Weeding must be thorough – it is not a job for children
- Weeding should be repeated once or twice each season
- Unless *Striga* is weeded or hand pulled before flowering, control will not be effective

### **Trap-crops or false hosts**

Many crops produce chemical stimulants from their roots that trigger *Striga* germination. Host crops (e.g. sorghum, maize) also produce another second chemical which is needed for *Striga* attachment. But many non-host crops do not produce this second chemical. Such crops (which are called trap crops or false hosts) induce suicidal germination. The *Striga* seed will germinate but will not be able to attach itself to the false host roots and will die off. Trap crops can be grown to reduce *Striga* seed numbers in the soil without themselves being affected by *Striga*.





**Figure 8.3. *Striga* life cycle when false host is used in rotation or improved fallow**

False hosts or trap crops include cotton, sunflower, sesame, soybean, groundnut, bambaranut, pigeonpea, lablab, beans, cowpea and legumes used as improved fallows (e.g. *Sesbania*, *Leucena*, *Callindra*, *Crotalaria*, *Mucuna* and *Desmodium*). False hosts can be used as intercrops, improved fallow or in crop rotations.

### **Intercropping**

Maize or sorghum is intercropped with a crop like groundnut, cowpea, or sweet potato, which produces good soil cover. Fewer *Striga* plants will emerge and flower. To achieve this, the intercrop should be planted at the same time as maize or sorghum. *Striga* will still affect maize or sorghum plants, but weeding is easier because fewer *Striga* plants will emerge. Also the intercrops will add an extra yield.

### **Intercropping maize with *Desmodium* (push-pull strategy)**

This practice involves double row intercropping maize with the fodder legumes silver leaf (*Desmodium uncinatum*) or green leaf (*Desmodium intortum*). When the intercrop is fully established, *Striga* emergence is reduced by up to 40%. *Desmodium* improves soil fertility and at the same time smothers the few emerged *Striga* plants. Being perennial, it can be used as feed for dairy livestock, also improving manure quality. However, even though *Desmodium* fixes nitrogen, nutrients are still mined through crop and fodder harvest, thus there is need to integrate livestock activities so that manure can be recycled into the system.

### **Crop rotation with food crops**

Crop rotation is probably the least labour intensive method to reduce *Striga* infestation in a field. It is a well-known strategy for reducing pest and disease

infestations in general. To control *Striga* in heavily infested fields, non-cereal crops should be planted for more than 3 seasons, in the same field. Choose crops that are profitable and also fit into the daily diet of the household. Groundnut, pigeonpea, soybean, beans, sesame and sweet potato have proven to be very productive in a rotation, giving higher productivity compared to continuously growing maize in *Striga* infested areas. Nitrogen fixing crops are an advantage as they reduce the *Striga* seed population and simultaneously increase cereal yields by increasing soil nitrogen. Some varieties are particularly effective in stimulating *Striga* seed germination; such varieties should be selected.

### **Crop rotation with fodder crops or improved fallow legumes**

In an improved fallow system a herbaceous/shrub/tree legume is grown in rotation with the crop, with the purpose of fixing nitrogen. In addition to improving soil fertility, some of the legumes recommended for improved fallow also reduce the *Striga* seed bank in the soil (false hosts). Such plants include *Sesbania*, *Calliandra*, *Crotalaria*, *Desmodium*, *Gliricidia* and *Leucena* among others.

#### **Remember**

- In the crop rotation, exclude maize or sorghum for at least 2 seasons – the longer the better
- Grow crops which are marketable and economically profitable, and also adapted to local conditions
- *Striga* will still infest the maize plants intercropped with fallow species during the first season. But weeding is easier because less *Striga* plants will emerge. The intercrops will also add an extra yield
- Even though infestation is drastically reduced in the crop following the Improved Fallow period, a few *Striga* plants will still attack the cereal. To avoid re-infestation uproot these *Striga* plants before they flower

### **Catch cropping**

Grow a *Striga* host crop such as sorghum or finger millet at higher-than-normal density in a *Striga* infested field for several weeks until the parasite has attached to the roots. Then uproot the infested crop to destroy the *Striga*. Catch cropping can reduce the *Striga* seed bank considerably within two seasons. Catch cropping should be used where *Striga* infestation is very high. The uprooted crop can be used as livestock feed.

### **Chemical control**

Herbicides are rarely used to control *Striga* because they are expensive and often not cost-effective unless the farmer is producing a high value crop, e.g. a seed crop. Regular direct spraying of 2,4 D<sup>2</sup> before flowering will reduce the *Striga* seed bank just as weeding does. Herbicide handling requires special equipment and training.

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2. Dichlorophenoxyacetic acid 1% solution

### ***Striga* control needs an integrated approach**

The best and most effective way to control *Striga* is to use an integrated approach, i.e. use several control methods at the same time. For example:

- soil fertility improvement + crop rotation + hand weeding
- soil fertility improvement + hand weeding
- soil fertility improvement + intercropping + hand weeding

However, farmers should be encouraged to experiment and learn the best management techniques, rather than being convinced to use a method they are not comfortable with. Farmers should start experimenting with at least one or preferably two or three control methods. Once they gain more confidence in *Striga* control, they can try other methods to get even better results. Field Studies 8.3 and 8.4 describe experiments to understand and control *Striga*.

#### **Remember**

- All control methods require extra effort by the farmer
- Control methods must be used regularly as a standard practice. Even one season of unchecked *Striga* growth might bring the farm (and possibly the whole community) back to square one in terms of infestation
- Try to motivate and encourage farmers by illustrating the benefits achieved
- *Striga* control should be a community effort

## Field Study 8.1. Recognising Weeds and Discussing Weed Control Methods

### Objectives

- classify weeds according to economic significance as perceived by farmers
- identify factors which lead to heavy weed infestation
- identify what practices and innovations farmer use for weed control
- identify what exercises to carry out and what type of trials/experiments to establish
- develop farmer-acceptable management strategies for weeds

### Materials

- pen, paper
- hoe

**Time required:** 2 hours (preferably during crop season).

**Procedure:** Farmers gather in a cropped field and then walk in small groups in different directions, collecting weed samples. They come back to compare the samples and discuss.

### Questions for group discussion

- What is the weed status in the plot? What are the dominant weeds? (Record local names)
- Are there weeds you discovered for the first time?
- How would you classify the weeds, which weeds are difficult to control and why?
- Is it worthwhile to weed? What are the costs and benefits?
- Do you experience the same problem in your own fields, how many of you?
- How do you control weeds in your fields? What do you use for weeding? Is the method effective?
- What is the best time to weed? During what stage of crop growth should you weed?

## Field Study 8.2. Weed Management Trial

**Objective:** To demonstrate the effect of weeds on crop growth and yield, and show how good weed control during a crop's critical period is the most effective

### Materials

- maize or sorghum seed
- hoes
- record sheets
- measuring tape

**Time required:** season-long experiment, with weekly visits to trial site

### Procedure

1. Design treatments together with farmers. For example, if sorghum is the main crop in the area the group might decide to have some or all of the following treatments:
  - T1: hand/hoe weed an area of 50 m<sup>2</sup> at 0 and 30 days after planting
  - T2: hand/hoe weed an area of 50 m<sup>2</sup> at 0 and 60 days after planting
  - T3: follow extension recommendations

- T4: normal farmer practice
  - T5: control (no weeding)
2. Take samples every week from each treatment. Groups should keep records and notes for evaluation at the end of the crop season. Ideally, each group maintains a data table to record number of tillers, plant height and disease presence at the end of every week, and to record yield at harvest.
  3. Analyze and discuss results of all treatments.
  4. Formulate recommendations on good weed management for the group.

#### **Questions for group discussion**

- What effects of weeds do you observe, e.g. what are yield differences between T4 (farmer practice) and T5 (control).
- Seeing the results of the experiment, is it worthwhile to weed? How would the cost (labour) compare with the benefits (higher yield)?

### **Field Study 8.3. Examining *Striga* and Discussing Control Measures**

**Objective:** To learn how *Striga* grows and multiplies, and ways to control it

#### **Materials**

- records sheets
- pen
- plastic bag

**Time required:** Season-long study with monthly visit to *Striga*-infested field; could be extended to last over two or three seasons (see also Field Study 8.4)

#### **Procedure**

1. Early in the season with first emergence of *Striga*, pull up a few affected maize or sorghum plants and examine how the parasitic plant is attached to the roots. Discuss how the weed sucks moisture and nutrients from the host plant. Also compare with some non-affected plants in the same field and see how much damage has been done during the first (underground) stages of *Striga* growth. In fact, maximum damage is done during this stage.
2. Four to six weeks later, examine *Striga* plants again. Look for capsules with seeds and try to collect them. See how small and numerous the seeds are, and how easily they can be transported by wind, water, farm implements, animals and even people's clothing.
3. Decide on the best measures to control *Striga*.

### **Field Study 8.4. Experimenting with Biological *Striga* Control**

**Objective:** To learn a method of biological *Striga* control

#### **Materials**

- fertilizer and/or manure
- clean seeds of food crop and cover crop (e.g. maize and cowpea)
- fencing material

**Time required:** long-term experiment, with several short visits over a period of two or three growing seasons. Control measures have to be carried out over several seasons to show results.

## Procedure

This study is conducted together with Field Study 8.3

1. At the beginning of the season study *Striga* growth and spread (see Field Study 8.3).
2. During the season, discuss with the farmers which control measure or combination of control measures they want to try out. For example, a combination of control measures could be: weeding + soil fertility improvement + intercropping.
3. Shortly after harvest, select a *Striga*-infested field and divide it in two plots. Plot A is the 'improved plot' for experiments. Plot B is the 'unimproved plot' which is farmed as usual. If possible erect a simple fence between the two plots, to avoid people and animals going back and forth between them.
4. After harvest, remove all *Striga* and affected crop residues from plot A. Decide on soil fertility improvement measures (manure, fertilizer or both). Decide on intercrop combination for next season (e.g. maize-cowpea) and make sure clean seed will be available in time.
5. Plant and fertilise crops at the beginning of next season on plot A, using clean seed. Plot B is cropped as usual.
6. During the cropping season remove (pull) all *Striga* seedlings before flowering stage from plot A. Try to avoid contamination with *Striga* seed from plot B. Fertilize the crop on plot A as required. Also control other weeds in addition to *Striga*.
7. At harvest, record yields from both plots A and B. The effect of weeding, fertilization and soil cover may not be easily seen in the first year. If possible, repeat the experiment in the second year or even third year.
8. For the next one or two seasons repeat steps 4 to 7 on the same plots. For every season keep records of *Striga* infestation in both plots A and B.
9. Throughout the experiment, compare *Striga* infestation and crop performance in both plots. Try to understand the reason for any differences observed.

### Remember

- To control *Striga*, farmers should have some knowledge of its biology
- *Striga* is an indicator for low soil fertility
- Control is a long-term approach. It may take some seasons to have effect – crop yield will not increase immediately
- *Striga* control needs a community effort

# Module 9. Land Degradation, Control Barriers and Pegging <sup>1</sup>

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## Learning objectives

- Understand the principles of soil erosion
- Understand the importance of integrated soil and water management in erosion control
- Know a few erosion control barriers
- Learn how to implement no-till tied ridging
- Learn how to make an A-frame and how to peg contour lines

## Principles of Soil Erosion

Soil erosion means the movement of soil from one place on the farm to another. Usually erosion is caused by water, but it can also be caused by wind if the soil is dry and bare, like a bare winter-ploughed field exposed to strong November winds before the first rains.

Water is the most serious cause of erosion. The faster the water flows the more power it has, which means the more soil it can erode. If you see fast flowing water on your land, take action immediately! Fast flowing water steals the soil and with it, the soil nutrients which your crops need.

### Water: friend and foe

Water is our friend because it gives life to the crops and the trees and it fills the rivers and streams with the water we need. But fast flowing water is our enemy, because it steals our soil and disappears very quickly. We want the water to stay with us; we do not want it to run away with the soil.

*Mr Mafuta, farmer in Zaka, Masvingo*

**Raindrop erosion:** When raindrops fall on the ground they have a certain power or energy. The bigger the raindrops the more energy they have. During heavy showers the energy is high and the raindrops can even damage the soil structure by breaking up clumps or aggregates of soil particles (see Module 1 on soil structure). When soil aggregates break up into smaller pieces, the soil becomes less resistant to water moving on the surface, because smaller soil particles are easily dislodged by flowing water. Water that flows on the surface is called run-off.

**Sheet erosion:** When water runs on the surface in a uniform way without flowing into small channels or depressions, it is called sheet erosion. This can typically be seen when the roots of a tree are becoming exposed and all the soil that used to cover the roots is eroded.

**Rill erosion:** When run-off starts to 'meet' in small channels or depressions in the land, it is called rill erosion. The channels or depressions are called rills. Figure 9.1 shows a typical situation, where water flows in rills onto a newly ploughed field. The rills cross the furrows and will eventually break the contour to the right.

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<sup>1</sup>. Large parts of this Module are adapted from Agritex/ZFU 1999

Rills are a sign of serious problems. If you see rills on your land, take action! Water flows fast in rills. Therefore, very soon the rills get deeper, water will flow faster and faster, and more and more soil will be stolen from the field. During heavy showers even crops may flow away or be seriously damaged.

**Gully erosion:** When rills become very deep, say more than 50 cm, we call them gullies. A gully is therefore a place where a lot of rills meet and a deep 'scar' is made in the land. When a rill has developed into a gully it is very difficult to reclaim, because it requires a lot of work. But it is still possible through a community effort where everybody works together.

Gullies can grow up to hundreds of meters long, more than 30 m wide and over 20 m deep. They not only take soil, they also take land that used to be fields or grazing areas. Gully erosion can be prevented only by controlling the earlier stages of erosion.

### Discussion

- Try to think about the way water flows on your own land, what you do about it, and how maybe you could avoid rill-damage in your land.
- How can you make water flow slow and gentle?
- How can you keep water and moisture safely in your land?



Figure 9.1. Uncontrolled runoff from grazing areas creating rills and breaking contours in field

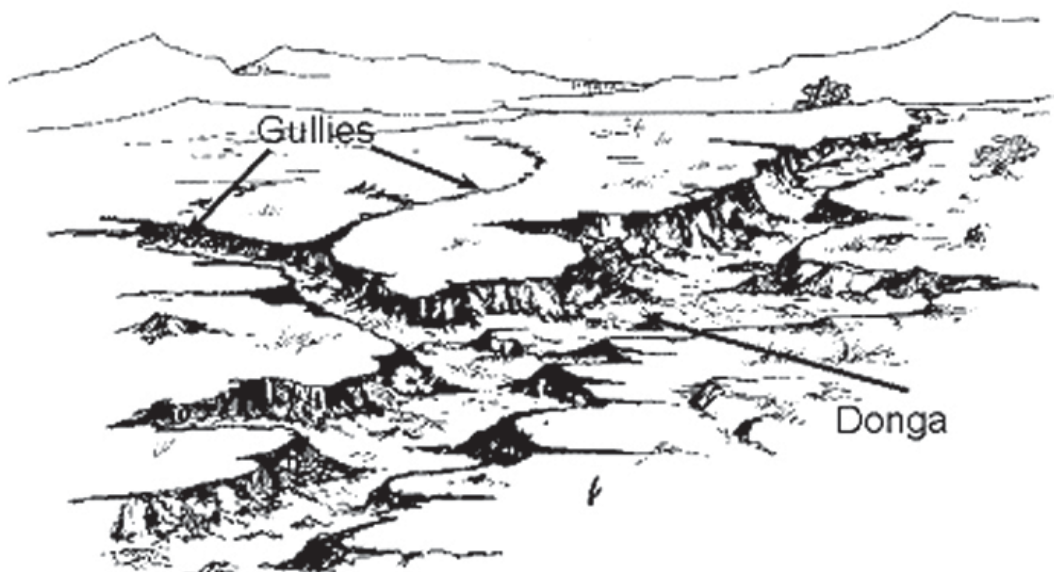


Figure 9.2. Rills developing into gullies and dongas



## How to Improve Soil and Water Management

First, find out where water flows fast and where rills or gullies have developed. The best way to do this is to walk around your land (fields as well as grazing areas) when it rains, to see what happens. As you walk around the land, try to find out where the water comes from. Then find ways of controlling it right at the source, which is usually a kopje or at other people's fields. Discuss the problem with your neighbours and agree on a plan to reduce the flow of water. Explain to them that if the water is trapped on their land it will benefit their crops and will prevent further soil erosion down-slope. Help them and also try to see things from their point of view, and thereby reach a common understanding of the problem and how to solve it, *by working together*.

**Controlling rills and gullies:** There are many ways of controlling rills and gullies. Most are cheap and easy to apply, but they require labour. The key issue is to reduce the speed of the water and increase the amount of water that seeps into the soil (infiltration). The easiest way to do this is to 'block the road' for run-off. This can be done by planting grasses like Vetiver grass in a dense hedge or several dense hedges straight across the rill.(see also Field Studies 9.4 and 9.5). Sisal planted very closely together is also effective. Another option is to lay out stones across a rill. This is known as a stone check or cross dam. Gully reclamation usually requires a community effort, with *everybody* in the community improving the existing conservation measures/ structures in their own lands and also working together in the communal grazing areas and near the gullies. Therefore the main activities should be, good conservation work in the fields and control of rills leading to the gully. These activities can be combined with tree planting around the gully or construction of stone checks or planting of bananas or Vetiver strips within the gullies to conserve soil and water.

### Remember

- Gullies can only be reclaimed through good soil and water management
- Good soil and water management is required throughout the whole catchment
- Gullies cannot be reclaimed by working inside the gully alone

### The importance of soil cover

**Mulch:** The destructive impact of raindrops can be reduced by covering the soil with a mulch of stover and other plant residues. The energy or power of the raindrops will be taken out by the layer of mulch, so water will reach the soil gently and will not destroy the soil aggregates. More water will infiltrate and the soil will become wetter and better for the crop.

**Intercropping:** Another option is to grow cover crops that can protect the soil; or to plant crops densely, e.g. by intercropping. To intercrop means to grow different crops on the same field. For example, an intercrop of maize and beans will provide a good leaf cover for the soil and at the same time it will increase yield. Some years ago people believed it was ‘backward’ to intercrop, but we now know that intercropping has many advantages: gives higher yields, physically protects the soil, and improves soil fertility. Many of the ‘traditional’ ways of intercropping are very valuable for soil and water management, and can be used to increase yield.

### **Control barriers**

For many years in Zimbabwe, contour ridges have been promoted as the best way to conserve soil. However, in many cases, the standard contour ridge has not proved to be the best method for soil and water management. Many other methods are available, some of which have been tried in parts of Zimbabwe – with good results, especially in drier areas. Some of these alternative methods are described below. Field Studies 9.1 to 9.3 describe how to build and use simple levelling tools.

**Infiltration pits in the (existing) contour drain:** The standard contour drain is designed to divert water from the field, but a lot of water can be harvested in the drain by digging water infiltration pits that trap the run-off water from the field. This is an easy way to improve the standard contour drain. Infiltration pits are very simple to make. Simply dig square pits in the existing contour drain. No pegging is needed. No instruments are needed except picks and shovels. The amount of run-off water that can be harvested depends on the size and spacing of the pits. Farmers have tried many different sizes and spacings, all the pits have worked well.

#### *Advantages of infiltration pits*

- existing contours can easily be improved with infiltration pits
- they conserve water and moisture that will benefit crops, especially during dry spells
- they reduce the amount of water flowing in the contour drain and the waterway, thereby reducing erosion
- they trap the fertile topsoil that otherwise would have been carried away. This topsoil trapped in the infiltration pit can be carried back to the field to restore soil fertility
- infiltration pits reduce the risk of overflow or breakages in the contour ridge.

#### *Disadvantages of infiltration pits*

- it is hard work every year to carry soil back from the pit to the field and spread it.
- to maintain their harvesting water capacity, infiltration pits must be re-dug almost every year
- infiltration pits may cause waterlogging in years of excessive rainfall.

**Size and spacing of infiltration pits** (guideline based on Zaka farmers' experience)

- length 2m, width 1m, depth 50 cm to 1m
- spacing: 10m between the pits

If you decide to dig small or shallow pits less than 50 cm deep, space the pits closer, preferably at every 4m or 5m

#### **Infiltration pits and compost**

Many farmers who have tried infiltration pits have also used the pits for making compost. This is done by throwing stover and other plant residues into the pits. Let it stay there during winter and then spread it onto the field just before ploughing. During late rains and winter showers, the material becomes organic fertiliser.

**Dead level contour ridges:** A dead level contour ridge looks exactly the same as a normal, graded standard contour ridge. The aim of the standard contour ridge is to divert excess water away from the field. The aim of the dead level contour is to keep water in the drain. Thereby soil and water are retained in the field, and we can grow crops that require more water in the ditch with less risk of them being eroded by flowing water. An existing graded contour ridge cannot be converted into a dead level contour ridge.

**Trash lines:** These are simply lines of previous crop residues laid along the contour in 1m to 2m wide strips; pegging is therefore still needed. One could also call trash lines a line of mulch. The trash acts as a barrier, reducing the speed of run-off and increasing infiltration. Trash lines can be very effective in low-rainfall areas where the slope gradient is low and the land is almost flat. One big advantage is that trash lines can easily be moved if you need to change the lay-out of fields or if pegging was not done properly. Compared to the conservation works (which require digging) this is a big advantage.

**Stone lines:** In case there are plenty of stones in the field, they can be moved and arranged in lines along the contour. Like trash lines, stone lines are permeable



**Figure 9.3. Stone lines laid along the contour slow down the runoff and encourage infiltration**

barriers: some water will flow through them, but a lot of soil and water will be trapped and infiltration will increase. Before placing the stones in a line, prepare a shallow trench, 10-15 cm deep and about 30-40 cm wide, by digging along the pegs. First place larger stones at the bottom of the trench as a foundation. Then place smaller stones on top to a height of 25-30 cm. Stone lines can be further improved by planting grasses or fruit trees just in front of the stone line.

**Vetiver grass hedges:** A continuous dense hedge of Vetiver grass along the contour will conserve soil and water as well as (or even better than) the standard contour ridge. Vetiver grass is an infertile plant, i.e. seeds of the grass do not germinate when sown. And since Vetiver does not produce root shoots either, it never becomes a weed that spreads into the field. It simply stays where we plant it! Field Studies 9.4 and 9.5 provide guidelines for establishing a Vetiver nursery and planting Vetiver contour hedges.

#### *Advantages*

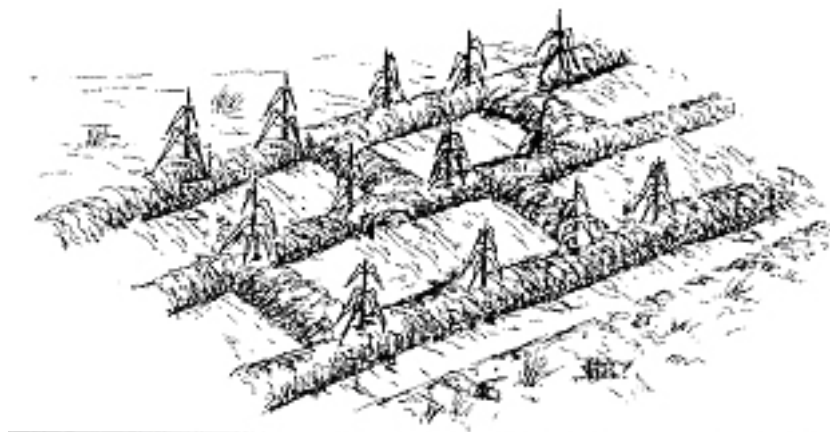
- Vetiver becomes very drought tolerant 6-8 weeks after planting
- Vetiver does not suffer from waterlogging: the more water the better
- a Vetiver hedge occupies very little space in the field (a hedge is about 50 cm wide)
- Vetiver grass can be used for many purposes, e.g. thatch, mulch, compost
- it is not vulnerable to veld fires or burnings. On the contrary, fire encourages tillering and formation of a more dense hedge.

#### *Disadvantages of Vetiver*

- Vetiver will work properly only if it is planted in a dense hedge. There must be no gaps in the hedge
- to establish a Vetiver hedge, fresh planting material is needed because the seeds are infertile. Planting material is scarce
- newly planted Vetiver must be watered during the first 6 weeks if it does not rain.

## **No-Till Tied Ridging**

No-till tied ridging is a conservation tillage system consisting of ridges which are cross-tied at regular intervals with small dams. The basins formed between



**Figure 9.4. Tied ridges; crops planted on the ridge**

the cross-ties prevent the water from flowing off the field. Once the ridges are established the land is not ploughed for up to 5 years. That is why it is called no-till. The only tillage operation to be carried out is re-ridging. This system therefore saves draught power.

#### *Advantages*

- increases yields, particularly when combined with improved soil fertility
- less tillage work required in following season
- reduces soil erosion
- conserves moisture
- reduces the impact of waterlogging in wetlands

#### *Disadvantages*

- master ridge needs correct pegging at 1:100 grade
- difficult to establish small grains and cotton on the ridge top
- control of weeds, especially Couch grass, can be a problem

### **Land preparation for no-till tied ridging**

Check the field for rills, depressions and contours which are overflowing. Water flowing in from outside the field might destroy the ridges. Therefore the contours must be in good condition. If rills and depressions are deep, tied ridging should not be applied until the rills are reclaimed. The field should be well ploughed on the contour before tied ridges are established, in order to:

- enhance deep rooting of crops
- control perennial weeds like Couch grass
- provide enough loose soil to build ridges .

In case there is too much rain, excess water has to drain in order to avoid waterlogging. Therefore ridges have to be laid out on a gradient of 1:100. You can use a line-level or A-frame to peg out a master ridge line along the contour in the middle of the field. Once the master ridge is pegged, further contours can be pegged and manure can be spread along the line of each ridge, before making the ridges.

### **Making the ridges**

*Option A.* You have already pegged a master ridge line using a line level or A-frame. Using a plough and two to four animals (oxen or donkeys), plough a furrow along the master ridge line. Turn at the end of the field and come back, throwing the soil towards the small ridge so that it becomes a big ridge about 90-100cm wide at the base and 15-20cm high. The top of this ridge should not be pointed but must be shaped like a V so that the water can infiltrate into the ridge, as shown in Figure 9.5. Continue making more ridges parallel to the master ridge line by throwing the soil from both sides to the centre to form ridges until the whole field is ridged.

*Option B.* Ridges can also be made with a high-wing ridger. The advantage compared to the plough is that only one operation is required. However, this ridger requires high draft power (4 oxen).

*Option C.* Ridges can also be made with an ox-drawn cultivator with hilling blades attached. The advantage compared to the plough is that only one operation is required.

**Tying the ridges:** After making the ridges, ties should be made. Ties should be lower than the ridge ( $\frac{2}{3}$  the height of the ridge). Spacing of the ties will depend on slope. On flat land, the ties should be made every 3 to 4 m. On steeper land ties should be made every 2 m. On and around anthills, make ties as close as 1m. Several tools can be used for making the ties

- hand hoe and shovel
- local tie maker, made from a beam and a piece of old steel
- single animal tool bar with the tie maker blade.

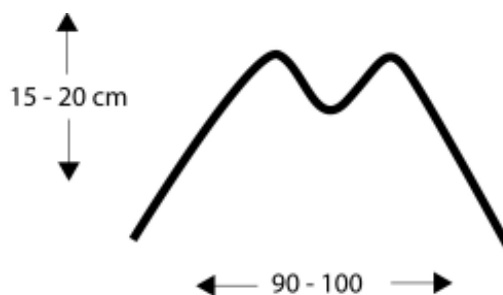
#### Some useful ideas

- a single ox or donkey can be used when tie-making
- when making ties with oxen, use a cultivator yoke
- many farmers have successfully made ridges using hoe and shovel
- some farmers make ridges at weeding and keep them the following season.

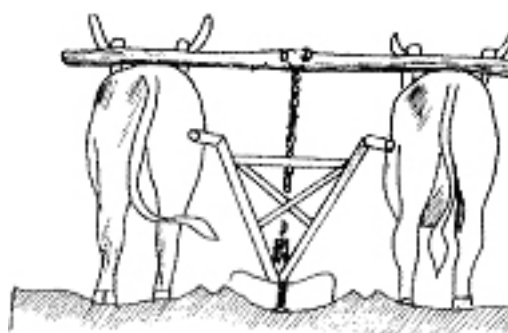
#### Choosing planting position

Planting can be done on top of the ridge, on the ridge flank or on the furrow-bottom, depending on the problem you are facing.

- *Planting on the ridge top* is best for rooting and for fertility. It is easy to weed mechanically without disturbing plants. In wetlands/vleis this is the best position as it keeps the feet of the crops dry. However, the ridge top dries quickly, which can cause poor germination, particularly with small grains and cotton. Therefore it is best in areas with higher rainfall (Natural Regions I, II and III) and ideal in wetlands.
- *Planting on the ridge side* is better for crop establishment, but it is more difficult to plant and to weed mechanically.
- *Planting in the furrow* is best in very dry areas (Natural Regions IV and V), as the furrow is the wettest point. However, waterlogging can be dangerous.



**Figure 9.5.** Cross-section of a ridge with typical V-shaped top



**Figure 9.6.** Ridges made by high-wing ridger



**Figure 9.7.** Tying by hand

Furrow planting must always be combined with manure or fertiliser as the soil in the furrow is poor. Mechanical weeding is impossible as the crop stands in the way.

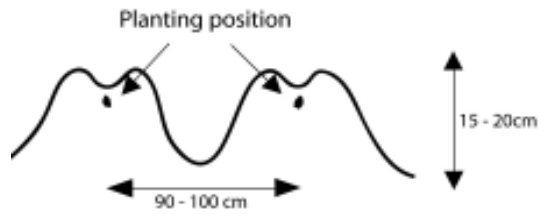
### Some useful ideas

- try out which position is best for your soils and get your own experience
- in vlei/wetlands some farmers plant maize on the ridge top and rice in the furrows.

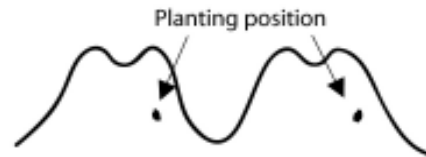
### Rainwater Harvesting

There are many ways of harvesting rainwater. The design and lay-out depends on the requirements, the money available, and the type of rainwater harvesting project. Most farmers cannot afford to construct a big water tank, but other options are possible. You can harvest water from thatched houses in oil drums, or you can divert water falling from the roofs to a banana stand. Schools usually have more resources. They can harvest a lot of rainwater from the roofs of the school block, either through gutters fixed to the roofs or in channels on the ground leading to an underground tank. The construction of such a tank should be supervised by an experienced builder.

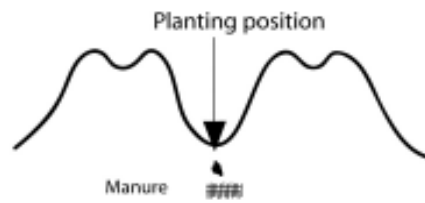
Another option is to harvest the run-off from the ground around the homestead to a stand of fruit trees. These are called run-off orchards, and consist of small basins made around every tree. The run-off water collects in the basin, increasing water available for the tree, which will yield extra fruit.



**Figure 9.8. Plant on top of ridge in wetlands**



**Figure 9.9. Plant on the ridge side**



**Figure 9.10. Plant in furrow (semi-arid areas)**



**Figure 9.11. Different methods of harvesting water for fruit trees**

## Field Study 9.1. Making an A-Frame

**Objective:** To learn how to make an A-frame to be used for pegging

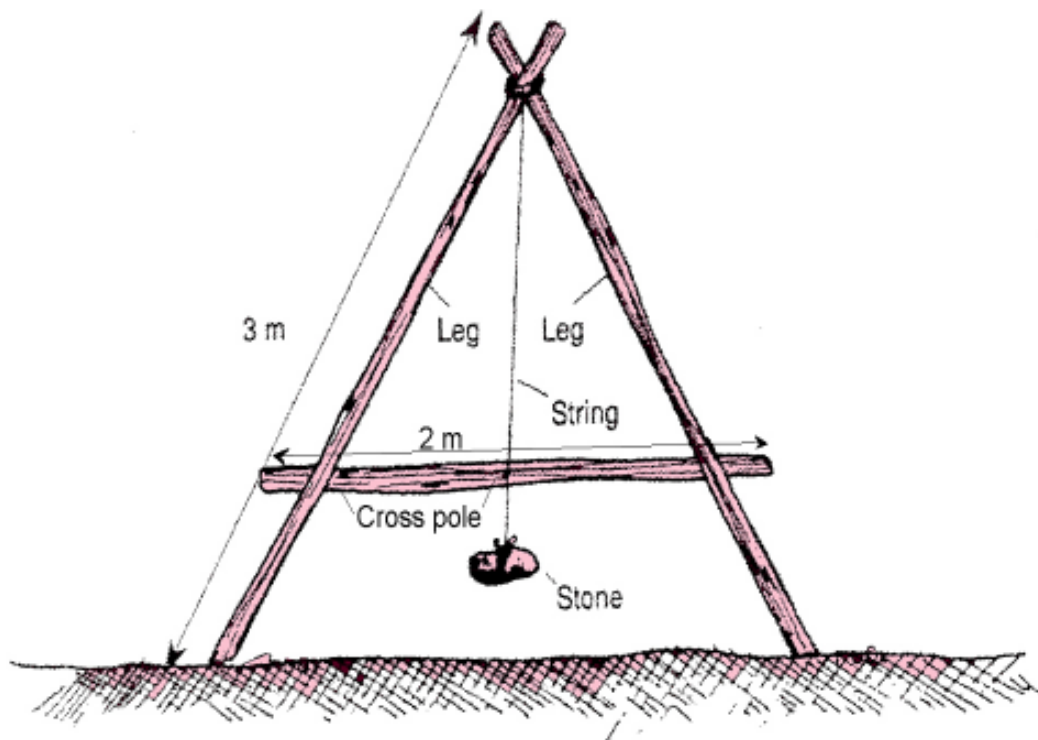
**Time required:** 2 hours

### Materials

- approximately 2 m of strong string
- 1 stone (oblong, about the size of a fist)
- two straight poles, each 3 m long
- one straight pole 2 m long
- knife

### Procedure

1. Tie the two long 3 m poles tightly together at the top. Then tie the shorter pole across the two long poles to form the shape of the letter 'A'.
2. Tie a string around the stone, and tie the other end of the string to top of the 'A' where the two long poles are joined. Make the A-frame stand upright. The stone should hang about 15 cm below the cross pole.
3. Go to a house with a level floor and stand the A-frame with one leg resting on a flat stone or a book. Make a small temporary mark on the cross pole to show the position of the string.
4. Move the A-frame so that the other leg now rests on the book or stone. Make another temporary mark on the cross pole to show the position of the string.
5. Make a very clear and permanent mark exactly in the middle between the two small temporary marks.



**Figure 9.12. The A-frame**



## Field Study 9.2. Pegging with the A-Frame

**Objective:** To learn to peg level contour lines using an A-frame

**Time required:** 4 hours

**Materials:** A-frame (see Field Study 9.1), 20 pegs or stones

### Procedure

Pegging with an A-frame requires two people.

1. Go to the centre of the field and mark it with a peg. Place one leg of the A-frame right next to the peg.
2. Hold this leg in place while slightly moving the other leg up and down the slope until the string is exactly in front of the permanent mark in the middle on the cross pole. Mark this point on the ground with a second peg. The string should be very close to, but never touch, the cross pole.
3. Pivot the first leg around while holding the other leg at the second peg. Move the first leg slightly up and down the slope until the string is again right in front of the mark.
4. Continue like this to the field boundary. (See Figure 9.13)
5. Return to the centre of the field where the very first peg was placed and move in the opposite direction to the other end of the field following steps 2-3.

### Useful ideas

- Every time before using the A-frame, check its accuracy on a level floor. If the poles are not tied together properly the A-frame will not be accurate!
- Do not use the A-frame when there is a strong wind as the string will be disturbed, and you will not be able to do accurate work.



Figure 9.13. Using the A-frame

## Field Study 9.3. Making a Line Level

**Objective:** To learn to construct a line level to be used for pegging

**Time required:** 2 hours

### Materials

- small spirit level to put on a line or string
- two straight poles with flat ends (3-8 cm thick, about 1.5 m long)
- 11m of nylon string (the yellow “Builder’s line” is good)

- ruler
- knife
- stones or wooden pegs to mark contour lines

### Procedure

1. With the knife, mark a groove on both poles at exactly the same height. Make sure the poles are standing straight upright. The grooves should be at chest height.
2. Mark another groove exactly 4 cm below the first groove, on each pole. Use the ruler to measure.
3. Tie a knot at the centre of the string where the spirit level is to be attached
4. Tie the string to the top grooves using about 50 cm at each end so that the line is approximately 10 m long. When the two grooves are at the same height, we are pegging at 'dead level', which means that water will not flow in any direction.
5. For pegging at a gradient, use the upper groove on one pole and the 4cm lower groove on the other pole. This gives a gradient of 1:250 using a 10 m line, which is the gradient recommended by AREX for standard contour ridges. This is done when we want the water to flow in one direction. Water will flow in the direction of the pole with the higher groove, because that pole is standing in a lower position when the bubble in the spirit level is in the level position.
6. For tied ridging a gradient of 1:100 is recommended. To obtain this gradient, make the lower groove 10 cm below the upper groove (not 4 cm).

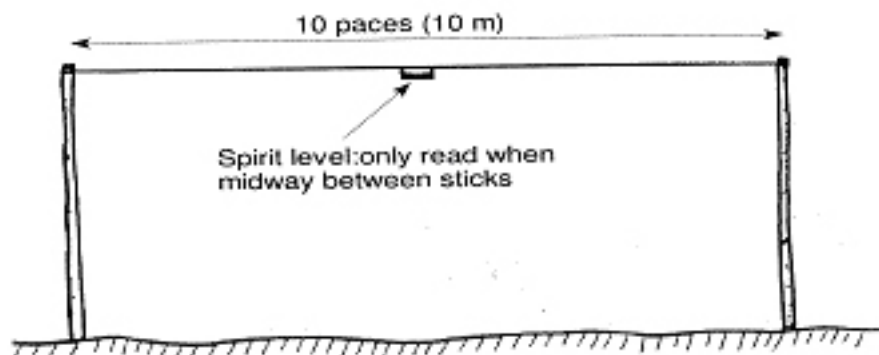


Figure 9.14. The basic line level for dead level contours

## Field Study 9.4. Pegging with the Line Level

**Objective:** To learn to peg level and graded contour lines using a line level

**Time required:** 4 hours

### Materials

- line level
- 20 pegs or stones

### Procedure

Pegging with a line level requires four people: one leader who reads the spirit level and three assistants referred to as A, B and C.

1. Go to the center of the field, and mark it with a peg. Assistant A holds his pole right next to the peg while assistant B goes in the direction we want to peg until the string is very tight. Both poles should be straight upright.
2. Attach the spirit level at the centre of the string. Based on the readings, the leader then directs assistant B, up and down the slope until the bubble in the spirit level is right in the center position.
3. When the bubble is in the center position, assistant C puts the second peg in the ground right next to assistant B's pole, so that the position of both poles is now marked.
4. Assistant A goes to the second pole, while assistant B goes in the direction he/she thinks is right for the contour. The leader then attaches and reads the spirit level again and directs assistant B up and down the slope until the bubble is in the center position.
5. Continue like this (steps 2-4) until you reach the field boundary.
6. When you reach the field boundary, go back to the first peg at the center and start pegging the other direction until you reach the field boundary at the other end. The field is now ready for conservation works along the pegs.

#### **How to peg dead level and graded contours**

- For dead level contours use the same height on both poles
- For graded contours with a gradient of 1:250 use the upper groove on one pole and the 4 cm lower groove on the other pole
- For tied ridging with a gradient of 1:100 use the upper groove on one pole and the 10 cm lower groove on the other pole
- These instructions are for a 10 m line. If the line is longer or shorter, the numbers will be different.

#### **Useful ideas**

- If you are not sure whether to peg at dead level or at a gradient, ask your local extension worker for advice.
- Do not use a string that expands when it is wet or soaked. That will make the line level inaccurate.
- If the ground is not level, make sure that the poles are not standing in a furrow, on top of a ridge, or on an anthill. If possible, the poles should be placed on spots that are representative of the field.



**Figure 9.15. Using the line level**

- Just place the pole on the ground, do not push it into the soil. To avoid sinking into the soil, poles should never have sharp ends. You can attach a small plate at the bottom, so that the pole does not sink in.



**Figure 9.16. Ploughing along the marked contour**

## **Field Study 9.5. Establishing and Managing a Vetiver Nursery**

Vetiver can only be grown from fresh planting material (planting slips). Therefore try to establish a Vetiver nursery from where farmers can ‘harvest’ planting slips every year. The nursery should therefore be permanent.

**Objectives:** To study the Vetiver plant, and ensure that farmers have a permanent source of planting material

**Time required:** preparation includes finding a site for the nursery and finding a source of fresh planting material. Establish the nursery in the rainy season (3 hours).

### **Materials**

- fresh Vetiver planting material
- hoe
- water

### **Procedure**

The site for the nursery does not need to be fenced, unless there is a lot of livestock around. If the grass is planted in December to February it does not even need to be near a water source (e.g. a borehole or a dam). It can be almost anywhere, but since Vetiver grows very well in wet areas, a vlei or some place near a vlei, is ideal.

1. When planting Vetiver grass, split a larger plant into small planting slips, just like when shallots are planted. Then simply put the planting piece or planting slip in a small hole in the ground. Make sure all the roots are covered with soil. Plant the slips with 20-30cm between each plant. Water them unless the soil is already moist.

2. During the first weeks, check regularly whether the nursery is OK. The slips should start shooting within the first 2-3 weeks. Water if it does not rain.
3. When the grass has grown tall, cut or trim it down to 10 cm. This will increase tillering and thus increase production in the nursery.
4. When the time is right for using Vetiver in the fields, uproot as much grass as needed, but make sure that enough grass is left behind to re-establish the nursery. By doing so, enough planting material will be available for the following season.

## **Field Study 9.6. Planting Vetiver Contour Hedges**

**Objective:** To learn how to use Vetiver grass for soil and water conservation, and learn correct planting techniques

**Time required:** variable, depending on need for contour pegging; re-visit several weeks after planting and next year

### **Materials**

- Vetiver planting material
- hoe
- A-frame or line-level

### **Procedure**

First decide where to establish a Vetiver hedge. If it is in a field with a contour ridge, the hedge should be established in front of the drain, so that run-off water from the field will meet the Vetiver barrier before entering the drain. If the land does not have any contour, it must be pegged at dead level.

1. Plant the Vetiver slips very closely together. In the nursery 20-30cm spacing was used, but for a Vetiver contour hedge, the plants must be much closer, i.e. at only 8-10cm spacing (less than one fist).
2. After 3-4 weeks check the newly established hedge for plants that have not started shooting. They should be replaced immediately with new slips from the nursery, because a Vetiver hedge must be continuous with no gaps; otherwise it does not work very well.
3. Three to four years later, the hedge will be big and strong and all the soil trapped by the hedge will be forming a strong and permanent terrace of fertile soil.
4. The terrace is formed by all the soil carried away from the field by run-off water, which is now trapped by the Vetiver hedge.

### **Useful ideas**

- For checking rills and small gullies, plant small but dense Vetiver hedges across where the water flows.
- Try planting fruit trees in front of a Vetiver hedge, the moisture and soil trapped there will provide an excellent environment for fruit trees.
- The roots of Vetiver are very aromatic. In Zimbabwe they have been used as snake and insect repellent.

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*In compiling this manual the authors have drawn freely from similar manuals developed and published by others. We have tried to draw the best from the various manuals and references listed below.*

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# Annex 1. Trial Record Sheet/Technology Sheet

Adapted from Agritex/ZFU 1999

Name of field school farmer: .....  
 Type of experiment.....  
 Fieldname/number..... Soil type:.....

	Plot A (control) <b>USUAL PRACTICE</b>	Plot B <b>NEW IDEA</b>
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**What did you do?**

- What did you want to learn?
- What did you try out?
- How did you lay out the field? (size, shape)
- When did you plant?
- Which variety?
- When and how did you apply fertiliser?
- What spacing did you use?

**What differences did you observe?**

- Plant height
- Vegetative development
- Flowering (earlier/later)
- Weed growth
- Soil erosion (rills/sheet erosion)
- Earlier or later maturing?
- Size of cobs/heads
- Size of grains
- Total yield
- Labour: which plot required more work and why?
- What else did you observe?

**What lessons have you learnt from your experiment?**

- What are advantages?
- What are the disadvantages?
- What would you do differently next year?



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## **Annex 2. Crop/Management Trial – Some Practical Tips**

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Adapted from Agritex/ZFU 1999

### **How best can farmers experiment and test new ideas?**

When you try out a new technique, you need to compare it to the usual practice. Only by comparing results, will you know whether the new technique is better or worse than the old one.

### **How to compare?**

An easy way to compare is put the two techniques (old and new) side by side in the same field. If possible divide the field exactly in the middle along the contour so that both sides are the same size. Vetiver grass strips can be used to divide the field. It is important to put the two techniques in one single field because conditions in different fields may be very different, making it difficult to compare. Also take care that the two parts of the field are not too different. For example if one side is a wetland and the upper slope is dry, you cannot compare the two.

### **What else should be considered while experimenting?**

If you are concerned how a new technique or idea will perform, try it on a small piece of land at first. This will avoid severe losses if the technique fails. Remember, some tests are successful – but others may fail.

- Use the same seed and the same spacing on both sides (unless you want to compare varieties and spacing)
- Plant both sides on the same day to ensure that all plants have the same conditions
- Apply the same amount of fertiliser or manure on both sides unless you want to see how the plants grow with different amount of fertiliser or manure
- Weed on the same day in the same way on both sides unless you want to observe the effect of different types or times of weeding.

### **How to observe and monitor simple trials?**

Observing your trials helps you to identify the reasons why a certain technique performs better or worse than another technique. When the crop is grown with two different techniques side by side in the same field you can see the differences clearly. For example, on one side the maize might grow faster or be taller, or cobs might be bigger, compared to the other side. Record all your observations so that they are not forgotten, and can be later analysed in more detail. It is important to be honest in one's own judgments. Often the farmer is in favour of an improved technique and becomes 'blind' when it does not perform as expected.

Keep a trial record sheet with your observations at various stages (see Annex 1). This will help you to share your experiences with other farmers and the extension worker; and you will be able to look at the record sheet next year and build on these experiences.

If a technique or idea is successful, in the next season you can apply it over a bigger area. If the experiment fails, it is very important to discuss it with other farmers and your extension worker: why did it fail, how can it be modified and improved? Never give up if success does not come immediately. Try to find the reason why the trial failed, otherwise you cannot learn from it.

If you record your long-term observations about the crop and the field, season by season, you can create your own reference material and build up your farming knowledge step by step. You can recall the best ways of doing things, building on experiences of previous years. Thus, you do not repeat mistakes. The record sheet shown below, will help you in observing and recording.

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**Assessment sheet for experiments, to be used by the farmer**

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At crop emergence  
Before first weeding  
Mid season  
At harvest

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